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Project appraisal under risk, threat and uncertainty : a case study of the afforestation project of Bihar, India.

Shukla, Devendra Kumar

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Project Appraisal under Risk, Threat and Uncertainty: A Case Study of the Afforestation Project of Bihar, India.

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by

Devendra Kumar Shukla
M.Sc. (BHU), A.I.F.C. (Dehra Dun)

Department of Forestry and Wood Science
School of Agricultural and Forest Sciences
University of Wales
Bangor, U.K.

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Summary

In view of the Indian Government's growing commitment to forestry, a number of afforestation projects have been implemented. But most projects in developing countries do not conclude as per plan, uncertainty being a major factor. This study undertakes physical, financial, economic and social appraisal of the afforestation programme through case studies of the farm forestry (FF) and the rehabilitation of degraded forest (RDF) components and discusses the conceptual and methodological issues in appraisal of these projects under risk, threat and uncertainty.

We have used three different approaches to risk appraisals in the present study. They are: the expected value of NPV through the illicit felling models; the cumulative distribution function comparisons through stochastic efficiency rules; the utility function of the project managers. Physical (logistic and Weibull models), financial and management decision (deterministic and probabilistic models) models developed in the study help in threat appraisal through quantification of physical loss, financial appraisal of its consequences and formulation of a management strategy under the threat of illicit felling. The risk analysis of the FF and the RDF component using Monte Carlo simulation is used to generate probability of return profiles and the results are compared through stochastic efficiency rules. The utility functions of the project managers are used to describe their risk attitude. The study shows that most managers are risk averse and the analysis of their utility functions supports the decreasing absolute risk aversion hypothesis. It emphasizes the need for a risk policy in the Forest Department.

The economic appraisal examines the interaction of the FF and the RDF components with the economy rather than the treasury. Illicit felling is accounted for as a benefit to the economy. A 'Shadow pricing approach' is adopted for economic and social appraisals. For the social appraisal, inputs and outputs are estimated in terms of net discounted utility-weighted consumption flows. All the parameters of social and economic appraisal such as the consumption value of unit reinvestment, utility weight for incremental consumption at different consumption levels, social discount rate and economic discount rate are estimated.

To study farmers' adoption behaviour, principal component analysis is used to explore significant factors and a logit model is developed after that to estimate probability of adoption. The study indicates that adoption of FF can be explained in an overall framework of evolutionary theory proposed in this study. The evolutionary theory posits that farmer tree growing can be considered as a land use strategy in response to both changing macro and micro factors, many of which relate to characteristics of the farmers, their resource endowments etc.

It is concluded that success of projects can be assessed by taking account of the factors influencing the variability in the project outcome and understanding the whole process of people's interaction and participation in the project.

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List of Abbreviations

BCR	Benefit-cost ratio
CBA	Cost-benefit analysis
ECBA	Economic cost-benefit analysis
EDR	Economic discount rate
FCBA	Financial cost-benefit analysis
FF	Farm forestry
FRI	Forest Research Institute
FSI	Forest Survey of India
GOB	Government of Bihar
GOI	Government of India
GRS	Gumla, Ranchi and Sahebganj districts
IOCR	Incremental output-capital ratio
IRR	Internal rate of return
NPV	Net present value
RDF	Rehabilitation of degraded forest
SCBA	Social cost-benefit analysis
SDR	Social discount rate
SGH	Singhbhum E, Garhwa, Hazaibagh districts
SIDA	Swedish International Development Authority
SOC	Social opportunity cost of investment
STP	Social time preference
SWR	Shadow wage rate

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My basic concerns in the research topic arose over a period of years during my association with forestry as a forest manager and administrator. Many of the broader concerns have yielded ground to the narrow focus.

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Chapter 1

Introduction

The ecological security of India depends on its forest cover. In recent years issues relating to deforestation and degradation have received great attention from professional foresters and academicians. Indian forests are under great pressure to supply fuelwood and other forest produce to a growing population. Fuelwood is still the most important form of domestic energy both in rural and urban areas. The demand for fuelwood as well as other forest produce is increasing with increase in income and population. Many poor people living in and around forests are integral part of the forest ecosystem and depend heavily on them for subsistence needs. Most forests are in a state of degradation due to over exploitation to meet the demands (including both legal and illegal removals). Consequently, the productivity of natural forests and plantations is very low.

The Forest Department in India is currently facing the greatest challenge, since its inception in 1891, in striking a balance between meeting people's demand and preservation of the resource base. The response to such a situation has been three fold:

(a) enrichment of growing stock by rehabilitation of existing forests through raising plantations of fast growing species,

(b) encouragement of community and farm forestry, and

(c) promotion of people's participation in forest conservation and management through joint forest management plans (JFMP).

There is an urgency to manage forests sustainably and to augment the raw material production.

1.1 Rationale of the study

In view of the Government's growing commitment to forestry, a number of forestry projects (mainly afforestation) have been implemented with the help of bilateral (ODA, SIDA etc.) or multilateral agencies (World Bank) in various states of the country. The success of such projects is usually assessed using cost-benefit analysis (CBA) tools coupled with a separate study of socioeconomic factors. The emphasis in such evaluations seems to be on assessing the financial and economic viability in a fixed framework rather than assessment of the projects in their totality. The current procedures of project appraisal are inadequate as they do not incorporate risk and uncertainty in project appraisal directly. Such inadequate and incomplete evaluation leads to unrealistic formulation of projects and consequently most projects in developing countries do not conclude as per plan. Recent studies (Pohl and Mihaljek, 1992) of the World Bank-assisted projects have shown that a large degree of uncertainty encompasses the project outcome. Little and Mirrlees (1991) have also observed that 'much of these investments yielded little or nothing', uncertainty being a major factor. These studies point out to the need for a proper evaluation of projects, incorporating two main elements in the project evaluation:

(a) taking into account the factors influencing the variability in project outcome, and, (b) understanding the process governing community and people's participation.

Such a holistic and objective evaluation would, help in assessing the real success of projects, both from growth and distributional perspectives and would lead to suitable policy instructions for formulation of projects in future.

In the Indian State of Bihar, the forest resources have been shrinking rapidly. The per capita forest area is only 0.07 ha but over 40% of the people are dependent on forest for their fuelwood requirements and also for sustenance. The forestry sector is also facing a resource crunch. An afforestation project was implemented from 1985-1991 in Bihar with the assistance from Swedish International Development Authority (SIDA). This project focused on enhancing the productivity of existing forests and improving the forestry resource base outside the conventional forest area through participation of people. The evaluation of this project and its success from the perspective of growth and distribution, is of great importance for formulation of future projects.

1.2 Objectives of the study

The present study aims to find out the use and applicability of CBA methods in economic analysis of afforestation projects in general, and attempts to carry out detailed financial cost-benefit analyses (FCBA), economic cost-benefit analyses (ECBA) and social cost-benefit analyses (SCBA) of two components viz. Farm forestry (FF) and Rehabilitation of Degraded Forests (RDF) of the SIDA-supported social forestry project, in particular under risk. It further aims at identification of elements of variability influencing the project outcomes and developing a methodology for incorporating these elements in the decision analysis of the project.

The specific objectives of the study are:

(1) to study the use and applicability of cost-benefit analysis in evaluating afforestation projects;

(2) to undertake detailed cost-benefit analysis (FCBA, ECBA and SCBA) of FF and RDF components under risk and uncertaint;

(3) to make a risk analysis of FF and RDF using simulation techniques;

(4) to examine project evaluation under an socioeconomic and institutional framework for policy formulation and decision making.

1.3 Scope and coverage

The thrust of afforestation projects is likely to be in two directions:

a. afforestation in legally defined 'forest' areas, and,

b. extension of afforestation outside forest areas i.e., on private and non forest land

The study encompasses these two components of afforestation projects viz. Farm Forestry and Rehabilitation of Degraded Forests representing afforestation in private and public land respectively. Strip plantations and community woodlots have not been taken up because their shares in total project expenditure are very small and the techniques of appraisal are not fundamentally different. The study covers only districts of Chotanagpur and Santhal Parganas, Bihar, as the SIDA project was confined to these areas only.

The study uses the techniques of developmental cost-benefit analysis. Environmental cost-benefit analysis, though equally relevant for developing countries, is beyond the scope of the present study.

1.4 Plan of presentation

The thesis is divided into eleven chapters. After the introduction, the second chapter provides background information about the Republic of India and the State of Bihar with special reference to the forestry sector. A brief review of past evaluation of afforestation projects is also presented in this chapter. An overview of project appraisal techniques and their application in the study for appraisal of afforestation projects is presented in Chapter 3. In chapter 4 the data base and methodology of data collection are presented. The data will be used for analysis in subsequent chapters. Chapter 5 discusses some models to estimate yield under the threat of illicit felling. Chapter 6 presents some financial decision models for illicit felling. Financial appraisals of the Farm Forestry (FF) and the Rehabilitation of Degraded Forests (RDF) components are also carried out. Chapter 7 discusses the concepts and methodology of ECBA. ECBA is taken up for the FF and the RDF. Chapter 8 examines the FF component in relation to farmers' tree management strategies. An adoption (of farmer tree growing) decision model is also presented. Chapter 9 discusses the methodology of SCBA and uses it in case studies of the FF and the RDF components. Some national parameters required in SCBA are also estimated. Chapter 10 examines the methodology of incorporation of risk in project appraisal. Risk analyses of FF and RDF are carried out using simulation techniques. The methodology of risk analysis is upgraded in a decision analysis framework. Finally, Chapter 11 discusses and analyses main findings of the study, indicates limitations and suggests further areas where refinements in appraisal methodology are required.

Chapter 2

Background to the problem

2.1 India: the land and the people

2.1.1 The land

India is the seventh largest country in the world in terms of area and the second largest country in the world in terms of population. It spreads between 8^0 4' N and 37^0 6' N latitude and 68^0 7' E to 97^0 25' E longitude covering an area of 328.76 million ha. The Republic of India forms a natural subcontinent with the Himalayas to the north and the Arabian Sea and the Bay of Bengal to the west and the east respectively. India shares its international boundaries (total 9988 km) with Tibet (the Xizang Autonomous Region of the People's Republic of China), Bhutan and Nepal to the north, Pakistan to the northwest and Myanmar and Bangladesh to the southeast. Mainland India comprises four well-defined regions: the Himalayas, the Indo-Gangetic Plain, the desert region and the southern region. The southern region includes Lakshadweep (Arabian Sea) and Andaman and Nicobar islands (Bay of Bengal). The rivers of India are generally divided into Himalayan rivers (snow-fed) and peninsular rivers (rain-fed). India is a tropical country but is subject to a wide range of climates. The climate of India is largely governed by monsoon. Four fairly distinct seasons are common to all regions, though, the length of seasons varies greatly in different regions.

2.1.2 Demographic features

India possesses about 2.4% of the total land area of the world but she has to support about 16% of the world's population. The population of India was 844 million according to the latest census of 1991. The annual compound rate of growth of population has been 2.11% for the period 1981 and 1991. The age profile of population is quite disturbing. About 40% population was in 0-14 year's group in 1991. Over the last five decades both birth rate and death rates have been declining (birth rate per 1000, 32.5; death rate per 1000, 11.4, 1991 census). In 1991, the density of population rose to 273 per sq. km from 230 per sq. km in 1981. However; it is unevenly distributed. The percentage of urban[1] population has grown every year. It was 25.7% of total population in 1991. A disturbing revelation of the 1991 census is decline in the ratio of female to male population (929 females per 1000 males) though 1080 females are born per 1000 males. Overall literacy level in India is 52% (female, 39.3; male, 64.1%)

2.1.3 Socio-cultural background

The population of India contains a multitude of racial, cultural and ethnic groups. Ethnically, India is one of the greatest melting pots of the world and its ethnic diversity is the most complex found anywhere outside Africa. The tribal inhabitants have survived in isolated geographical pockets and constitute 8.08% of the total population. There are sixteen languages recognized in the Schedule of the Constitution. Hindi, in *Devnagri* script, is designated as the official language. English is used as the principal medium of communication in the government and in business. Almost all the major religions of the world are represented in India. Four of them (Buddhism, Jainism, Sikhism and Hinduism) in fact, originated in the country. Hindus form the majority of the population in all areas except Jammu and Kashmir (where Muslims are dominant) and Nagaland (Christians are in the majority).

UNICEF (United Nations Children Emergency Fund) considers U5MR index[2] as the single best indicator of social development and well being rather than GNP per capita (GNP per capita for India US$ 310, 1992). India's rank was 42 (out of 145 countries considered) according to U5MR ranking in the year 1992. Another index mainly used by UNDP (United Nations Development Programme) to compare standards of living among different countries is HDI (human development index). HDI considers a broad list of parameters grouped into three main components viz. knowledge, longevity and income[3].

[1]The definition of urban adopted is as follows: (a) All places with a municipality, corporation, cantonment board or notified town area committee etc., (b) All other places with (1) a minimum population of 5000, (2) at least 75% of male working population engaged in non-agricultural pursuits and (3) population density of at least 400 persons per sq. km.

[2]U5MR is under-five mortality rate i.e annual number of deaths of children under 5 years of age per 1000 live birth (124 for India). The ranking is in descending order of mortality. It means rank 145 is the best.

[3] HDI is in 0-1 scale and ranking is in descending order of levels of living. HDI value of 1 indicates ideal standard of living.

HDI value of 0.382 gives India 135th place in the list of 173 countries (GOI, 1993). The population below the poverty line[4] was 39.3% (an earlier estimate for the same year was 24.1%) in the year 1987-88 according to an Expert Group of the Planning Commission. The estimates made for earlier years are not comparable because of change in methodology of estimation.

2.1.4 Agriculture and food production

Agriculture forms the backbone of the Indian economy and is the source of livelihood for more than 70% of the population. The contribution of agriculture in employment generation, industrial development and international trade is quite large. With the introduction of five-year plans in 1951 and with special emphasis on agricultural development, the pre-independence trend of stagnant agriculture was reversed. However, agriculture production in India (area under cultivation, productivity and total output) is influenced by a large number of nature determined factors (rainfall etc.). The total food grain production has increased from 108 M tonnes in the year 1971 to 185 M tonnes in the year 1994 because of an increase in productivity. The crop area has not shown any significant increase (1970-71, 124.3 M ha; 1992-93, 124.6 M ha) (GOI, 1993). The per capita availability of food grains, in fact has marginally decreased (1971, 469 gm per day; 1993, 466 gm per day).

2.1.5 Industry

The Government of India launched the process of industrialisation as a conscious and deliberate policy for economic growth in the late fifties. The annual growth rate of the industrial sector including mining, manufacturing and electricity generation was 8.5% during 1985-90. The rapid growth in industrialisation has been accompanied by a corresponding growth in technological and managerial skills of the industries. A noteworthy feature of industrial development in India is the growth of the public sector in a big way in heavy and basic industries. In 1989-90, public sector units accounted for 4.6% of the number of factories but they employed 51% of the productive capital. Annual

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[4] The poverty line is defined as the expenditure required for a daily calorie intake of 2400 per persons in rural areas and 2100 in urban areas. The expenditure is officially estimated at Rs 181.50 per capita per month in rural area and Rs 209.50 in urban areas at 1991-92 prices.

wages received by a worker in the public sector are at par with those in the joint sector but private sector workers receive about 43% less.

2.1.6 Natural resources

Natural resources influence the course of development. Therefore careful use of both exhaustible and renewable resources are a *sine qua non* in the process of development. The land utilisation pattern of India shows that about 13% of area is classified as barren land (includes mountains and desert). Agricultural land constitutes 41% of the total area (which includes orchards). The area legally described as forest in India is 77.008 million spanning over 23.4 per cent of the total geographical area. The total forest land is basically divided into Reserved forest (RF, 53.9%), Protected forest (PF, 30.3%)[5] and unclassed (15.8%) on the basis of rights to the local people. However, based on visual and digital interpretation of TM (Thematic mapper) data of Landsat satellite imagery, the Forest Survey of India (FSI) and the National Remote Sensing Agency (NRSA) have estimated that 19.47% (Dense forests, 11.7%; Open forests, 7.6%; Mangrove, 0.1%; Scrub, 1.8%[6], FSI, 1993) of the total geographical area of the country is under tree cover.

The area under forests in India is less than 2% of the total forest cover of the world but it has to support more than 15% of the world's population and 14% of the cattle population. Besides this forests are not well stocked and their distribution is highly irregular. The annual production of wood is 0.7 cu m per ha as compared to the world average of 2.1 cu. m. The average growing stock is 32 cu. m per ha against the world average 110 cu. m. (FSI, 1987). Despite the specific emphasis in the National Forest Policy, 1952, that "India, as a whole, should aim at maintaining one-third of its total land area under forests", the diversion of forest land for non forest uses has continued in utter disregard for long term consequences. Between 1951-1980 more than 4.3 M ha forest land was diverted to other land uses (agriculture, river valley projects, transmission lines and road etc.). Before 1981 the power to divert forest lands to other land uses was

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[5] Both RFs and PFs are managed by the Forest Department. The main difference is that local communities rights are very limited or absent in RFs (all activities not specifically permitted are prohibited), whereas in PFs local people generally have extensive rights and all activities are permitted unless specifically prohibited.

[6] Dense forest, crown density >40%; Open forests, crown density 10% to <40%; Scrub, crown density <10%.

vested with the state governments. The enactment of the Forest (Conservation) Act, 1980 checked the indiscriminate diversions of forest land reducing the average annual rate of diversion to 6.69 thousand ha (1981-87) from 144.26 thousand (1951-80) (FSI, 1987). Among other biotic influences grazing and fires have had a significant effect in shaping the character and composition of forest vegetation in India. Fire and grazing have resulted in dominance of hardy and unpalatable species like teak (*Tectona grandis*)and sal (*Shorea robusta*) in deciduous forests. Bamboo is now confined to small pockets in central India. In India, wood fuel accounts for about 30% of total energy consumption. In household sectors, the percentage share of fuelwood is as high as 68.5% in rural areas and 45.5% in urban areas .

The plan outlays and expenditure on forestry sector have not been commensurate with the demand placed on forests for supply of forest products. During the First Five-year Plan (1952-57), the expenditure on forest development was 0.5% of the total outlay, which has marginally risen to 1% of the total outlay by Seventh Five-Year Plan.

Three National Forest Policies have been enunciated in the country since the inception of the first one in 1894. The current National Forest Policy was passed by the Parliament in December 1988. The current policy emphasises the new strategy of forest conservation. Conservation includes 'preservation, maintenance, sustainable utilisation, restoration and enhancement of natural environment'. The principal aim of the Forest Policy is to ensure environmental stability and maintenance of ecological balance. The derivation of direct economic benefit is subordinate to this principal aim.

2.1.7 Economy and planning

The Indian economy is a mixed economy. Two features of the Indian economy, viz. the growth of the public sector and economic planning, make it distinctly different from the capitalistic economies. The Indian experience shows that the mixed economy is a fixed proposition for a developing country as it allows for a modest rate of growth which is both steady and less subject to fluctuations in the economic activity at the international level (Chakravarty, 1987). The national income of India registered 5.5% per annum increase during the eighties. The government introduced four major policy initiatives after the 1991 fiscal crises. They were: (1) macro-economic stabilization through fiscal correction (abolition of various subsidies, cut on non planed expenditure),

(2) export oriented trade policy, (3) industrial policy reforms (deregulation and foreign investment), and, (4) public sector reforms (efficiency).

2.1.8 Constitution and administrative setups

India is a sovereign, socialist, secular, democratic republic. The constitution of India is federal in structure with unitary features. The Republic of India is a union of 25 states and 7 union territories. The division of powers between the union and the states is well demarcated. The President of India is the constitutional head (head of state), but the executive power rests with the Prime Minister (head of the government) and the Council of Ministers. The judiciary and the executive are separate. Suffrage is universal over the age of 18.

The administrative structure is made up of three types of civil services: All India service, union service, state service.

2.2 Bihar: general features

2.2.1 Physical environment

The state of Bihar is situated in the northeast of India and has a total geographical area 173,877 sq. km. located between latitudes 21^0 58' 10" and 27^0 31' 15" north, and longitudes 83^0 19' 50" and 88^0 17' 40" east (Map 2.1). Bihar consists of two distinct physical units of roughly equal areas. They are the Gangetic plain, mostly in the northern half and the Chotanagpur plateau, in the south. The northern part of the Gangetic plain covers an area of about 51,800 sq. km to the north of the river Ganga while the remaining covers an area of about 33,700 sq. km to the south of Ganga. The plateau region covers an area of about 90,000 sq. km. A number of rivers descend from Nepal and drain into the Ganga. They carry large amounts of silt and are highly flood prone. The plains to the south of the Ganga are higher in elevation in the south and slope towards the Ganga. The Chotanagpur plateau is a region of great unevenness. It consists of a succession of plateaux (300m to 1000m).

Map 2.1 Map of India and Bihar showing study area

Most of the area of Bihar falls under 'Eastern plateau and hill region' and 'Middle Gangetic plain region' of the Agro Climatic Zones of India. A very thin strip in the east bordering West Bengal falls under the Zone III viz. the lower Gangetic plain region.

2.2.1.1 Rivers

The river Ganga dominates the life style and culture of the northern part of the state. The majority of northern rivers are snow-fed and are perennial, while rivers in the southern part of the country are rain-fed and most of them dry up in summer.

2.2.1.2 Climate and rainfall

Bihar lies in the transition zone between moist areas of West Bengal in the east and drier areas of Utter Pradesh in the west. The normal annual rainfall of the state is 1272 mm. The average number of rainy days is 53.7. Over 50% of the total rainfall is during monsoon months (mid June to mid August). The average temperature during rainy seasons is 29 ^{0}C. The summer temperature ranges between 32 ^{0}C and 44 ^{0}C.
The temperature in winter months varies between 5 ^{0}C and 11 ^{0}C.

2.2.2 Demographic features

Bihar is the second most populous state of India. The total population of the state as per the 1991 census is 86,338,853. The average population density of the state is 497 persons per sq. km against the national average density of 273 persons per sq. km. According to the 1981 census, the scheduled castes form 14.55% of the total population and the scheduled tribes, mostly confined to South Bihar, constitute 7.66% of the total population. The urban population is 13.14% of total population. 38.5% of the population was literate according to the 1991 census (GOI, 1993). The livestock population of the state is 35,580,173 as per the 1982 cattle census.

2.2.3 Natural resources and land-use patterns

Bihar is very rich in mineral resources. Minerals are confined to the plateau area and include some of the largest deposits of coal and iron ore in India. In addition, Bihar has good deposits of bauxite, copper, manganese etc.

The land use statistics of 1988-89 show that over 43% of total geographical area is 'net sown area' (GOI, 1993).

2.2.4 Economic development

All available economic indicators show that Bihar is the poorest state in the Indian union. In fact, the gap between the most developed state and Bihar is widening. Agriculture is the only source of income and employment for about 75% of the population. The absence of effective land reform policies and their implementation within the state is a major cause of under-development and poverty (Bharti, 1992). The percentage of people living below the poverty line was 40.8% in 1987-88. The contribution of forestry towards state income is less than 1%.

2.3 Forest scenarios in Bihar

2.3.1 Forests and their distribution

The area legally (under the Indian Forest Act, 1927) constituted as forests is 29,226 sq. km. which is 16.8% of the total land area of the state. The distribution of the forest however, is highly uneven. North Bihar has no forest except for a small area in the north-west where the Himalayan foothills intrude from Nepal. The per capita forest area in Bihar is only 0.03 ha against the all India average of 0.09 ha. (Forest Survey of India, 1991). Out of the total forest area of 29,226 sq. km, the gazetted reserve forest (RF) accounts for 5,051 sq. km and the protected forests (PF) 24,168 sq. km, while the remaining 7 sq. km. are unclassed forests. The protected forests are heavily burdened with rights which are legally recognised as a result of forest settlement proceedings and recorded in Khatian part II. In the PFs, the villagers have the right to take timber and bamboo for the construction and repair of their houses, wood for fuel and also the right to graze cattle and collect MFP (Minor Forest Produce).

2.3.2 Forest cover

As already stated, the area of land legally constituted as forests are 29,226 sq.

km but not all of this areas is covered with trees. The forest cover is a better indicator of the state of forests than the recorded forest area. In Bihar the area actually having forest cover of more than the 10% of crown density assessed by the forest survey of India is only 26,587 sq. km which comes to 15.29% of the total geographical area but it is 90% of the forest cover (Fig. 2.1).

The latest assessment of 1993 is based on visual and digital interpretation (with partial ground checks) of false colour composites of TM (Thematic mapper) data of Landsat imageries on 1:2,50.000 scale pertaining to the period 1990-91.

The spatial resolution of the TM sensor was 30 m against the spatial resolution of 79 m in the case of MSS (multi spectral scanner) used in earlier interpretation. There has been a decrease of 81 sq. km in forest cover in the 1993 assessment as compared to 1991 assessments. This may not be because of any deforestation or degradation during this period but it may be as a result of better methods of interpretation assisted with ground verifications.

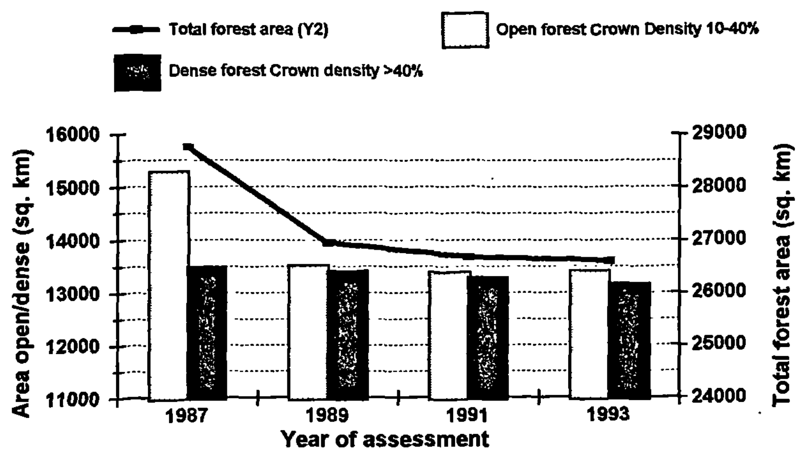

Fig. 2.1 Forest cover of Bihar

There are as many as 15 (out of 31) districts in Bihar which have no forest at all. There are no forests in the whole of Saran and Darbhanga divisions and very little in Kosi divisions. In this tract, there are large chunks of cultivable land owned by absentee landlords who find tree farming much more convenient and attractive than agriculture as the latter needs constant attention which the absentee landlords are unable to give. The big landlords also wish to put their holdings under tree cover to circumvent the provisions of land ceiling acts which are applicable to agriculture lands but not to lands under tree cover. Farm forestry has enormous scope in this tract but the SIDA-supported project was not extended to this part of Bihar.

2.3.3 Forest Types and important species

According to Champion and Seth's classification (Champion and Seth, 1968) of forest types in India, the following types of forests are found in Bihar. The area covered by each type as a percentage of total forests (29226 sq. km) is given in brackets. The sum is not 100% due to rounding off.

1. Dry peninsular sal (54.54%)
2. Dry peninsular sal with *Acacia catechu* (6.58%)
3. Dry peninsular sal with dry bamboo (2.41%)
4. Dry Siwalik sal (1.36%)
5. Moist peninsular sal (Singhbhum valley) (10.44%)
6. Moist (Gangetic high alluvial) sal (1.25%)
7. Northern dry mixed deciduous forest (1.25%)
8. Northern dry mixed deciduous forest with Boswellia (14.05%)
9. Northern dry mixed deciduous forest with bamboo (1.89%)
10. Northern dry mixed deciduous forest with *A. catechu* (5.37%)
11. Dry tropical Butea forest (0.35%)
12. Gangetic moist deciduous riverine forest (0.53%)

The representative species under different forest types are as below:

1. Forest type 5B/C 1c: *Shorea robusta, Anogeissus latifolia, Terminalia bialata, T.belerica, Diospyros melanoxylon, Adina cordifolia, Aegle mermelos, Madhuca indica, Schleichera oleosa, Bombax ceiba, Gmelina arborea, Boswellia serrata, Pterocarpus marsupium, Acacia catechu, Dendrocalamus strictus.*

2. Forest type 5B/C2: *Boswellia serrata, Hardwickia binata, Butea monosperma, Aegle marmelos, Cleistanthus collinus, Cochlospermum* spp., *Nycthanthus arbortristis, Anogeissus pendula, Acacia nilotica, A.catechu, Dendrocalamus strictus.*

3. Forest type 5B/e5: *Butea monosperma.*

4. Forest type 3C/C 2e: *Shorea robusta, Anogeissus latifolia, Pterocarpus marsupium, Terminalia alata, Madhuca indica, Lagerstroemia parviflora, Adina cordifolia, Albizzia* procera, *Emblica officinalis, Ougeinia dalbergioides, Syzygium cumini, Diospyros* spp.

5. **Forest type 3C/3(i):** *Acacia catechu, Dalbergia sissoo*

2.3.4 Growing stock

An estimate has been made of the growing stock of different species in the forests under the control of the forest department, Bihar (Fig. 2.2). The estimation of average volume in different forests is carried out by the Forest Survey of India. It varies from 16.7 cu m per ha (Santhal Parganas) to 52.3 cu m per ha (Ranchi). In some areas of Sighbhum East and Singhbhum West district per ha volume is as high as 67.2 cu m (High forest).

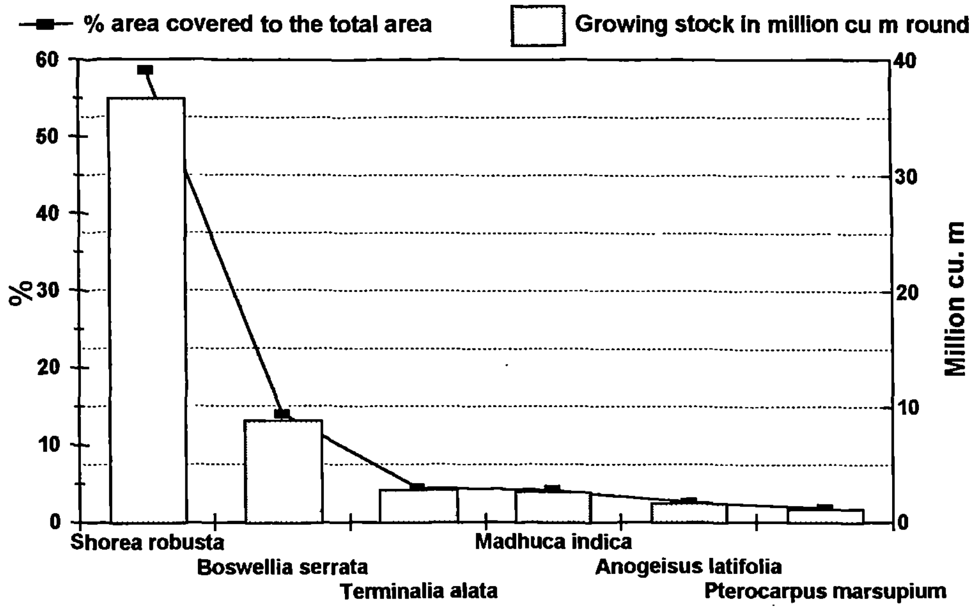

Fig. 2.2 Growing stock

2.3.5 Production of forest produce

The production of both timber and fuelwood showed a declining trend after 1987, in contrast to an increasing trend during the period 1960-1980. This can be attributed to (a) declaration of large forest areas (of high crown density) as Wild Life Sanctuaries and National Park and consequent ban on commercial felling in these forests and (b) degradation of existing forests. Fig. 2.3 presents the net timber production for the period 1960-1992. It is clear that timber production has followed a decreasing trend over 33-year period. The trend in timber production is shown using time series data of 33 years (1960-92). The following polynomial model ($1/\ln Y=b_0+b_1X+b_2X^2+b_3X^3$) was fitted to the data. The t-ratios are given in parentheses:

$$1 / \ln Y = 0.77185 + 4.39457E\text{-}04X - 4.94698E\text{-}05X^2 + 1.28962E\text{-}06X^3$$

(3.262) (-5.416) (7.296)

R Square = 0.88477, Adjusted R Square = 0.87285, n=33

where Y is timber production in cu m, and X is time trend variable.

The model is evaluated against alternative forms using residual analysis and mean absolute deviation ($MAD=[\sum_{i=1}^{n} (y_i-\hat{y}_i)]/n$, where y_i and $\hat{y}$ are observed and predicted values respectively and n is number of years). The above model was found to give best fit to the data. The predicted value (exp{1/(1/lnY)}) and 95% CI (confidence interval are calculated from the above equation. The fitted model is extrapolated to compute forecasts (Fig. 2.3). A major disadvantage in this method is that it imposes global assumptions about the nature of any underlying trend. A formal time series analysis may require computation of the 'root mean squaire error' and possibly ARMA (autoregressive moving average) process. But this analysis is only exploratory in nature and demonstrates declining trend in timber production.

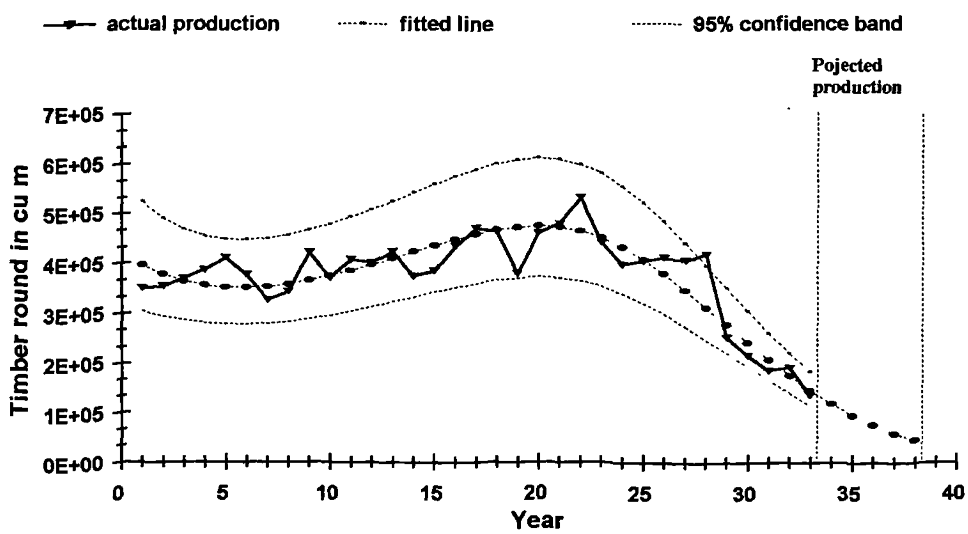

Fig. 2.3 Trends in timber production, 1960-92 (1960=1)

2.3.6 Administration and management of forests

The forests are managed by Forest Service, headed by the Principal Chief Conservator of Forests, who works under the administrative control of Government of Bihar. The forest service, Bihar has a total staff strength of around 10,000 officers and subordinate staff.

The forests of the state are managed under the written scheme of management called 'working plans'. The working plans are based on principles of sustained yield. The main silvicultural systems followed are: (a) coppice with standard system, (b) sal selection system, (c) conversion to uniform system, and, (d) coppice selection.

2.3.7 Revenue and Expenditure

The trend in total revenue and expenditure at constant price (of 1980) is shown in Fig. 2.4. The plan expenditure which is used in forest developmental activities has grown at an annual compound rate of 3.9% (for the period 1960-92) while the non-plan expenditure (used for salaries etc.) has shown growth rate of 5.4%. The revenue from forests has grown at a faster rate as compared to expenditure. This is mainly because of a sharp increase in prices of timber and fuelwood after 1980. The plan expenditure which is used in forest development activity has increased marginally despite SIDA-aided social forestry projects. The non-plan expenditure (used for salaries etc.) has grown at a much faster rate. The time series data (1960-1992) of annual supply of timber and revenue from timber shows that up to 1980 production of timber and revenue (at constant price) from timber has increased moderately and the price of timber has not increased above inflation. After 1980 the production of timber started declining and the price was showing increasing trends (Fig. 2.5). In the case of fuelwood between 1975 and 1985, though the supply was almost constant, the price had shown a sharp increase due to a shortage of fuelwood in neighbouring states (Fig. 2.6).

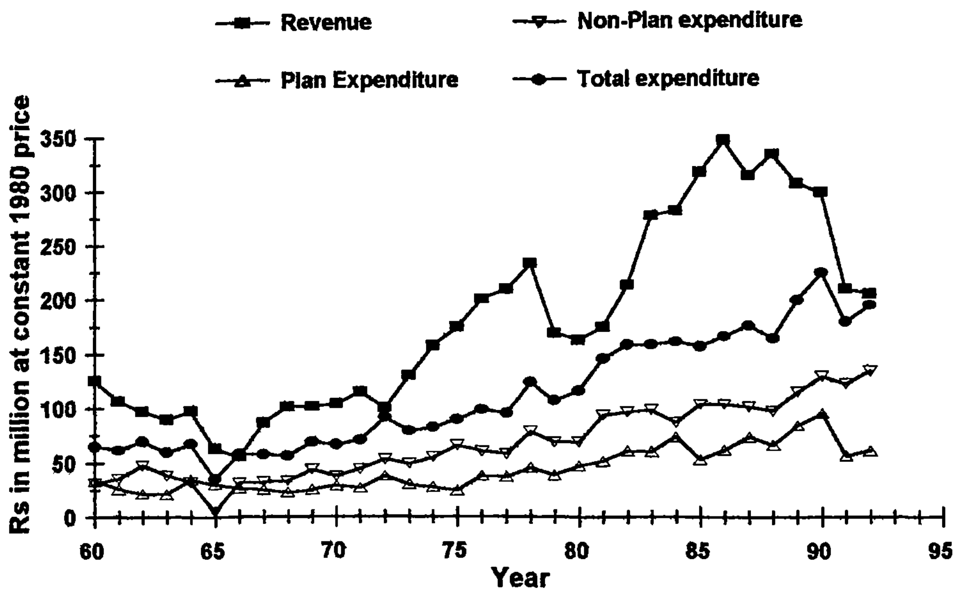

Fig 2.4 Revenue and expenditure (1960-92)

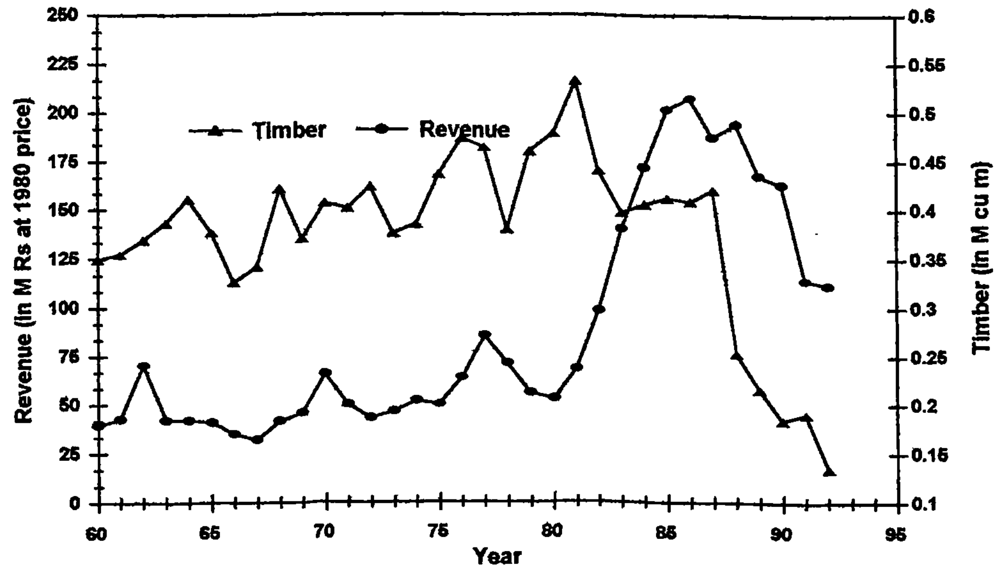

Fig. 2.5 Timber supply and revenue (1960-92)

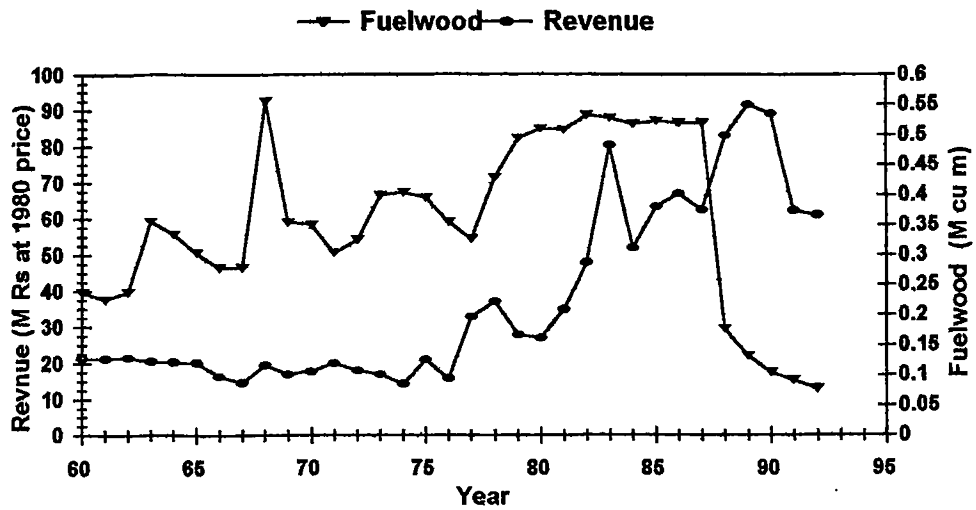

Fig. 2.6 Fuelwood supply and revenue (1960-92)

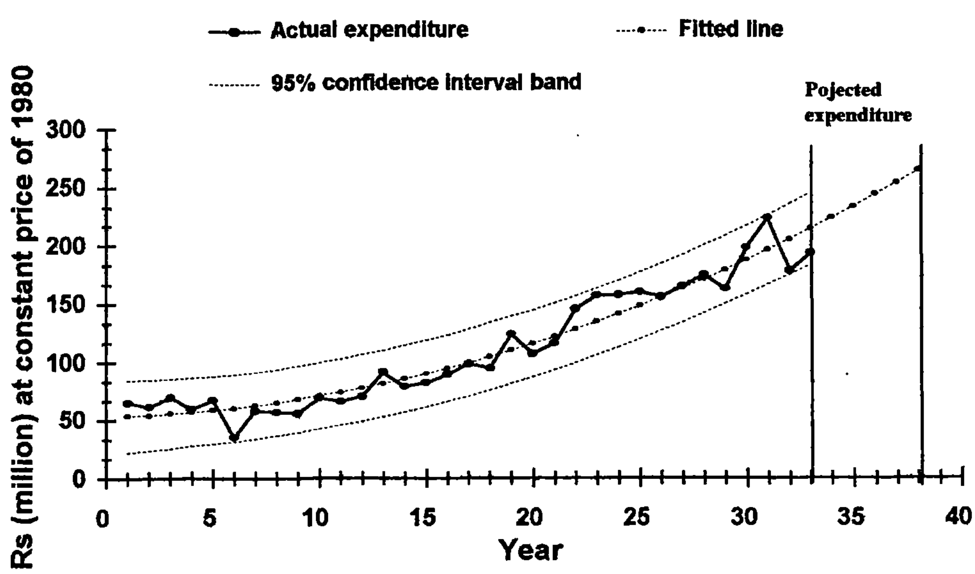

Fig. 2.7 Expenditure on forests (1960-92)

The trend in total expenditure (Y) was projected using time series data of 1960-1992. A quadratic or second degree polynomial model was fitted in the form; $Y=b_0+b_1X+b_2X^2$. The values of coefficients and estimates are given below with t- value in parentheses.

$$Y = 53117.36 + 456.99X + 134.45X^2$$

(0.445) (4.588)

R Square=0.93452, Adjusted R Square=0.93015

To use the quadratic trend equation for forecasting purposes, we substitute the value of X (X=34,35,36) in the above equation (Fig. 2.7). The continuing increase in expenditure is of serious concern to the government, in view of decreasing revenue, though, direct economic benefit from forests is a only secondary aim in National Forest Policy Document.

2.3.8 Major issues before Forest Department, Bihar

The main issues before the forest department, Bihar are as follows:

- The progressive degradation of forests, due to intensive pressure from human and cattle population, is leading to serious environmental degradation and destruction of biodiversity in addition to causing loss of revenue to the government and hardship to the people directly dependent on forests.
- Grazing far beyond the carrying capacity of forests has taken its toll on plantations and also affected the natural regeneration adversely.
- A paucity of funds is hampering forestry development activities in Bihar. The degradation of the forests is also leading to lower return from the forests.
- The demand for forest products especially fuel wood is far in excess of the supply from the forests. This adverse supply and demand situation can partly be redressed by increasing the productivity of the forests (restocking the gaps).
- Forests and the adjoining areas in the Chotanagpur plateau are subject to increasing soil erosion.
- The productivity of plantations and natural forests fall well short of what could be realistically attained mainly because of two reasons:

(a) unrecorded and recorded removals well beyond the regeneration capacity;

(b) use of poor genetic stock in plantations.

- There is tremendous urgency to find ways to develop the institutional framework including respective roles of the public and private sectors in forestry, keeping in view the objectives (some times contradictory) of National forest policy.

2.4 Past Evaluation of afforestation projects

2.4.1 Afforestation Projects

Afforestation projects constitute a major component in rural development programmes. The term 'afforestation projects' is used to include all the forestry projects with a component that involves tree growing. A number of tree growing projects initiated in the past are continuing today under various names like social forestry, community forestry, extension forestry etc. depending on ownership of land (forest land or private land), implementing agency, main beneficiaries (panchayat, individual farmers). The conventional distinction (Shah, 1988) of 'production forestry' and 'social forestry' (Westoby, 1968; Slade and Campbell, 1986) is now diminishing due to adoption of joint forest management (JFM) in most states as JFM ensures sharing of forest produce (both major and NTFP) between people and forest department even in respect of plantations grown in RFs and PFs.

Afforestation programmes in India have been taken up under various schemes of the central and the state governments. A number of afforestation projects supported by bilateral and multilateral agencies have also been implemented in different states. Main funding agencies include the World Bank (WB), Overseas Development Administration (ODA), Swedish International Development Authority (SIDA), Canadian International Development Agency (CIDA), Danish International Development Agency (DANIDA) and United States Agency for International Development (USAID).

2.4.2 Afforestation projects in Bihar

Plantations on a large scale have been raised in Bihar right from the inception of the First Five-Year Plan (FYP). Table 2.1 summarizes achievements under afforestation projects.

Table 2.1: Achievements under afforestation projects

FYP=Five year plan

Plan	Period	Block plantation (in ha)	Linear Plantation (in km)
1st to 5 th FYP	1951-52 to 1978-79	62710	490
6th FYP	1980-81 to 1984-85	56920	1780
7th FYP	1985-86 to 1990-91	119680	1457
Total	1951-1991	239310	3727

Source: GOB (1995)

The Bihar Forest Department had realised the need to promote tree growing outside forest land as early as the late 1970s. Although growing of fruit trees and a few timber trees (e.g. *Dalbergia sissoo*) has been a very old practice in North Bihar, the real impetus to private tree growing came after the report of the National Commission on Agriculture in 1976. However very little was achieved in the initial years mainly because of a paucity of funds. The real change came with the National Rural Employment Programme (NREP) and the Rural Landless Employment Guarantee Programme (RLEGP) in 1981 with 20% of total rural development funds earmarked for afforestation. In South Bihar, afforestation programmes were started along similar lines to those of North Bihar. However, there was little impact of promotion of farm forestry through free distribution of seedlings, as most villagers have recorded rights to collect forest produce and those who did not have rights, did manage anyhow (illicit felling). In 1978-79, an afforestation programme was initiated for plantations in degraded forests, road-side etc. The scope was later widened to include raising plantations on farmers' land at government cost. However, rich, politically influential and absentee landlords benefited from the scheme.

In addition, plantations under a number of other schemes such as Drought Prone Area Programme (DPAP), Quick Growing Species (QGS), Rural Fuelwood Plantation (RFP), Canal Embankment Plantation (CEP), Plantation of Tasar Host Plants and A Tree for Every Child Programme were also taken up. In 1989-90, most schemes were replaced by Jawahar Rozgar Yojana (JRY; a scheme for employment generation, with funds being directly channelled to village panchayats) and a total of 40 million seedlings were planted. However, in the following years, planting decreased to about 10 million seedlings annually. The approach remains unchanged.

2.4.3 SIDA-supported social forestry project of Bihar

The Bihar Social Forestry Project (BSFP) aided by SIDA, started in the year 1985 In Chotanagpur and Santhal Parganas, for a six-year period divided into two phases, each of three years (Phase 1, 1985-88; Phase 2, 1989-91) and terminated in the year 1992. The SIDA's contribution was originally agreed at SEK 207 million (US$ 25 million).

2.4.3.1 Objectives

The project had both production and development objectives. The production objectives are summarised in the Appraised Project Document (APD) and Amended Project Document (APD II) as ' increasing the production (for self-consumption and surplus for the market) and access to fuelwood and minor forest products in rural areas'. The specific objectives were:

(a) production of wood (including fuelwood, small timber and poles) and non timber forest produce (NTFP) in rural areas for the market as well as for self-consumption.

(b) development through participation of villagers, self-reliant system of tree growing to the particular advantage of the poorer section of the population and of women (as fuelwood collectors), development of a new type of organisation, new attitudes and skills within the forest department compatible with the support functions required from social forestry.

2.4.3.2 Components

To achieve the objectives, the project had the following five components:
(a) farm forestry (FF), (b) rehabilitation of degraded forests (RDF), (c) strip plantations, (d) institutional plantations and (e) Harijan land planting.

(a) Farm forestry

The objective of the Farm Forestry scheme was to motivate, encourage and assist individual farmers to plant trees, preferably on lands which were uneconomical for agriculture, as an integral part of the farm production system. Any farmer could participate in this component but the project would 'aim particularly at SC, ST, small and marginal farm families and 'other backward classes' (OBC)' (APD). Each participating farmer received up to 1000 seedlings, a proportionate amount of fertiliser and insecticide free of cost and was paid cash (termed as 'societal compensation') for digging pits, planting and maintenance of surviving seedlings (counted at the end of the second year of planting). One objective within FF was the allocation of government waste land to landless families for tree growing.

(b) Rehabilitation of degraded forests

The RDF component was confined only to protected forests (PFs) where villagers had recorded usufructuary rights (recorded in Khatian part II) to harvest produce to meet their own needs. For each participating village, the project aimed to increase productivity of forest areas degraded by previous over-exploitation. In theory at least, most of these forests were under a 'coppice with standard system' which relied upon natural regeneration and the coupes earmarked for right holders' coupes could meet villagers' (including both right holders and other non-right holders) demands without affecting the felling cycle adversely. But actually, these areas were highly degraded due to continuous biotic pressure (demand for fuelwood, grazing incidence and illicit felling). The following operations were carried out in RDF:

(1) cutting back malformed stems and bushy growth to produce coppice growth (mainly of *Shorea robusta*) in about 60% of the total RDF area.

(2) planting on sizeable blanks (of >1 ha) within the degraded area with fast growing species.

(3) protection of these areas involving VFCs (Village Forest Committee) and all right holders.

(c) Strip plantations

The strip plantation were to be implemented on government land (not forest land) along road sides, canal banks and railway lines. The strip plantations were dropped during the first phase of the project, because it was not possible to develop a mechanism whereby these areas could be declared as PF's to assure usufructuary rights to landless people in the vicinity.

(d) Institutional planting

This component was added as an extension activity and involved mainly village schools in tree growing activity. There were two main problems in implementing this scheme:

(1) Schools and other institutions could not make available lands required for plantations;

(2) Very few village schools had boundary walls to ensure protection of plantations.

(e) Harijan land planting

A small component of tree growing on lands allocated to Harijan (SC) families was added in the first year of the project. The project was to take responsibility for establishing and protecting the plantations.

Participation in the production and distribution process was to be encouraged through the formation of VFCs, representing the main users and target groups which would work as a link between the forest department (FD) and the farmers. The nature of rights and duties of each group was to be enshrined in a Joint Management Plan (JMP). The FD had also appointed 'contact persons,' chosen from among the villagers, in each participating village.

2.4.4 Evaluation of afforestation projects

The basic purpose of evaluation is to find out levels of people's participation and flow of benefits according to the defined objectives of the project. Evaluation is defined as 'a systematic process which attempts to assess objectively, the impact of a project in the context of the project objectives' (FAO, 1985). The evaluation of a project may be taken up before *(ex-ante* evaluation) or after the completion (*ex-post*) of the project or during the implementation (concurrent evaluation) of the project. The methodologies used both in *ex-post* and *ex-ante* analyses are basically similar except the kind of information used and the methodology of information collection varies. The conventional evaluation was limited to assessment of physical and financial benefits from the project only. The quantification of the actual flow of benefits to defined groups (e.g. society, farmers, labours, women etc.) was seldom attempted. However, many donor agencies have carried out numerous detailed studies in the form of reviews (FAO, 1992), case studies (FAO, 1989), full-fledged evaluations (Arnold et al., 1989; Arnold et al., 1990) and project completion reports. The Institute of Resource Management and Economic Development (IRMED) and the National Council of Applied Economic Research (NCAER) have carried out pilot studies to develop a suitable methodology for evaluation of social forestry projects and have applied it in assessing the potential of social forestry for employment, income and asset generation in rural areas (IRMED, 1989; NCAER, 1988).

2.4.5 Evaluation of SIDA-supported Bihar Social Forestry project

Afforestation projects were started in Bihar way back in 1951 but the evaluation of different components was limited to silvicultural and administrative aspects only. The reported physical targets and achievements are given in Table 2.2.

Table 2.2 Physical achievement of Bihar Social Forestry Project, 1985-92

Project components	1985-88 T=A	1988-89 T	1988-89 A	1989-90 T	1989-90 A	1990-91 T	1990-91 A	1991-92 T	1991-92 A
RDF									
Villages	315	-	149	-	243	-	277	-	194
Area	14595	5000	6383	10918	11454	9000	12212	8401	7781
Seedlings	37.7	6.0	6.5	10.9	12.1	9.0	12.5	8.6	7.9
FF									
Villages	1521	800	535	1100	813	1250	1091	775	734
Beneficiaries	50131	3000	21582	44000	33442	50000	47912	25125	23793
Seedlings	159.1	22.5	18.6	33.0	32.3	37.5	42.6	23.0	21.8
SP									
Length	205	-	2	-	-	-	-	-	-
Seedlings	1.01	-	0.05	-	-	-	-	-	-
IP									
Institutions	108	-	34	-	125	-	110	-	66
Seedlings	0.4	0.24	0.09	0.3	0.47	0.36	0.36	0.20	0.18
HLP									
Area	2200	768	296	-	660	-	1200	-	563
Seedlings	6.5	1.9	0.76	1.5	1.7	2.5	3.0	1.6	1.4
FRD									
Seedlings	4.2	-	0.56	-	0.39	-	-	-	-

Notes: 1. Key: T= Target; A= Achievement, SP=Strip Planting, IP=Institutional Planting, HLP=Harijan Land Planting, FRD=Free Distribution.
2. Beneficiaries, villages and institutions are expressed in numbers, seedlings in million, length in km, area in ha. Targets were revised in the APD II to correspond to the achievements for the first three years. Source: Arnold et al., 1990 and GOB, 1995

The evaluation of the SIDA-supported BSFP was carried out by an independent and external mission headed by J.E.M. Arnold. This mission had covered aspects like participation, socioeconomic impact and institutional issues but economic analysis based on field data was not attempted. Comments on participation of farmers and other socioeconomic issues were based on the team's own observations and on the observations of earlier joint review missions. The comments on some issues raised in the report were presented more as opinions or hypotheses rather than as definitive judgements (Arnold et al., 1990). A number of separate case studies were also carried out on functions of Non-Government Organisations (NGO) involved in the project (Verma, 1988), participation of women (GOB, 1987) and seedling distribution (Munda and Verma, 1987).

Farm Forestry and Rehabilitation of Degraded Forests were the most important components of the project (Table 2.2). Therefore, they were taken up for detailed economic analyses. Some of the important findings of earlier evaluations and subsequent case studies are summarised as below:

• The BSFP meant a budget increase for afforestation. However, the total government budget to the FD was not increased. It resulted in a scaling down of other forest activities.

• Participation of the villagers , in the form of VFC, JMP and CP is essential to the social goals (Arnold et al., 1990). But most of the VFCs were inactive and ineffective.

• Quality aspects such as survival of seedlings, growth rate, planting stock were neglected to achieve quantitative targets (number of beneficiaries, number of CPs, seedlings distributed, area planted etc.).

• During project implementation, it became clear that most of the farmers did not plant trees for meeting their fuelwood needs. Fuelwood continued to be collected from nearby forests.

•The management of strip plantations was unclear and nearby villagers never got the expected usufructuary rights. Similarly the tree patta[7] system never worked.

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[7] In the tree patta scheme, landless were given the right to use the government land (not forest land) for growing trees and also had right to the forest produce.

Chapter 3

Evaluation of afforestation projects: theoretical and methodological framework

3.1 Introduction

In recent times, projects have emerged as the cutting edge of development (Gittinger, 1982). Over the last 15 years there has been a proliferation of afforestation projects in India, with a total investment of approximately 20 billion rupees (1983 price) from international donor agencies alone. The main objective of project appraisal has been the efficient allocation of investment funds. But now, the issues relating to distribution of income and environment have achieved great attention particularly in developing countries. Investment funds are scarce and there are many competing uses for them. The process of selection of the best project or projects from a number of alternatives is 'project appraisal'. The process of project appraisal and its outcome largely depend on the policy objectives of the agency on whose behalf the appraisal is undertaken.

3.2 Methods of project appraisal

There are several methods of project evaluation. Each method concentrates on certain aspects of a project. The most common methods of investment appraisal are:

(a) Simplistic investment appraisal methods

(b) Cost-benefit analysis

(c) Cost-effectiveness analysis

(a) Simplistic investment appraisal methods

Simplistic investment methods are commonly employed by business firms and are suitable when the project involves very high degree of risk . These methods include:

(i) cut-off period

(ii) pay-off period

(iii) rates of return (Price, 1989)

(iv) ranking by inspection (Gittinger, 1982)

(v) proceeds per unit of outlay (Gittinger, 1982)

(vi) average income on base value of the investment (Gittinger, 1982)

(vii) maximum forest rent (Price, 1989)

(viii) profit after interest (Price, 1989).

One of the major limitations of these methods is that they ignore time preference. They are not comprehensive enough to include all important aspects of project appraisal and may lead to misleading conclusions.

(b) Cost-benefit analysis

Cost-benefit analysis (CBA), also known as benefit-cost analysis, has been defined as 'an economic appraisal of the costs and benefits of alternative courses of action, whether those costs and benefits are marketed or not, to whomsoever they accrue, both in present and future time, the costs and benefits being measured as far as possible in a common unit of value' (Price, 1989). Cost-benefit analysis provides an objective framework for analysis of projects. CBA for the appraisal of projects has been advocated by many authors and organisations, the seminal contributions in this field being Little and Mirrlees (1968, 1974), UNIDO (1972) and Squire and Van der Tak (1975).

(c) Cost-effectiveness analysis

This method is particularly useful in very uncertain or risky projects. Costs of a project can be estimated fairly accurately because major costs of a project are usually incurred at the beginning of project and only the minor costs are incurred towards the end. Benefits of such projects are difficult to estimate accurately. The cost-effectiveness analysis (CEA) ranks projects according to their costs and their effectiveness in achieving a goal. It involves primarily:

1. Defining an objective
2. Listing the alternatives to achieve the objective
3. Cost of each alternative
4. A criterion to evaluate cost against effectiveness of the alternative methods in meeting

the objective.

There are number of items like pure public goods, which cannot be valued meaningfully. Pure public goods (defence, health etc.) jointly benefit many people and people find it difficult to assign any value to such goods. Under such circumstances cost-benefit analysis becomes impossible as the benefits cannot be objectively valued. Cost-effectiveness analysis is very useful in such situations. The cost of providing the same level of benefits in different ways can be compared. It is also useful in such situations where the appropriate methodology to value non-market items is not available.

(d) Other decision-making methods

Cost-benefit analysis and cost-effectiveness analysis are used more than any other methods. There are several other decision-making frameworks which are also used in project appraisal independently or together with CBA methods. They are:

(i) Technology based standards

(ii) Risk-risk analysis

(iii) Risk-benefit analysis

(iv) Environmental impact analysis

(v) Economic impact analysis, and

(vi) Operational research techniques such as multiple objective programming techniques etc.

3.3 Cost-benefit analysis

Cost-benefit analysis in not an agreed body of methodology accepted by all practitioners (Price, 1989). In fact, CBA is a general philosophy of evaluation. Evaluation agencies often are faced with problems relating to the computation of undistorted market price, estimation of shadow wage rate, choice of decision criteria and identification and quantification of all costs and benefits.

CBA usually involves:

1. Identification and quantification of value of the costs and benefits in each year of the project
2. Calculation of an aggregate present value of the project by discounting both costs and benefits to the reference year and adding them up.

3. Selection of an indicator of project choice and calculation of its value for the project.

CBA techniques can be broadly categorised into two types: environmental CBA and developmental CBA. Environmental CBA is mainly concerned with the evaluation of non-market costs and benefits and is practised mainly in developed countries. Developmental CBA deals with distortions of market price and distributional issues and has much relevance to developing countries. Nonetheless, environmental effects of a project are of vital importance to developing countries and developed countries are also concerned with distribution issues.

Sometimes, the term extended CBA is used to include environmental considerations in developmental CBA, by definition (Price, 1989), CBA considers 'all costs and all benefits'.

The project costs and benefits once quantified need to be evaluated in terms of a common value. Depending on type of value-base used, there can be different types of CBA. The standard CBA types and their value-base are:

(i) Financial CBA (market price, real terms)

(ii) Economic CBA (efficiency price)

(iii) Social CBA (social price)

Financial CBA (FCBA) is carried out from the point of view of private investor's profitability. Economic appraisal (ECBA) is concerned with profitability to the whole economy or society. But environmental benefits and costs are also included. Generally for public funded projects, both analyses are carried out together. Social CBA (SCBA) is the most comprehensive form of CBA. It incorporates the distributional objective into the numeraire and focuses on income.

3.3.1 Economic efficiency and government's intervention

In neoclassical economic theory, free markets will lead to static and dynamic efficiency under 'perfect' competition (Killick, 1981). Perfect competition is characterized by:

(a) a large number of buyers and sellers,

(b) 'private good' characteristic of each product, and

(c) free and voluntary transactions of private goods.

When markets for particular goods fail to meet the neoclassical conditions of perfect competition, a situation of market failure takes place. In the case of market failure, the government's intervention is required to achieve 'dynamic' and 'static' efficiency through objective plans and projects (Ward et al., 1991). But in most of the developing countries governments' interventions may best be described as nonoptimal or suboptimal. The corrective measures generally taken by governments include import bans and export subsidies etc. Shadow prices in economic appraisal are used to correct distortions in prices resulting from market failure and government's suboptimal or nonoptimal interventions. If all the interventions were optimal and appropriate, the financial prices would reflect economic values and shadow prices would not be required in projects.

In presence of market failure and government failure, the prices of commodities differ from their economic values in terms of willingness to pay for these commodities. But 'merit goods' (e.g. public housing, support for art and culture or even food grains when considered as basic human rights) cannot be valued in terms of willingness to pay objectively as their values are held in common by society and may not be reflected in individual demands (Musgrave and Musgrave, 1989).

Thus, economic values and financial values of a commodity differ primarily because of: (a) market failure; (b) government failure; and, (c) merit goods and demerit goods (Ward et al., 1991).

The combination of these factors together with political and other considerations, leads to large scale distortion in the economy which makes project appraisal exceedingly difficult.

3.3.2 Methodologies of CBA

Manual of Industrial Project Analysis for Developing Countries (OECD, 1968) and *Guidelines for Project Evaluation* (UNIDO: Dasgupta, Sen and Marglin, 1972) were the first comprehensive manuals in the field of applied cost-benefit analysis for developing countries. Subsequently, the manuals were revised and further developed (Little and Mirrlees (henceforth: LM), 1974; UNIDO, 1978). Now, these are the most accepted methodologies for project appraisal. The applied aspects of these methodologies were further developed by many workers according to specific requirements of developing countries (Dasgupta and Pearce, 1972; Layard, 1972; Squire and van der Tak, 1975; ODA, 1977, 1988; Gittinger, 1982; Layard and Glaister, 1994).

There is very little fundamental difference between two methodologies viz. LM (1974) and UNIDO (1978) (ODA, 1988). In respect of shadow pricing of tradable goods, or tradable contents of non-tradable by reference to border price, both methodologies are similar. Irvin (1978) has described UNIDO methods as a variant of the LM method rather than an alternative.

In the LM method emphasis is on trade efficiency whereas the UNIDO method focuses on domestic consumption in the hands of the average individual. The justification for using a domestic consumption numeraire is based on the fact that consumption is the ultimate goal for investment.

3.3.3 The numeraire in CBA

The common unit of value is referred as the 'numeraire' in cost-benefit analysis. Both the project costs and the project benefits are measured in terms of their contribution to the economy. They must be expressed in a common unit of value. In fact the numeraire is a common denominator for measuring benefits and costs. In the LM method, the numeraire is 'uncommitted social income measured in terms of convertible foreign exchange' whereas the UNIDO numeraire is 'aggregate consumption of an average income consumer, measured in domestic currency'. The main difference between the two methodologies is the unit of account or numeraire used. The two prominent forms of numeraire in CBA , widely used by multinational agencies are : the willingness to pay (WTP) or aggregate consumption numeraire, and the foreign exchange numeraire. WTP numeraire values non-traded goods and services on the basis of willingness to pay and it values traded goods and services in foreign exchange at border price. Both are expressed in domestic currency. The foreign exchange numeraire requires that non-traded goods are valued in terms of their value equivalent on foreign exchange while traded goods be valued in their direct impact on foreign exchange. The 'uncommitted public income in terms of 'foreign exchange ' is the numeraire in LM methodology (Little and Mirrlees, 1974). This is also adopted by Squire and van der Tak (1975), Bruce (1976), Scott et al., (1972) and Little and Scott (1976). Lal (1980) assumes that both private and public savings are equally valuable and expresses the numeraire as 'savings expressed in foreign exchange'. Dasgupta, Sen and Marglin (1972) define their numeraire as average consumption measured in domestic currency. Hansen (1986) emphasises 'critical consumption' rather than 'average consumption'. The critical consumption is the level of consumption at which the government would be indifferent about letting the private sector consume the unit of foreign exchange rather than government keeping it as public income. UNIDO (1978) advocates the use of domestic currency available for an average individual as the numeraire. However it is convenient both in terms of computation and application if the numeraire is taken as 'the value at present-day prices of domestic currency used for consumption by citizens having the mean income level for the country (Price, 1989).

A numeraire should be selected, not on the basis of some pre-conceived notions but with due regard to the nature of the investment project, the investing agency and the beneficiary. For instance, for appraisal of a government forestry project using non-traded material and labour inputs, and producing a non-traded output, expressing all values in convertible foreign exchange (LM numeraire), will involve a lot of unnecessary calculations. The use of UNIDO numeraire, i.e., expressing all values at domestic prices, appears to be a better approach in this case. Conversely, if a project involves international trade, LM numeraire appears to be a natural choice.

The selection of a currency of a country as the numeraire is not sufficient. It must be specified (UNIDO, 1978; Price, 1989) with respect to:

a. base year, i.e. value of the currency with respect to inflation,

b. convertibility of the currency in domestic and international markets,

c. use of income from the project: consumption or investment

d. ownership of the currency: government or private

Since the afforestation project uses mainly non-traded goods and surplus labour to produce goods for local consumption, the domestic currency (Indian Rupee) in the average consumer's hand has been selected as the 'numeraire' for the study.

3.3.4 Discount rate

The value of consumption at two different points in time is not equal. Therefore an appropriate allowance for the time value of consumption should be given. Discounting is reciprocal to compounding. The future values of benefits and costs can be expressed in terms of present value by dividing the future value (at time t) by $(1+r)^t$. 'r' is the rate by which present consumption is preferred to future consumption and referred to as a time preference rate or discount rate. Discounting does not reflect inflation or deflation or any change in the purchasing power of money. The arguments for and implications of discounting are discussed by Price (1973, 1993).

The objective estimation of the discount rate for project appraisal is very complex.

Apart from theoretical and practical problems in estimation, it involves ethical and social issues. For developing countries choice between present and future consumption is puzzling. The discount rate is the most crucial parameter in the evaluation of afforestation projects. A high discount rate favours early exploitation and a low discount rate favours investment in long-term afforestation projects. The question of the appropriate discount rate for public project appraisal has been a subject of extensive controversy. Stiglitz (1994) has identified the following key areas where the disagreement generally exists:

a. differences in views about the structure of economy, for example, tax-structure
b. differences in views about the relevant constraints, for example, saving constraints
c. differences in values i.e., attitudes towards inter-generational distributions

The market interest rate is often regarded as the indicator of time preference. But it is not possible to find a single market interest rate because of: (a) uncertainty of future returns, and (b) credit risk involved. The most commonly used estimate of time preference is the rate on long-term government bonds. These bonds are generally regarded as free of risk. But as the future inflation is not known, there is no truly risk-free interest rate. Layard and Glaister, (1994) have suggested use of post tax interest rates on long-term risk free bonds (after adjusting for inflation) for estimation of the discount rate.

There are two main approaches used in estimation of discount rate in ECBA and SCBA: (a) the social opportunity cost of investment (SOC) and (b) social time preference (STP).

The SOC (or economic discount rate) measures the value to the society of the next best alternative investment. It is expressed in terms of marginal product of capital (q). Bruce (1976) and Irvin (1978) advocated that 'q' should be multiplied by a standard conversion factor (SCF) to convert it to a border equivalent of opportunity cost of capital. Such an estimation procedure is questioned by Price (1993) because it amounts to using a discount rate which is not applicable for the country where investments are made. The main criticism is that it uses a one-off numeraire conversion in a formula which repeatedly revalues through time, so the influence of the SCF is small in the short term but large in the long term. There are other criticisms also (for a detailed account see, Price, 1993).

The STP measures the society's trade off for present consumption in order to improve future consumption. The STP is generally indicated by the consumption rate of interest (CRI) which measures the rate of decline of one unit of average consumption over time. STP approach for estimating social discount rate has been suggested by many analysts for forestry project appraisal (Harou, 1985; Hoekstra, 1985, 1987; Kula, 1988; Price, 1988, 1989, 1993). Feldstein (1964) and Marglin (1963) also emphasised that the relative weights which society places on consumption at different times in the future should be used in project appraisal.

It has been suggested (UNIDO, 1972; Harou, 1985) that the appropriate discount rate (STP) can be estimated by studying governmental choices of individual public projects as it represents government policy with respect to the desirability of consumption at different times. The lowest rate of return on projects accepted in the past indicates the upper limit of the social discount rate. But Government choose projects to meet many objectives - social, environmental, strategic etc. This approach has several other drawbacks also listed by Price (1993).

3.3.5 Criteria of profitability

In CBA indicators of non-discounting types are not used as they fail to allow for the time value of consumption. Allowance for time value of consumption is achieved through discounting.. There are three most commonly used investment indicators:

(i) net present value (NPV) or net present worth (NPW)

(ii) benefit-cost ratio (BCR), and,

(iii) internal rate of return (IRR).

We will now briefly discuss the significance and limitations of these criteria.

NPV is the difference between the discounted benefit (i.e., present value of the stream of benefits) and the discounted costs (i.e., present value of the stream of costs), whereas BCR is their ratio. IRR is the value of the discount rate which makes the discounted benefits equal to the discounted costs. Mathematically, the three criteria can be written as follows:

$$NPV=\sum_{t=0}^{t=N} \frac{B_t-C_t}{(1+r)^t} \text{..........................} eq. (3.1)$$

$$BCR=\frac{\sum_{t=0}^{t=N}\frac{B_t}{(1+r)^t}}{\sum_{t=0}^{t=N}\frac{C_t}{(1+r)^t}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.(3.2)$$

IRR = the value of r that makes:

$$\sum_{t=0}^{t=N}\frac{B_t-C_t}{(1+r)^t}=0\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.(3.3)$$

where, B_t is the benefit in year t (t = 1, 2,...N), C_t is the cost in year t (t = 1,2,...N), r is the discount rate expressed in decimals and N is the number of years over which costs and benefits occur.

In order to be desirable, the NPV of any project should be positive or its BCR should be greater than unity or its IRR should be greater than the market rate of interest. This simple 'accept - reject' rule is an oversimplification of the real world decision-making situation.

The NPV criterion in FCBA evaluates the projects by looking at the easiest and possibly the best alternative: lending the money at the market rate of interest (Trivedi, 1987). The project should yield more than that would arise from lending money at the market rate of interest (market rate has to be adjusted for inflation). Thus, it is the market rate of interest which should be used as the discount rate to calculate NPV. BCR also uses the market rate of interest to discount future cash flow. A positive NPV implies that the discounted benefits are greater than the discounted costs. Therefore, it also implies a BCR>1. BCR has been called as a variant of NPV (Mishan, 1975).

The IRR decision rule suggests that if a project's IRR is less than the market rate of interest, it should be rejected because a higher rate of return can be obtained by lending the money in the market.

The NPV, BCR and IRR give similar investment decisions in unlikely situations when projects are truly independent and there are no operative constraints (Prest and Turvey, 1965). Where these conditions do not exist, the choice of appropriate indicator is of vital importance because the three indicators do not always point in the same direction and the decision regarding ranking of the projects may be influenced by the choice. The choice of appropriate indicator has been discussed amongst economists (Baumol, 1972, Mishan, 1972a, Mishan, 1972b, Dasgupta and Pearce, 1972). Many academicians and practitioners of project appraisal (Foster and Brook, 1983; Schallau and Wirth, 1969) favour IRR, whereas several others (Gasner and Larsens, 1969; Price and Nair, 1984; Price, 1989; Price, 1990) are critical of it. Criticism of IRR includes its sensitivity to the time phasing of benefits, the size of capital outlay, the problem of multiple roots (Feldstein and Flemming, 1964; Dasgupta and Pearce, 1972; Price and Nair, 1984; Price, 1989). The multiple root problem arises because IRR is the solution to a polynomial equation.

High IRR ensures that the benefits would outweight the costs at a high discount rate, but the society may prefer to discount at a lower rate than the IRR.

Ranking of mutually exclusive projects further exacerbates the disadvantages of IRR in comparison with NPV. The NPV criterion gives a straightforward rule: accept whichever project produces the highest NPV. This is based on two assumptions: (a) investment funds are freely available and, (b) the market rate of interest gives full allowance for different time spans and different timings of cash flow. If mutually exclusive investments are not isolated (i.e., if their replacement at the end of their operational lives is contemplated) ranking cannot be made on the basis of absolute size of positive NPV. The correct approach is to take an infinite time period.

If there are two mutually exclusive projects with IRR equal to 15% and 20%, and the market interest rate is 10%, the IRR decision rule should be interpreted as suggesting only that both the projects are independently worthwhile, but not that the project with 20% IRR is preferable. In order to use IRR decision rule to rank such projects, we need to use 'incremental yield approach' or Irving Fisher's theory of interest (Dasgupta and Pearce, 1972). It involves calculation of the IRR of not only the two projects, but also of their differential cash flows. IRR criterion would not work even in the case of independent projects if the market interest rate varies with time in such a way that at one instant it is above the IRR and at another instant it is below the IRR.

The choice of indicator ultimately converges on the NPV and BCR. One major drawback of the BCR is its inability to indicate the true quantum of net benefit. NPV per unit area is, in general, the best criterion for afforestation projects appraisal (Price and Nair, 1984 and Price, 1989) except under budgetary constraints, when BCR is a preferable criterion (Brent, 1990).

3.3.6 Treatment of inflation in project appraisal

Price stability is essential for stability in economic life. Inflation is an increase in price level over time. In a market economy, producers take decisions on production according to the demands for their products. Therefore, any changes in price will ultimately influence the production decision.

Inflation affects the estimation of cash flow as below:

- The estimation of a project's cash flow involves the estimation of future rates of inflation i.e. future prices of individual inputs and outputs. If all the prices change at the same rate, the decision will not be affected. Conversely, if the prices of input and output change at different rates, such changes in relative prices should be predicted explicitly, instead of adjusting the discount rate (Price, 1991).
- It is expected that in presence of inflation in a economy, the money rate of return on market investments is likely to rise along with general price trend ($(1+m)=(1+r)(1+i)$, where m is money interest rate, r is real interest rate and i is inflation rate).
- In order to estimate the profitability of a project, price fluctuations both in input and output are to be considered. In a state of high rate of inflation, investment in a project will be adversely affected because of problems in estimation of output.

Generally, cash flow is generated at constant prices assuming that inflation will affect both costs and benefits equally. It allows the analyst to avoid making estimates of future inflation rates (Gittinger, 1982). It also takes account of long term changes in relative values of inputs and outputs. Sometimes, it is easier to carry out project appraisal in current prices but the discount rate must be expressed in current prices after adjusting it for general inflation.

3.3.7 Shadow Pricing in projects

The shadow price measures the 'worth' of a unit of each of the commodities as measured by the objective function (Layard and Glaister, 1994). If market price of a commodity reflects its shadow price, there is no need to carry out a complete cost-benefit

analysis. A financial appraisal will be sufficient. But this is not the case for most commodities. Usually the market price of a commodity does not reflect its worth because:
(a) the market prices are distorted by taxes, subsidies, monopoly, unemployment or overvalued currency, especially in developing countries
(b) for non-market goods we do not have a market price at all . Similarly there are no market prices for the externalities of market goods.

The concept of shadow price offers a practical solution to the problem of measuring 'worth' of commodities in a situation where market price structure is distorted and estimation of price of commodities is difficult.

3.3.7.1 Shadow pricing of tradable commodities (TG)

Goods and services can be classified into basically three different types from the point of view of valuation :
(a) Traded or tradeable commodities which are actually exported or imported
(b) Non-traded commodities which are consumed within the country itself
(c) Partially traded goods having both the features.

The LM approach estimates tradable at border prices as c.i.f (cost, insurance and freight) for imports and f.o.b. (free on board) for exports thus eliminating the effects of all internal tariffs and taxes, as tariffs and taxes are not a real cost to the economy.
The f.o.b. and c.i.f. prices can be converted into the domestic currency using the official exchange rate. The net benefit (NB) can be given as:

$$NB = OER\,(X-M) - D \qquad \text{eq. (3.4)}$$

where OER is the official exchange rate, X is the f.o.b. value of export good in dollars, M is c.i.f. value of import goods in dollars and D is the value of all domestic inputs at market prices in rupees.

The UNIDO method uses the SER (shadow exchange rate) instead of OER. The SER is a ratio of domestic price (rupees) to border price (dollar) of traded commodities weighted by the share of each commodity in a country's total trade.

$$NB' = SER(X - M) - D \qquad \text{eq. (3.5)}$$

and

$$SCF = OER / SER \qquad \text{eq. (3.6)}$$

where SCF is the standard conversion factor

$$NB'' = OER\,(X - M - SCF^{*}D) \qquad \text{eq. (3.7)}$$

Equations 3.4 and 3.7 illustrate a difference of LM and UNIDO methods. This expression (eq. 3.7) gives the net benefit in border accounting rupees or the convertible foreign exchange numeraire of the LM methodology. Standard conversion factor can be calculated for the country as below (Bruce, 1976):

$$SCF = (M+X) / [(M+T_m)+(X-T_x)] \qquad \text{eq. (3.8)}$$

where X is the f.o.b. value of all exported goods, M is the c.i.f. value of all imported goods. T_m is tax on imports and T_x is the internal tax and tariff on exported goods. Thus, $M+T_m$ is the domestic market value of all imported goods and $X-T_X$ is the same for all exported goods. Therefore equation (3.8) is the ratio of value of all traded goods at border prices to the same at domestic market prices. The equation (3.8) is simplified form of the equation derived by Balassa (1974) which includes all tradables of an entire country.

$$SCF=\frac{\sum_{i-1}^{i=I} e_x X_i+\sum_{m-1}^{m=M} i_m M_m}{\sum_{i=1}^{i=I} e_x X_i(1-T_x)+\sum_{m=1}^{m=M} i_m M_m(1+T_m)} \qquad \text{eq. (3.9)}$$

where e_x is the elasticity of supply of exported goods, i_m is the elasticity of demand for imported goods, X_i is the f.o.b. value of ith exported good. M_m is the c.i.f. value of mth imported good. T_x is the internal tax on exported goods. T_m is the import tax.

The estimation of e_x and i_m is difficult. Hence, the simplified expression (eq. 3.8) is commonly used.

3.3.7.2 Shadow pricing of non-tradable commodities (NTG)

SCF calculated above is often used for non-tradable commodities also. The use of equation 3.8 for non-traded goods is an over-simplification. Non-traded goods can be divided into a traded goods component and other factor components which can be valued at border prices. The equation (3.7) can be modified as:

$$NB' = OER(X-M) - \sum_{z=1}^{z=Z} b_z D_z \ldots\ldots\ldots\ldots\ldots eq. (3.10)$$

where D_z is the zth domestic non-traded good.

In the UNIDO approach, the domestic prices of non-traded goods expressed in the numeraire, will give the economic prices. Since most of the inputs and outputs of afforestation projects fall in this category, this method is widely used.

3.3.7.3 Shadow pricing of partially-traded commodities (PTG)

In the case of partially-traded commodities, the proportions which are met from domestic production, and from exports and imports have to be estimated separately in LM method. The latter (export / import portion) can be treated as tradable. Consumption conversion factors for each commodity need to be estimated in the former category. In UNIDO method NTG component of PTG can be priced in the domestic market in numeraire equivalent and TG through SER.

3.3.7.4 Shadow pricing of land and labour

The shadow prices of land and labour can be estimated in terms of their opportunity costs. The marginal product of land and labour can be estimated in terms of agriculture production per unit of agricultural land and labour respectively for India. A standard conversion factor (based on a bundle of agricultural commodities) is estimated by Lal (1980). However in the UNIDO method only the forgone marginal product has to be estimated.

The labour market in India is not competitive. There exists underemployment and unemployment in a labour surplus economy such as India. The domestic market may overstate the wages of unskilled labour in comparison with its opportunity cost because of the Minimum Wages Act. In the UNIDO methodology, the value of output forgone by withdrawing labour from its previous occupation is taken as a measure of productivity of that labour. As most of the forestry operations are seasonal, the wages of the casual agricultural workers need to be weighted by an estimate of the degree of unemployment (Bruce, 1976: Irvin, 1978).

$$m=\left(\frac{1}{n}\right)\sum_{i=1}^{i=n}\left[\frac{D_i}{S_i}\right]w_i \quad \text{eq. (3.11)}$$

where m is shadow wage rate, D_i is the demand for casual employment, S_i is the supply of casual labour, w_i is the wage of casual labour in the month i and n is the number of months.

Little and Mirrlees (1974) have suggested taking a seasonally weighted average of the casual daily wage rate over the year, multiplied by the estimated average number of man-days worked per annum in the region. Some alternative and more precise methods for estimating shadow wage rates will be discussed in Chapter 7.

3.3.8 Income distribution

Projects tend to affect distribution of income. Should projects be used as instruments to redistribute income or should the issue of distribution of income be left to the tax structure? Musgrave (1969) argues that projects should be judged only on efficiency grounds and that taxation should perform redistribution objective. In practice it is difficult to devise a tax structure targeted specifically to the beneficiaries or losers of the project. The excess tax burden on tax payers may result in loss of efficiency in the economy.

ECBA accounts for aspects relating to allocational efficiency for the economy as such. However, the social welfare of a country cannot be measured in terms of economic growth alone. What needs to be critically examined is how the gains or losses in the economy are distributed amongst people because equal cash flows to individuals at different levels of income and at different points in time have different values. The distribution aspect has both inter-temporal and intra-temporal (or inter-personal) dimensions. SCBA addresses this aspect of projects. Inter-temporal dimensions involve relative weighting of present consumption and future consumption (present savings) of individuals at the same consumption level while intra-temporal dimensions absorbs relative weighting of benefits of a project to individual at different consumption levels. The most common system of giving weights to different groups comes from utility of income functions. This aspect will be discussed in detail in Chapter 8.

It is also possible to estimate the costs and benefits to different groups in society separately and let the policy makers assign appropriate weights to different groups.

3.4 Treatment of risk

3.4.1 Risk, uncertainty and threat

Risk and uncertainty influence the efficiency of resource use in afforestation projects and decision-making processes. Risk management is important whenever decision outcomes are uncertain, as occurs for most afforestation projects. The usage of the terms risk, uncertainty and threat are not universal. Risk is often used synonymously with threat. We use 'threat' to represent physical changes over time. Price (1993) argues that the only sensible way to include threat in economic evaluation is to understand the processes and to predict explicitly the physical products required to be valued. This aspect of threat appraisal will be discussed in detail in evaluation of Farm Forestry and Rehabilitation of Degraded Forests components of the afforestation project by explicitly exploring illicit felling in plantations and farmers' adoption pattern in Chapter 4 and Chapter 9 respectively.

Knight (1921) proposed three major categories to delineate the degree of knowledge in decision making processes. They are: perfect knowledge, risk, and uncertainty. Perfect knowledge exists when the decision outcomes are known with certainty. When the decision maker has the knowledge of probability distribution of outcomes, it is termed a risk situation and if no probability distribution of outcomes exists, it is termed an uncertain situation (Knight, 1921). However, in an uncertain situation, only beliefs are held about the probability of occurrence of outcomes. Thus, the distinction between risk and uncertainty has focused primarily on objective versus subjective probabilities (Sonka and Patrick, 1984). Sims (1981) has distinguished between a subjective probability which he requires for the theory of individual decision making, and an objective probability which is required to reflect a scientific consensus. Subjective and objective probabilities are distinguished by assumptions about prior information. Anderson et al. (1977) argue that all probabilities are subjective because the decision maker must subjectively make assumptions about whether any objective data are appropriate for the decision. A different and more useful form of distinction is often drawn between events which are 'statistical' (i.e. capable of very extensive repetition) and those which are 'non-statistical' (essentially unique events) (Lindley, 1971). Many decision situations are unique. This requires decision makers to make 'non-statistical' or subjective probability assessments which are consistent and 'coherent'. Coherence, in terms of laws of probability, can be defined as 'a condition on a set of probabilities for which a particular system of bets guarantees a *priori* no winner or loser (Bessler, 1984).

Thus, the distinction between risk and uncertainty (or statistical and non-statistical events, or objective and subjective probabilities) is useful only in conceptual terms. It has limited value in the practical process of risk assessment and analysis (Hertz and Thomas, 1983). Price (1989) has also concluded that 'uncertainty is not really distinct from risk............but [part of] ..a continuum from virtual ignorance to virtual certainty'.

3.4.2 Risk and discounting

In the conventional business approach, a risk-adjusted discount rate can be obtained by adding to the pure temporal discount rate, a risk premium. The size of risk premium is determined by the riskiness of the project. The risk-adjusted discount rate produces directly risk-adjusted NPV. This method is easy to apply and appears to be correct as interest rates are always high in risky investments. But the main problems in using the risk-adjusted discount rate are as follows:

- The main practical problem is related to the actual quantification of risk premium for various categories (e.g., high, low) of risk over time (Trivedi, 1987).
- It scales down the best estimate of NPV. What is required is an allowance for the dispersion around the best estimate or mean (Brent, 1990).
- It assumes that risk increases over time (Sugden and Williams, 1978).
- It combines two different concepts (risk and discounting) that should be best dealt with separately (Price, 1993).

3.4.3 Sensitivity analysis

Sensitivity analysis is used routinely as a standard practice in project appraisal. Sensitivity analysis is defined as 'the quantitative process of seeing what change in the value of a dependent variable is consequent on a chosen change in the value of one or more of the variables that determines it' (ODA, 1988).

The appraisal of a project involves estimation of a number of variables. It is important to know how sensitive expected NPV is to the estimates made about the different variables of the project. This would also indicate the permissible margin of error in the estimates of variables and their effect on outcome. Sensitivity analysis helps in identifying key variables that should be analysed further to obtain reliable estimates. It also indicates critical areas that require special attention to ensure the desired outcome of the project. Sensitivity analysis has some drawbacks also. They are:

- Sensitivity analysis may indicate combined effect of a change of all variables simultaneously but the outcome is difficult to analyse as we do not know the possible relationship among variables.
- Sensitivity analysis does not consider the complete distribution of outcomes of a variable. The importance of change in the value of a variable on outcome depends on the standard deviation of that variable.
- This method does not specify how the decision rule should be modified in the light of results of the sensitivity analysis.

3.4.4 The use of normal distribution

In this method we assume that the range of possible outcomes of a project are normally distributed. Then the probability of a project actually producing a negative NPV can be calculated. We assume normal distribution of outcomes because:

1. If n (number of outcome) is 'sufficiently large' (theoretically, $n \to \infty$), sample mean ($\bar{x}(n)$) is approximately distributed as a normal random variable with mean μ and variance σ^2/n (see, Chung, 1974, for a proof).
2. For any distribution - no matter how skewed; the following theorem is true:

$\mu - k\sigma$ to $\mu + k\sigma$ for $k>1$ encompasses at least

$$\left[1-\left(\frac{1}{k}\right)^2\right]100$$

percent of the observations (Chebyshev's Inequality).

It means that even for a skewed distribution 88.88% observation will fall within (mean) ± (3 standard deviation).

3. The range of normal distribution is $-\infty$ to $+\infty$.

For estimation of distribution of NPV, a risk-free or risk-adjusted discount rate can be used. The investment decision advice is based upon whether or not the probability of a negative NPV exceeds some pre-defined limit (Lumby, 1981).

3.4.5 Risk analysis

Project appraisal necessarily involves risk and uncertainty about values used in cash flow. Sensitivity analysis is used in highlighting key parameters. But often projects are very complex and it is difficult to quantify the change in project worth in response to change in the movement of one variable, keeping other variables constant. Risk analysis can handle some of the shortcomings of sensitivity analysis. Although the technique of risk analysis is well established, it is not popular amongst project analysts because of complexity of computation and lack of information on the appropriate probability distribution of variables. Little and Mirrlees (1974, 1991) and Gittinger (1982) refer to the need for risk analysis but find sensitivity analysis more practical because of computation problems in the case of risk analysis. Some other practitioners of project appraisal (e.g. ODA, 1988) also admit that 'the formal techniques of risk analysis are unlikely to be used' and favour sensitivity analysis. There are four main steps in risk analysis:

(1) Disaggregation of all components of a project into risk variables

(2) Generation of probability distribution of variables

(3) Determination of correlation (if any) among variables

(4) Simulation mainly using Monte Carlo methods

Risk analysis presents the outcome of a project in terms of probabilities, but does not offer any criteria for selection of projects on the basis of different probabilities of risk. Many decision rules and criteria have been developed for evaluating alternative courses of action (Young, 1984). The most commonly used criterion is the expected value (EV) rule (Brent, 1990).

$$EV = \sum [\text{Probability}].[\text{Outcome}]$$

The EV is equivalent to the mean (weighted) but it does not tell how representative is this value of the whole distribution. The greater the degree of variation (Variance or Var.), the less representative is the mean value.

$$\text{Var.} = \sum [\text{Probability}].[\text{Outcome - Mean outcome}]^2$$

The expected utility model (EUM) provides a systematic approach of interpretation of the results of risk analysis. It seeks to construct an actual utility function for the investors on the assumption of investors' risk behaviour (risk-averse, risk-neutral, risk-seeking) and to rank alternatives upon the consideration of risk involved rather than the expected NPV. The accurate estimation of the utility function of decision makers is difficult because of theoretical and practical problems in utility elicitation. To overcome this problem, an efficiency criterion is used to partially order choices. The most common efficiency criteria are as below:

(a) First degree stochastic dominance rule

(b) Second degree stochastic dominance rule

These criteria and some other criteria will be discussed in detail in Chapter 10.

Now, we consider arguments put forward both in favour of and against ignoring risk in public projects.

Since, risk is measurable (by definition, Knight, 1921), it is insurable by paying a fixed premium. The premium can be considered as a cost in the project like any other cost. So, there is no need to consider risk separately (Knight, 1921). We presume that Knight (and much of the literature) really means "threat" not "risk". Insurance companies don't reclaim on better-than-expected outcomes. And threats like fire, illicit felling etc. do reduce the value of public investment (Price, pers. comm.)

Arrow and Lind (1970) gave a mathematical proof that there is no need to consider variance in public projects based on the notions of 'risk pooling' and 'risk spreading'. As the number of tax payers tends to infinity, the cost of risk tends to zero.

Arrow and Lind (1970) 's theorem is based on simplified assumptions on public sector projects. They are not tenable under the following conditions:

- When pure public goods (defence project) are involved, benefits per person are not reduced by increasing the number of beneficiaries (Brent, 1990).
- In most afforestation projects the cost accrues to tax payers (mostly urban) but generally the benefit accrues to the farmers (non-tax payers, rural).
- Government having a large diversified portfolio is generally assumed to be risk neutral but project managers (responsible for implementation of projects) may not be risk neutral as their performance is evaluated from success or failure of the projects and a certain outcome may be preferred to an uncertain one of the same expected NPV.

3.5 Project appraisal : some alternative approaches

3.5.1 Logical framework approach to project appraisal

The US Agency for International Development (USAID) adopted the logical frame work (LF) method in 1971. Now, it has become a dominant method for appraisal of projects supported by USAID. The LF requires the specification of project goal, purpose, inputs, outputs and of assumptions about the project environment. It provides a common vocabulary oriented to generic feature of a project for analysis by a multi-disciplinary team (Clements, 1995). LF method permits, but does not require, cost-benefit analysis and/or cost-effectiveness analysis (CEA). Cost-benefit analysis is rarely used in the LF method and CEA has been used in about 23 % of USAID projects. Most initial decisions are made on the basis of the policy perspective of the individual country and the focus of the project.

3.5.2 Basic needs approach

In the late 1960s, economic growth was synonymous with development while in the late 1970s development was defined in terms of both growth and distributional aspects. Many developmental economists (Hicks and Streeten, 1979) have questioned the validity of the use of growth and income distribution as indicators of development in project appraisal. They emphasized the non-income dimensions of welfare of individuals. The non-income indicators include certain critical essentials or basic needs required for the well-being of people. It was found (Hicks and Streeten, 1979) that the correlation between basic needs indicators (viz. expectation of life at birth, % of required calorie consumption, infant mortality, primary enrolment, literacy, average persons per room and % of nouses without piped water) and GNP per capita for developing countries were significantly low as compared to those for pooled data which included all countries.

To incorporate the basic needs concept in project appraisal Harberger (1978, 1984) recommended treatment of basic needs as a public good . The consumption by the poor generates direct benefits for the poor and indirect benefits for the rich. Hence, consumption by the poor is referred to as a public good. Scandizzo and Knudren (1980) emphasised the market determination of food consumption which depends on the consumption behaviour of both the rich and the poor rather than on the consumption of the poor alone. The size of the basic needs gap is determined by the market behaviour (preferences) of the group in poverty, while the value to be given to the incremental consumption by the group in poverty, is determined by the preferences of the group just above the target level (Brent, 1990).

In the Harberger approach, the social demand curve is formed by the demand curve (preferences) of the rich by adding the demand for food by the poor. In the Scandizzo and Knudren approach, the social demand curve is defined as:

Social demand = Da + Dp

where Da is the 'social agent''s demand and Dp is the demand of the poor.

The social agent recognizes individual preferences only when the private demand by the poor is above 'the desired consumption level'.

Nair (1981) has developed a methodology to assign weightage to benefits according to their contribution to basic needs fulfilment. The market value of a good is multiplied by a basic needs conversion factor (BNCF) for that good. In the case of income, only the basic needs component is considered. Nair treats all labour costs and a part of staff salary as basic needs income. All goods and income below the basic needs reference lines are given a weightage of one. The basic needs criterion for selection of alternative is to maximise (Nair, 1981) :

$$[\, b_g . (GE - SCg) + b_i (IE - SCi) \,] / N$$

where GE is the basic needs value of the goods, IE is the basic needs value of income, SCg is the basic needs opportunity cost of goods, SCi is the basic needs opportunity cost of income, b_g and b_i are weights for aggregation of goods and income balance sheet and N is the project life. The basic needs effect is evaluated at two stages:

1. Preparation of separate balance sheets, for goods produced and income generated for all alternatives and their weighting according to their basic needs component.
2. Shadow pricing goods and income in terms of their basic needs component.

The weakness of this approach lies in the fact that real society does not exist in two clear groups : 'haves' and ' have-nots' (Trivedi, 1987).

In short, basic needs approach is essentially an alternative to the distributional weight (Harberger, 1978) or simply an income weighting scheme (Ray, 1984).

3.5.3 Capabilities approach to project analysis (CAPA)

The concept of 'capabilities' as a basic requirement for well-being has been developed by Sen (1981, 1985, 1993). Clements (1995) has developed the capabilities approach to project analysis (CAPA) based on Sen's notion of 'capabilities'. This approach focuses directly on human development index (HDI) scores. The method uses HDI scores for handling distributional aspects and employs CBA methods for the rest of the analysis.

The CAPA is more informationally demanding than CBA. Apart from estimating a project's economic benefits, the CAPA also inquires about the capability standards of the beneficiaries, and how the project augments them. The CAPA permits impact comparisons between social sector projects (health, nutrition, drinking water etc.) and investment in energy or industry.

3.6 Conclusions

CBA is the most comprehensive approach for use in afforestation project appraisal. But there are various problems in its practical application, mainly because of:
(a) the existence of a large number of non-market products of forestry and problems associated with their evaluation;
(b) joint production function or multiple use of plantations (e.g. timber production, wildlife conservation, recreation, soil conservation etc.);
(c) the varied economic nature (public, mixed or private goods) of the products of plantations.

Traditionally, forests have been treated as a source of raw material to meet the increasing demands of development without even acknowledging innumerable non-market uses. As both timber and other products are produced jointly, the valuation of their benefits and costs offers some conceptual problems. Now, we have some sophisticated techniques to evaluate benefits and costs formerly considered intangibles.

The selection of a suitable discount rate is the most controversial issue in the application of CBA for forestry project appraisals (Harou, 1985: Price, 1988) as the selection of discount rate affects viability and profitability of projects more than anything else. The economic reasons for discounting are widely debated. The Forestry Commission in the UK uses different discount rates for appraising different types (e.g. silviculture, plantation and harvesting) of projects. Lowering the discount rate for forestry projects is often proposed, but it may accelerate the process of destruction of tropical forests rather than conserving them (Price, 1991). It also encourages undesirable investment projects (Baumol, 1968).

CBA offers a possibility of superior economic evaluation of afforestation projects as compared to other techniques. But proper application of CBA techniques requires definite understanding of the project which often goes beyond the purview of the CBA framework. The correct application of CBA requires:
(a) correct quantification of costs and benefits
(b) correct social pricing of costs and benefits

(c) use of a proper discount rate and decision criterion

(d) use of appropriate techniques for considering elements of variability

(e) consideration of alternatives (alternative use of available resources, alternative institutional arrangements and alternative means of meeting objectives) (Price and Nair, 1984).

Omissions or improper treatment of the above requirements in application CBA for project appraisal may reduce the status of CBA to a mere tool to justify any project. Consequently, it may lead to questions on the validity of the methodology itself.

Chapter 4

Data base and methodology of data collection

4.1 Objective

One of the major objectives of the study is to undertake detailed cost-benefit analysis (CBA) of the farm forestry (FF) and the rehabilitation of degraded forests (RDF) components of the Bihar Social Forestry project. The CBA requires considerable data, in order to quantify the real impact of the project on the beneficiaries as well as from the perspective of growth and distribution issues. The data is also required to study farmers' adoption behaviour and to investigate elements of risk and uncertainty. The primary data were generated through (a) a socioeconomic survey and (b) measurement of the RDF and the FF plots for growth data collection. The secondary data sources included published government reports, research studies and unpublished government records, both of the forest department and other government departments.

4.2 Coverage

The Bihar Social Forestry project was confined to Chotanagpur and Santhal Parganas region of South Bihar only. FF and RDF were the two most important components (both in terms of physical and financial outlays and achievements) of the project. Therefore, only these two components were chosen for detailed analyses.

4.3 Secondary data collection

The main sources of secondary data were official records of the Forest Department, Bihar. The secondary data were collected at three levels; state, district and range or block level. State level data were collected from the offices of the Chief Conservator of Forests (Development), Chief Conservator of Forests (Social Forestry) and Divisional Forest Officer (Monitoring and Planning), Ranchi. At the district level, social forestry divisions were the most important source for obtaining plantation data. The detailed information which includes pit register, plantation journal and nursery register were available at respective range offices. The data regarding land use pattern, land holding, credit, poverty and caste structure were obtained from the Block Development Officer of respective blocks. The requirement of specific data and their sources are given in the following sections.

4.3.1 State level data

The data regarding the project as a whole were collected from the state level offices of the Forest Department and from the office of the Regional Development Commissioner. The data included:

1. Year wise targets and achievements (physical and financial) of the FF and the RDF components.
2. Total outlay of the project, year wise and division wise expenditure, break up of the expenditure in works (planting cost, wages and material cost) and non works (administrative, training, monitoring and establishment cost).
3. Survival percentage up to two years in FF and RDF.
4. Payment on societal compensation to farmers.
5. Schedule of rates for various forestry operations (planting, weeding, harvesting cost etc.)
6. Depot rates of different forest produce viz. timber, poles, fuelwood etc.
7. Cost of extraction and transportation cost of forest produce as poles, fuelwood etc. to central depots.

4.3.2 District level data

The district level data were obtained from the Deputy Commissioners of respective districts and the Divisional Forest Officers of the concerned divisions. The data included the following:

1. List of beneficiaries under FF scheme.
2. List of villages in the district and their demographic and socioeconomic data
3. Amount paid as societal compensation to individual farmers
4. Survival in plantations in RDF and FF.
5. Actual expenditure both in FF and RDF

6. Prosecution register and marking list for recording illicit felling in plantations

4.3.3 Range and Block level data

Detailed information of individual plantations was obtained from the Range Officer of Forests. Information regarding other aspects (land, irrigation etc.) of villages were available with the Block Development Officers. The following information was collected from their sources.

1. Nursery register of concerned nurseries.
2. List of beneficiaries, village wise.
3. Survival percentage in farmers' plantations.
4. List of right holders and record of rights.
5. Choice of species in the FF and the RDF components.
6. Prices of intermediate forest produce.
7. Harvesting and transportation cost and distance from market and/or forest department central depots.

4.4 Primary data collection

The objective of collecting primary data was to create a detailed quantitative and qualitative data base covering the study area. A structured survey and formats for silvicultural data were the main tools for primary data collection. Plantations were not harvested yet. Therefore, silvicultural data were collected to estimate yield.

4.4.1 Estimation of yield in the RDF plots

The yield of individual *Eucalyptus* plantations is estimated using the following basic equation given by Sharma (1978).

$$\ln V_T = b_o + b_1.(1/T) + b_2.(SI) + b_3.\ln N + b_4.(1/SI) \quad \text{......eq. (4.1)}$$

where V_T is the volume in $m^3 ha^{-1}$, T is the age of the plantation expressed in years, SI is the site index specific to the quality class, N is the initial number of trees per ha.

Sharma (1978) used data from 124 sample plots, which include the present study area of Bihar also, of stands of *Eucalyptus* of plantation origin, to determine the site indices of three (1,2,3) site quality classes (on the basis of top height-age relationship) and the value of regression constant and coefficients. These values are used in the present study and are given in the following tables (Tables 4.1 and 4.2).

Table 4.1 Site Indices for *Eucalyptus* hybrid plantations

Site quality class	Top height (m) at 8 years			Site Indices		
	Max.	Min.	Mean	Max.	Min.	Mean
1	26.6	20.2	23.4	24	18	21
2	20.2	13.8	17.5	18	12	15
3	13.8	7.4	10.6	12	6	9

Source: Sharma, (1978)

Table 4.2 Regression constant and coefficients for the equation

Site quality class	b0	b1	b2	b3	b4
1	3.08754	-7.51748	0.022068	0.609979	-44.04364
2	-2.34040	-10.93654	0.264975	0.216846	31.0078
3	3.50694	-14.93375	-0:045310	0.622400	-29.5316

Source: Sharma, (1978)

4.4.1.1 Sampling frame and the design

A total of 18 RDF plots were selected at random from six districts selecting three plots from each district. As the plots were spread over six districts and the agro-climatic condition of different districts were not the same, an assessment of site quality of individual plots was essential to estimate yield. The site index of individual plots was determined by the following equation (Sharma, 1978):

$\ln SI = \ln TH + 3.8814897\,(1/A) - 3.8814897(1/RA)$ ....eq. (4.2)

where *SI* is site index, *TH* is top height in m, *A* is age of plantation and *RA* is reference age i.e., 6 years.

The height of a uniform stand at a given age is a good indicator of the productivity of that particular site for a given species (*Eucalyptus* in our sample). The mean height of a stand (single species) depends on age and site class. 'Dominant height' (also called 'top height') is insensitive to stand density (i.e., in our sample illicit felling will not affect top height) and strongly correlated to volume growth. 'Dominant height' can be defined as 'mean height of 100 thickest stems per ha' (Alder, 1980). Sharma (1978) defined 'top height' as 'the height corresponding to the mean diameter (calculated from basal area) of 250 biggest diameter tree per ha'. This definition has been adopted in the present study to estimate the dominant height. In general, size of sample plot for uniform crops should vary between 0.04 and 0.08 ha (Alder, 1980). For measurement of 'top height' circular sample units (of diameter 8 m; area, 50.3 m^2) were used because they were easier to lay out as all the plantations were of uniform (2m × 2m) spacing. Each plantation was divided into numerous subplots by laying grid lines on the plantation map. For each plantation, sample units were selected on the map using a table of random numbers. The sampling units were located and marked on the ground using the pit register of respective plantations. Height of one dominant tree from each sampling unit (N_T=A_U.250/10000; where N_T is number of dominant tree sampled, A_U is area of sample unit. N_T=(50.3x250)/10000, i.e., 1.26 or approx. 1) was recorded. A Ravi multimeter was used for height measurement.

4.4.1.2 Sample size and precision

For each RDF plot 24 sampling units were taken for dominant height measurement (total sample size, 0.12 ha). A sample plot size of 0.04 ha is recommended by Adlard (1990) for plantations. A simple random sampling without replacement was used because it gave more precise estimators than sampling 'with replacement'. In this method, there is equal probability of selecting a sample of any combination of *n* units from the given population. It assumes infinite population size. So while calculating precision of estimates, the population has to be assumed as finite or an appropriate correction has to be made. It can be shown that a sample drawn from a normally distributed population (with mean, μ_X and standard deviation, σ_X) will also be normally distributed for any size n (i.e sample size) with mean $\mu_{\bar{x}}$ =μ_X. Conversely, if the population is not normally distributed and the *n* is large enough (n=10 to 20), the sampling distribution approximates normal distribution and the mean of this distribution is the population mean (Kalton, 1983).

$$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{n}} \cdot \sqrt{\frac{N-n}{N-1}}$$

where $\sigma_{\bar{x}}$ is standard deviation of sampling distribution or standard error, n is sample size and N is population size.

Since $\sigma_{\bar{x}} = \sqrt{sampling\ variance}$, N>>1 and f=n/N, Sampling variance (V) can be written as:

$$V = \frac{\sigma_X^2}{n}(1-f)$$

f is referred as finite population correction factor (fpc). The fpc term is neglected (i.e., treated as zero) when the sampling fraction (n/N) is < 0.05. It is obvious that the larger the sample size, the smaller is the standard error and sampling fraction has very little effect on precision. The standard errors and 95% confidence interval for mean were calculated for all the plots. The sample data of individual plots were also tested for normality (Kolmogorov-Smirnov (lillefors) test and Shapiro-Wilks test, Conover, 1971). The detailed statistics are given in the Annexure 4.1. The distribution of sampled data were normal for all the plots (17 plots at 95% level; one plot at 90% level). We can conclude that top height estimation, in the present study, is an unbiased estimate and even smaller sample size can achieve the desired precision.

4.4.2 Estimation of yield in farmers' plots

Though *Eucalyptus*[1] has been a much studied species, the volume tables for *Eucalyptus* in farmers' plots is not available for this region. The variation in growth and yields in farmers' plots was very high mainly due to variation in quality of soil and the genetic variability of the growing stock. In the present study, single tree volume equation was used as no other suitable stand volume equation was available. Circular sample

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[1] The species was initially referred to as *Eucalyptus* 'hybrid' (Family: Myrtaceae) It was later identified as a strain of *Eucalyptus tereticornis* Smith (FAO, 1979). Two hybrids of *E. tereticornis* and *E. camadulensis* Dehnh. var. camaldulensis - FRI-14 and FRI-15 have also been planted in some areas (Pandey, 1986; for a detailed botanical description see, Troup, 1932).

units (five per plot) of 4m diameter were selected on a random basis. Sampling precision and standard error were calculated as described in the previous section. Two types of measurements were taken:

(a) Diameter over bark at breast height (i.e 1.37 m) using a girth tape

(b) Tree height of sampled trees and height of one dominant tree per sample unit

The volumes of individual trees were calculated using the following equation (Chaturvedi, 1983):

VOB= -0.0001+0.31145 D^2H...eq. (4.3)

where VOB is volume over bark in m^3, H is height in m and D is diameter in m.

The primary variables calculated were:

(a) stocking per ha (total number of trees/area of plot in ha)

(b) diameter of the mean basal area tree (D_g), $D_g=\sqrt{\frac{\sum d^2}{N}}$, where d is diameter of individual trees and N is total number of trees

(c) stand height (H_O, the mean height of the 'dominant' trees).

(d) stand mean height (H) (mean of the sampled trees). H is calculated using Lorey's formula (Philip, 1994) :

$$H=\frac{\sum_{i=1}^{z} n_i g_i h_i}{\sum_{i=1}^{z} n_i g_i}$$

where n_i is number of trees in a diameter class, g_i is average basal area of diameter class and h_i is average height of the tree in a diameter class.

Stand volume is calculated by two different methods (Alder, 1980) as follows:

(1) The volume of the stand is calculated taking diameter D_g and height H using the equation 4.3 and then multiplying it by stand density.

(2) The volume of individual trees is calculated from diameter d and height h (h is height of individual trees). The sum of individual tree volume is used to estimate the stand volume.

The first method has an error that may result from distribution of diameters. The second method is used for further analyses because error in height estimation will not be much keeping in view the merchantable top diameter limit.

Eucalyptus was the principal species in farmers' plots. But some farmers had also raised *Acacia auriculiformis*[2] and *Dalbergia sissoo*[3] plantations, either mixed with *Eucalyptus* or as pure crops. Height and diameter measurements were also taken for these species and volume was estimated using the following equations:

1. *Acacia auriculiformis*

$$V=0.187693-2.825587D+0.054763DH+12.164775D^2-0.004788/D$$

where V is total volume over bark up to 5 cm (OB) in m^3, D is diameter at breast height in cm, H is height of tree in m (Mittal et al., 1991).

2. *Dalbergia sissoo*

$$\ln TH=3.281853-6.5690069(1/A) \quad \text{eq. (4.4)}$$

$$\ln B_m=b_0+b_1.\ln A.\ln S+b_2 A+b_3S+b_4\ln N \quad \text{eq. (4.5)}$$

$$\ln V_m=b_0+b_1.S+b_2[B_m/(B_m+B_t)]+b_3(1/A) \quad \text{eq. (4.6)}$$

where B_m is basal area of main crop, V_m is the total volume of the main crop in m^3/ha, A is the age of the plantation in years, B_t is the basal area of thinning crop, TH is the top height in m, S is the site index for the quality class and N is the number of stems per ha.

The value of the regression constant and coefficients for three quality classes were determined by Sharma (1979). The data set used to determine the equations 4.4, 4.5 and 4.6 relate to the neighbouring states of Uttar Pradesh, Gujrat and Haryana. It is plausible to assume that these could be applied to Bihar also in the absence of any other information. Top height is used as the indicator of site quality and the corresponding site indices are given in the Table 4.3. Table 4.4 gives the values of regression constants and coefficients for equation 4.5 and 4.6. These values are used in the present study. No thinnings have been considered. Only the main crop volume has been estimated taking $B_m/(B_m+B_t)$ ratio as 1.

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[2] *Acacia auriculiformis* A. Cunn. ex Benth. (Family: Fabaceae) is a leguminous, nitogen-fixing tree of the sub family Mimosoideae. It is native to Australia, Papua New Guinea and Indonesia. In a re-classification of the genus *Acacia*, *A. auriculiformis* has been placed in a new genus called *Racosperma* (Pinyopusarerk, 1990).

[3] *Dalbergia sissoo* Roxb. (Family: Fabaceae; sub family, Papilionoideae), a fast growing species, is native to sub-Himalayan region (for details, see, Bor, 1953).

Table 4.3 Site indices for *Dalbergia sissoo* plantation

Quality	Top height (10 years) in m			Site indices		
class	Min.	Max.	Mean	Min.	Max.	Mean
1	16.6	14.4	15.5	23	20	21.5
2	14.4	12.2	13.3	20	17	18.5
3	12.2	10.1	11.2	17	14	15.5

Source: Sharma (1979)

Table 4.4 Regression constant and coefficients for equations 4.5 and 4.6

Crop character	Quality class	b_0	b_1	b_2	b_3	b_4
Basal area	1	-5.00925	0.509325	-0.026432	-0.031157	0.726117
	2	-4.29216	0.602787	-0.045261	-0.018530	0.504507
	3	-2.36057	0.611090	-0.075681	-0.049139	0.352260
Volume	1	4.16171	0.013254	1.21661	-12.2021	
	2	2.93007	0.086725	0.98075	-15.6230	
	3	3.24097	0.80629	0.51021	-12.0975	

Source: Sharma (1979)

4.4.3 Socioeconomic survey of farmers

Structured surveys are almost indispensable in monitoring and evaluation of agriculture and rural development projects. They are used to study a wide range of subjects ranging from the composition of target population, to its reaction to project stimuli (Casley and Kumar, 1988). A structured survey was used to study people's participation and quantification of returns from the project.

4.4.3.1 Sampling methodology

The main object of sampling is to economise on resources that are required to collect and analyse data. It is impractical to collect information from every one in a large group. The best alternative is to gather information from only a small number of people, representing characteristics of the population. The questionnaire based survey was meant to cover all the villages under the farm forestry scheme but it was not possible to cover all villages and households with limited time and resources. Therefore, a modified version of multistage stratified random sampling viz. probability proportionate to size (PPS) sampling (Kish, 1965) was adopted.

4.4.3.1.1 Selection of Agro-climatic zones

Out of four agro-climatic zones of Bihar, the project area was confined to only one agro-climatic zone viz. Eastern Plateau and Hill Region VII. Therefore, it was not possible to divide the study area on the basis of agro-climatic regions. The total of 10 districts were divided into two regions (GRS and SGH) on the basis of % of tribal population to the total population (GRS, >35%; SGH, <35%). The validity of this purely arbitrary figure (35%) classification is tested in the following sections of this chapter.

4.4.3.1.2 Selection of districts

The number of beneficiaries in each district was roughly equal. In the year 1986-87, 21597 farmers had adopted FF and planted 14.48 million seedlings. These farmers were spread over 567 villages of ten districts. Three districts from each region (out of five each) were selected on a random basis for sampling. The sampled districts were Gumla, Ranchi and Sahebganj from GRS region and Singhbhum (E), Garhwa and Hazarbagh from SGH region. Selection of districts as separate strata for the purpose of sampling also needs statistical validation. It will be taken up in the next section .

4.4.3.1.3 Selection of villages

The number of beneficiaries in each village varied greatly. Therefore, selection of villages in the district could not be done using simple random sampling technique. In simple random sampling selection probabilities are equal for all units of the population. When the size of units are not constant, simple random sampling is not the appropriate procedure as it does not give weightage to the size of the units. In probability proportionate to the size (PPS) sampling, probability of selection is proportional to the size of the unit. The probability of drawing any specified unit differs from draw to draw unlike simple random sampling (Raj, 1972). There are mainly three types of PPS viz. PPS without replacement (PPSwor), PPS with replacement (PPSwr) and PPS systematic sampling (PPSss). In the present study PPSss is used as it is always more efficient than PPSwr (Madow, 1949). Goodman and Kish (1950) proposed a random systematic procedure that is the same as ordered systematic approach except that population units are listed in random order (we listed in ascending order) prior to sample selection. Hence, a modified version of multi stage random sampling (PPS ordered systematic sampling) was adopted and six villages were selected in each district. The details of methodology are as below (Kish, 1965; FAO, 1986; Raj, 1972);

Let Nd_1 ($Nd_1 = \sum_j^i X_j$, i=1,2,3.....N, X_j is the size of jth unit and *N* is total number of villages in the district d_1) is the total number of beneficiaries in the district (d_1) and md_1 is the number of villages to be selected (sample size) in the district d_1. Sample villages in the district d_1 will be selected with probability proportionate to the number of beneficiaries.

Let Nd_{1i} denotes the number of beneficiaries in the *i* th village of the district d_1 and Nd_1 denotes sum of beneficiaries in the district. The probability of selection of the *i* th village is $(Nd_{1i}.md_1)/Nd_1$.

The actual selection was implemented as follows:

(1) A complete list of all the villages and beneficiaries for each district was obtained from the office of the Chief Conservator of Forests (Social Forestry), Bihar. The villages were listed in ascending order depending on the number of beneficiaries. The cumulative number of beneficiaries was also listed along with number of beneficiaries of individual villages.

(2) computation of sampling interval (Id_1)

$Id_1 = Nd_1 / md_1$

(3) A random number (Rd_1) was chosen in the interval from 1 to Id_1.

(4) The units (villages) corresponding to the number $Rd_1 + j \times Id_1$ (j=0,1, 2......($md_1 - 1$)) were selected as;

Rd_1..................................1st 'hit'

$Rd_1 + Id_1$...........................2nd 'hit'

$Rd_1 + 2Id_1$.........................3rd 'hit'

$Rd_1 + 3Id_1$..........................4th'hit'

$Rd_1+(md_1-1)Id_1$................etc.

It is clear that the *i* th unit is included in the sample only if $Nd_1-1<Rd_1+j\ Id_1 \leq Nd_1$ (j=0,1, 2......(md_1-1)).

(5) The villages will be selected when the size in the cumulative size list equals or exceeds the 'hit'.

(6) The same procedure was followed for each of the six districts and the required number of villages (i.e., 6×6=36) were selected for sampling.

The main drawback of this method is that an unbiased variance estimator on the basis of single sample is not possible (Hartley and Rao, 1962).

4.4.3.2 The questionnaire

A careful review of all the available sources was done to avoid any duplication of data collection. It was decided to collect both quantitative and qualitative data through formal questionnaire based survey. The questionnaire was carefully designed to capture relevant information from the sampled respondents. Questions were included to elicit information regarding socioeconomic aspects of respondents, their resource endowment, knowledge about the programme and their involvement in the programme. The survey questionnaire was especially designed keeping in mind that most farmers were illiterate. The questions were translated into Hindi (the official language of India) and the Hindi version was used in actual survey. No hypothetical questions were framed and instead of general questions, specific questions were designed. Both closed and open-ended questions were included in the questionnaire because of their relative merits. A widespread criticism of closed question is that they force people to choose among offered alternatives instead of answering in their own words. Yet precisely because closed questions spell out the resource options. They are therefore more apt to communicate the same frame of reference to all respondents (Converse and Presser, 1986). Two separate types of questionnaire were designed to capture responses of participating and non-participating farmers (Annexure 4.2 and 4.3)

The questionnaire for participating farmers was divided into the following parts to cover all aspects of the FF and the RDF components of the project:

(a) village profile

(b) profile of the respondents

(c) occupation and assets
(d) knowledge and awareness about the programme
(e) selection of the species
(f) training and extension service
(g) acquisition and planting of seedlings
(h) protection problems in Farm Forestry
(i) benefits and income from Farm Forestry
(j) fuel needs of the farmers
(k) Rehabilitation of Degraded Forests.

The questionnaire for non-participating farmers included the following aspects to capture relevant information from the sampled respondents:

(a) profile of the respondents
(b) occupation and assets
(c) knowledge and awareness about the programme
(d) fuel needs of the farmers
(e) awareness about rehabilitation of degraded forest lands

4.4.3.3 Field work

The field work was one of the important aspects of the study because the data for cost-benefit analysis (of Farm Forestry and Rehabilitation of Degraded Forests) were mainly based on field work. The field work was carried out between September 1995 and January 1996. As I belong to the Indian Forest Service and worked in almost all the selected districts for 10 years, I was not taken by villagers as an ordinary researcher. This had both positive and negative points. It helped me to develop good rapport with villagers and they actively cooperated in the study but I found initially they were hesitant to answer questions regarding the forest department. This problem was expected and the questionnaires were designed so as to include only objective questions in sensitive matters. I was never associated with implementation, monitoring or evaluation of the project. This presented an additional advantage and villagers expressed their opinions frankly and freely.

The questionnaires were canvassed with the head of household (generally, it meant male member or *karta* in joint family) who took most of the decisions regarding plantation etc. Members of a family cooking in one hearth were defined as one household. Often large landlords own more than one house and they share some capital assets also with members of their family.

4.4.3.3.1 Pre-testing of the questionnaire

Any new questionnaire should be pre-tested on a few pilot respondents in order to identify weaknesses, ambiguities and omissions before it is finalised for the survey itself (Casley and Kumar, 1988). All questions were tested especially for variation in response, clarity of questions, respondents' interest and attention. Twenty potential respondents were interviewed using the test questionnaire. The whole questionnaire was evaluated for the order of questions, 'no response' flow and naturalness of different sections. After completion of interview, confusing and difficult questions were discussed with the group of respondents. This resulted in dropping of questions regarding credit sources, interest rate, peak season and off-season work availability.

4.4.3.3.2 Final questionnaire

On the basis of preliminary results, the final version of the questionnaire was prepared and used for the survey.

4.4.3.4 Statistical validation of sampling methodology

4.4.3.4.1 Discriminant analysis

The whole study area was divided into two regions (SGH and GRS) on the basis of % of tribal population to the total population. The use of tribal population as a criterion for classification has a sound theoretical basis. Tribals form a culturally and ethnically distinct group in the study area. Their socioeconomic characteristics and livelihood strategies are also different. In SGH region tribal population constitutes <35% of the total population while in GRS region their representation is >35% of the total population. The choice of 35% as a criterion for differentiating two regions is arbitrary. The whole population was stratified into two regions for sampling. We test the robustness of this classification empirically through discriminant analysis and examine some other criteria e.g. land holding, caste for classifying the same population.

Similarly, we have selected districts as units for stratification for sampling in both the regions. Selection of districts as units for stratification is purely arbitrary. Districts are only administrative units. They may or may not differ significantly among themselves in respect of socioeconomic characteristics of farmers and patterns of tree growing. The selection of districts as a unit of stratification is also tested through discriminant analysis.

4.4.3.4.1.1 The theory of discriminant analysis

Discriminant analysis was developed as a powerful tool for classification. The theory of discriminant analysis is fairly simple. Linear combinations of the independent variables (or predictor variables) are formed and serve as the basis for classifying cases into one of the groups. The analysis tests the validity of a classification and estimates the significance of mean value differences of cases by considering the within class variance relative to the between class variance. It considers all variables together by forming a linear combination of the independent variables. Thus, all the information contained in independent variables are incorporated in a single index. In discriminant analysis, the weights are estimated so that they result in the 'best' separation between the groups. The linear discriminant equation can be given as:

$$D = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots \beta_P X_P$$

where Xs are the values of independent variables and β's are coefficients estimated from the data.

The groups must differ in their D values (discriminant scores). Using the discriminant score, it is possible to obtain a rule for classifying cases into different groups (Bayes' Rule). The probability that a case with a discriminant score of D belongs to group i is estimated by (Hand, 1981):

$$P(G_i|D) = \frac{P(D|G_i)\ P(G_i)}{\sum_{i=1}^{g} P(D|G_i)\ P(G_i)}$$

where g is number of groups.

For a linear discriminant function to provide a classification rule that minimizes the probability of misclassification, it requires that predictor variables must be a sample from a multivariate normal population and the population covariance matrices must all be equal (Klecka, 1980). We have used dichotomous variables in our analysis. Theoretically, it is not appropriate to use dichotomous variables but in most cases this performs well (Gilbert, 1968; Moore, 1973). If it fails to give unbiased results, logistic regression can be used which requires much more limited assumptions about distribution of data (SPSS Inc., 1993).

4.4.3.4.1.2 Results and discussion

The variables used in discriminant analysis are listed in Annexure 4.4. The correlation coefficient matrix is used for preliminary selection of variables. Variables with high correlation coefficients were dropped from the analysis. The stepwise method (selection rule[4]: minimize Wilks' lambda[5], minimum tolerance level 0.001, minimum F to enter 3.84000, maximum F to remove 2.71000) is used for selection of the rest of the variables. If the classification is robust, the prediction of new cases can be done with high degree of certainty. The results of discriminant analysis are given in Table 4.5.

Wilks' lambda (or U statistic) is close to zero (possible range 0 and 1), in the case of a classification based on a region which indicates within group variability is very small compared to the total variability i.e. group means appear to be different. The percentage of cases classified correctly (100% for region) is one indicator of robustness of classification. The eigen value is another indicator to select the best criterion for classification. The coefficient of discriminant function is chosen so that ratio of between group sum of squares to within group sum of squares is as large as possible. Large eigen values in 'region' indicates 'good' function.

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[4] We have used Wilks' lambda as selection criterion. The other criteria e.g. Rao's V, Mahalanobis distance give similar results.

[5] The F value for the change in Wilks' lambda, when a variable is added to a model is given as:

$$F_{change} = \left[\frac{N-g-p}{g-1}\right]\left[\frac{(1-\lambda_{p+1})/\lambda_p}{(\lambda_{p+1})/\lambda_p}\right]$$

where Nis the total number of cases, g is the number of groups, λ_p is Wilks' lambda before adding the variable, and λ_{p+1} is Wilks' lambda after the inclusion.

Eigen value=(between group sum of squares)/(within group sum of squares)

The classification based on districts is also able to predict 98.02% cases correctly. The other statistic (eigen value and Wilks' lambda) also shows robustness of the classification.

On the basis of discriminant analysis, we can conclude that the classification based on regions (SGH and GRS) and districts give meaningful results. Therefore, stratification based on regions and districts enhances sampling precision and gives unbiased results.

Table 4.5 Results of discriminant analysis (N=252)

Basis of classification		n	% cases classified correctly	Funct.	Eigen value	After Funct.	Wilks' lambda
Region	SGH	126	100.00				
	GRS	126	100.00				
	Overall	252	100.00	1	23.5909	0	0.040666
Caste	Others	109	82.60				
	SC & ST	143	86.00				
	Overall	252	84.52	1	1.3625	0	0.423275
Land holding (Two groups)	≤1.90 ha	135	88.10				
	>1.90 ha	117	95.70				
	Overall	252	91.67	1	2.8561	0	0.258726
Land holding (Three groups)	≤1.50 ha	97	86.60				
	1.51-2.40 ha	81	76.50				
	>2.41	74	85.10	1	3.6234	0	0.162831
	Overall	252	82.94	2	0.3283	1	0.752831
Districts	Singhbhum (E)	42	97.60				
	Garhwa	42	95.20				
	Hazarbagh	42	100.00	1	9.3312	0	0.000673
	Gumla	42	100.00	2	5.1568	1	0.006955
	Ranchi	42	95.20	3	3.3562	2	0.042820
	Sahebganj	42	100.00	4	1.3846	3	0.186530
	Overall	252	98.02	5	1.2482	4	0.444798

Key: n= number of cases in each group, Funct.=linear discriminant function

4.4.3.4.2 Cluster analysis

The stratification of the population was based on two variables; regions and districts. Now, we examine the statistical validity of selection criteria for stratification. The objective is to form few relatively homogeneous groups from the total sample and to find out indicators and their contribution in differentiating the groups. In order to meet the above stated objectives, a cluster analysis of sample households was carried out.

Cluster analysis is used to form groups of similar objects. The most common criterion[6] for classification of cases into homogeneous group, is based on squared Euclidean distance. Euclidean distance (d_{ij}) can be calculated as:

$$d_{ij}=\sqrt{\sum_{k=1}^{p}(X_{ik}-X_{jk})^2}$$

where d_{ij} is the distance between cases i and j, X_{ik} is the value for the *kth* variable for *ith* case, X_{jk} is the value of *kth* variable for *jth* case.

To avoid the use of the square root, d_{ij} is often squared and referred as 'squared Euclidean distance'. Although both cluster analysis and discriminant analysis classify cases into groups, discriminant analysis requires one to know group membership for the cases used to derive the classification rule (Aldenderfer and Blashfield, 1984). In cluster analysis, group membership for all cases and number of groups are unknown. The estimation of similarity between cases using Euclidean and other distance metrics is strongly affected by elevation differences (i.e. variables with both large size differences and standard deviations can essentially swamp the effects of other variables with smaller absolute sizes and standard deviations) (Everitt, 1993). The squared Euclidean distance has the disadvantage that it depends on the unit of measurement for the variables. Sometimes, to avoid this problem, variables are standardized (mean= 0, SD=1). But this may lead to other problems. A number of methods have been suggested to calculate the similarity of profile data based on correlation, association coefficients, probabilistic similarity coefficients etc. (Aldenderfer and Blashfield, 1984).

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[6] The other criteria used in cluster analysis are Manhattan distance or city block matric, Minkowski metrics and Mahalanobis D^2.

We use variables in standardized form. The squared Euclidean distance in our analysis is used as decision criterion. The list of variables used in analysis is given in Annexure 4.2.

4.4.3.4.2.1 Results of cluster analysis

As many as 8 clusters were formed. Out of 252 cases 88 were part of six small clusters as shown in Table 4.6.

Table 4.6 Number of cases in each cluster

Cluster	Number of cases
1	5
2	85
3	17
4	34
5	7
6	79
7	20
8	5

The other 164 cases were grouped into two distinct clusters. The district-wise distribution of cases in the two largest clusters is shown in Table 4.7. The district-wise distribution of cases in two clusters show a distinct patterns. Most of the cases of SGH region are classified in cluster 2 while in cluster 6 the majority of cases are from GRS region.

The above analysis illustrates:

(a) the presence of two distinct homogeneous regions in the population.

(b) the grouping of cases into six homogeneous units representing six districts is not well pronounced. This may be due to strong influence of regional groupings.

Apart from the problems in using standardized form of data, no agreed methodology is available yet for determining the optimum number of clusters. Nevertheless, fusion coefficient and standard deviates can be used for determining the number of clusters, 'stopping rule#1' being decision criterion (t-statistic, df=n-2, where n is number of fusion coefficients) (Everitt, 1993).

Table 4.7 District wise distribution of cases in two dominant clusters

Regions	Districts	Cluster 2	Cluster 6
SGH	Singhbhum (E)	23	0
SGH	Garhwa	14	8
SGH	Hazaribagh	12	10
GRS	Gumla	8	20
GRS	Ranchi	12	14
GRS	Sahebganj	4	38

4.4.3.4.3 Conclusion

On the basis of results obtained from the discriminant analysis and cluster analysis, we can conclude that the population stratification for sampling along regions and districts is unbiased

Chapter 5

Physical appraisal of afforestation projects under the threat of illicit felling

5.1 Introduction

During recent years, tropical deforestation has received great attention from professional foresters, academicians and policy makers. The benefits of forest conservation and negative environmental impacts of deforestation are well documented in diverse disciplines. Deforestation is defined as 'a change of land use with the depletion of tree crown cover to less than 10 per cent. Changes within the forest class (from closed to open forest), which negatively affect the site or stand, and in particular lower the production capacity are termed degradation' (FAO, 1995). The focus is broadly concentrated on: (a) the causes of tropical forest decline, (b) the rate of decline and (c) consequences of deforestation (Uhl, 1984; Detwiler et al., 1988; Wilson, 1988; Shukla, 1990). Many observers have attributed deforestation to population growth, the process of economic development and misguided government policies (Cline-Cole et al., 1990; Deacon, 1994; Southgate et al., 1991). The majority of writings on deforestation belong to descriptive categories that do not include any statistical tests (Kummer and Sham, 1994). Brown and Pearce (1994), Kummer and Sham (1994), and Reis and Guzman (1994) have reviewed the econometric studies related to the causal factors of deforestation. One of the most striking aspects of the literature on tropical deforestation (causal factors) is the almost complete lack of detailed studies at the national level (Kummer and Sham 1994). However, studies on deforestation in Brazil, Indonesia, India, Malaysia and Thailand divulge different causes distinctive to individual countries (Bowander et al., 1988; Moran, 1993; Panyotou and Sungsuwan, 1994 and Krutilla et al., 1995). Detailed case studies at national or state level are required to capture the unique aspect of each country or state.

In addition to loss in the area of forests, there is loss of biomass within the forests. This is more difficult to quantify. Most studies do not take account of degradation (as defined earlier) of forests, whose impact is sometimes more serious than deforestation both qualitatively (opening of the canopy may result in dominance of 'light demanding' or pioneer species that in turn can disturb the vegetation pattern or even the whole ecosystem of the forest by diminishing or some times eliminating climax species) and quantitatively (e.g. loss in crown cover 60% to 30% (degradation) > loss in crown cover 12% to 9% (deforestation)). It is found that for a large tract of south and southeast Asia, including parts of Bihar (India), a 36.6% loss of forest area coincided with a 50.2% loss of forest biomass over the hundred-year period (1880-1980) and the degradation ratio (ratio of biomass lost to area lost compared with the initial biomass) increased from 1.32 (for the period 1880-1920) to 1.54 (for the period 1950-1980) (Brown et al., 1991 and Flint and Richards, 1991). Therefore, including both deforestation and degradation will be more appropriate, for assessing the state of tropical forests and in investigating factors responsible for it.

The illicit removal of trees, one of the most important causes of deforestation and degradation, has received little attention, in particular to:

1. Ascertain empirically its adverse impact on forest growth and yield.
2. Develop theories regarding its genesis and nature of occurrence.
3. Devise methodologies to incorporate it in the appraisal of forestry projects.

(Trivedi and Price, 1988).

A literature survey using BIDS (1981-10/96), CAB (1984-7/96) and TREECD (1939-7/94) data bases show very scanty (thirty-six papers) reference to illicit felling. In the majority of studies (e.g., Dhar, 1994; Houghton, 1991; Reddy et al., 1990), the role of illicit felling in forest degradation is limited only to a casual reference together with other factors like fire, grazing etc. Singh, (1981) considers illicit felling simply as a biotic interference in forests. There is a consensus that illicit felling is excessive and must be stopped to protect the forests from further deforestation and degradation. Yet our understanding of the problem is limited and is more the product of casual observation than meticulous econometric analysis. Notable exceptions are Trivedi and Price, (1988), and Price and Trivedi, (1994). Hofstad, (1994) has given a theoretical model treating illicit felling as 'a conscious and a well-planned activity'. There are a number of growth and yield models that incorporate losses due to natural mortality, fire, windthrow etc. Loss incurred by illicit felling is often ignored.

Appraisals of plantations subject to such threat can only be realistically conducted if the phenomenon of illicit felling is properly understood. This chapter deals with modelling and prediction aspects of illicit felling. The following dimensions of illicit felling will be examined in this chapter:

1. Model the mechanism of illicit felling.
2. Quantify its impact on the yield of plantations.
3. Devise a methodology for prediction of illicit felling.
4. Study its impact on silvicultural decisions.

5.2 The phenomenon

In India, wood fuel accounts for 65% of the total non-commercial energy consumption (GOI, 1992a). The Forest Survey of India (FSI) has worked out consumption of fuelwood in the country. The gap between consumption and recorded production is widening (Table 5.1).

Table 5.1: Recorded production and consumption of fuelwood in India

(Million tonnes)

Year	Recorded Production	Consumption	Production-consumption gap
1953-54	6.49	86.3	- 79.8
1960-61	8.15	99.6	-91.5
1965-66	9.16	109.3	-100.4
1970-71	11.62	117.9	-106.3
1975-76	19.00	133.1	-114.1
1987-88	28.00	157.0	-129.0

Source: FSI (1987)

The recorded production shown above gives only data on production by the government forests and does not include fuelwood production from trees on private land. However, data collected in the 28th round of the National Sample Survey indicated that approximately 30 million tons of fuelwood were obtained from non-forest government and private lands. Thus, it left a difference of 99 million tons fulfilled by unrecorded removal of fuelwood from the government forests in the form of 'rights' and 'illicit felling'. If we assume, even by most lenient estimates, that approximately 50% (of 99 million tons) fuelwood was collected by villagers in exercising their usufructary rights, the rest, 50 million tons, could only be attributed to 'illicit felling'. Swaminathan (1980) has also observed that a large part of India's fuelwood demand appears to be satisfied by illicit felling. This figure relates to fuelwood only. Illegal removal of timber is additional. The common presumption is that illicit felling is simply a theft of wood from the forests.

Therefore, it is a simple matter of stemming the theft, like policing the forests. But unless we understand the root causes we will be treating only the symptoms.

Two major causes of illicit felling in the tropics are rural poverty and need-availability gap for fuelwood and other basic products (Price and Trivedi, 1994). The use of forest produce by villagers is common in developing countries. Traditionally, villagers' demand for fuelwood and timber were met by 'right holders' coupes. But due to the increase in demand for forest products and depletion of forest resources, traditional mechanisms can no longer meet villagers' demand. This demand supply gap coupled with rural poverty results in the phenomenon of illicit felling.

The precise time and place of illicit felling is difficult to predict and depends largely upon accessibility to villagers and intensity of protection afforded to plantations by forest personnel. The efforts in protection of the plantation from illicit felling have only limited impact as they neither reduce the indispensable consumption patterns of forest produce nor provide alternatives to these resources. Efforts on the part of forestry personnel result in shifting the place and time of illicit felling and it also results in diminishing luxury consumption.

The incidence of illicit felling is not constant throughout the year. For instance, less illicit felling was observed in monsoon months when villagers were engaged in agricultural operations. Conversely more illicit felling was recorded in summer months when villagers had less opportunity of getting work (poverty factor) and because of higher requirements of forest produce to repair their houses before the onset of the monsoon (demand factor). Knowledge of this pattern is helpful in drawing up protection strategies for plantations and it also shows that the phenomenon of illicit felling cannot be explained only by quantifying dependency of villagers for fuelwood for household needs. The opportunity cost of fuelwood collection from the forests is equally important. The illicit felling problem has two dimensions:

(a) Illicit felling to meet local forest produce needs.

(b) Illicit felling to gain additional income.

Apart from the most common form of illicit felling discussed above, in some areas illicit felling is carried out by organized criminal gangs which is a law and order problem rather than a socioeconomic problem. This type of illicit felling is not included in the modelling because of its localised nature and its high value species (teak or sal) preference.

The illicit felling models given by Trivedi and Price (1988), are based on a constant (10%) 'proportionate loss' assumption. This means that every year loss is taken to occur according to an exponential or geometric progression, i.e. the remainder after two years is $(100\%-10\%)^2$.

$N_T=N(1-f)^T$..eq. (5.1)

where N_T is number of trees at the end of T th year.

N stands for the initial plantation density and *f* is the annual loss of tree numbers expressed as a decimal.

Table 5.2 shows the illicit felling pattern derived from the equation 5.1 above, taking the value of N=40,000 (40,000 plants in 16 ha) for the sake of comparison. Table 5.3 is based on actual data collected from the plot HBP1 (40,000 plants in 16 ha) from Hazaribagh district of Bihar, India.

Table 5.2 Illicit felling in *Eucalyptus* plantations (constant loss assumption)

N=40,000 f=0.1 (10%)

Year (T)	Number of trees left at the end of each year (N_T)	Cumulative felling (F_T) $N - N_T$	Number of trees removed (illicit felling) each year $F_T - F_{T-1}$	Proportion survived at the end of each year N_T/N
1	36,000	4,000	4,000	0.9000
2	32,400	7,600	3,600	0.8100
3	29,160	10,840	3,240	0.7290
4	26,244	13,756	2,916	0.6561
5	23,620	16,380	2,624	0.5905
6	21,258	18,742	2,362	0.5315
7	19,123	20,868	2,126	0.4783
8	17,219	22,781	1,913	0.4305
9	15,497	24,503	1,722	0.3874

Table 5.3 Illicit felling in the *Eucalyptus* plantation (plot HBP1)

N=40,000

Year (T)	Number of trees removed (illicit felling) each year f_T	Cumulative felling(F_T) $f_T + f_{T+1} + f_{T+2} + f_{T+3}$..................	Number of trees left at the end of each year (N_T) $N - F_T$	Proportion survived at the end of each year N_T/N
1	0	0	40,000	1.0000
2	0	0	40,000	1.0000
3	1200	1,200	38,800	0.9700
4	1201	2,401	37,599	0.9399
5	1232	3,633	36,367	0.9092
6	2361	5,994	34,006	0.8502
7	4406	10,400	29,600	0.7400
8	5198	15,598	24,402	0.6100
9	4821	20,419	19,581	0.4895

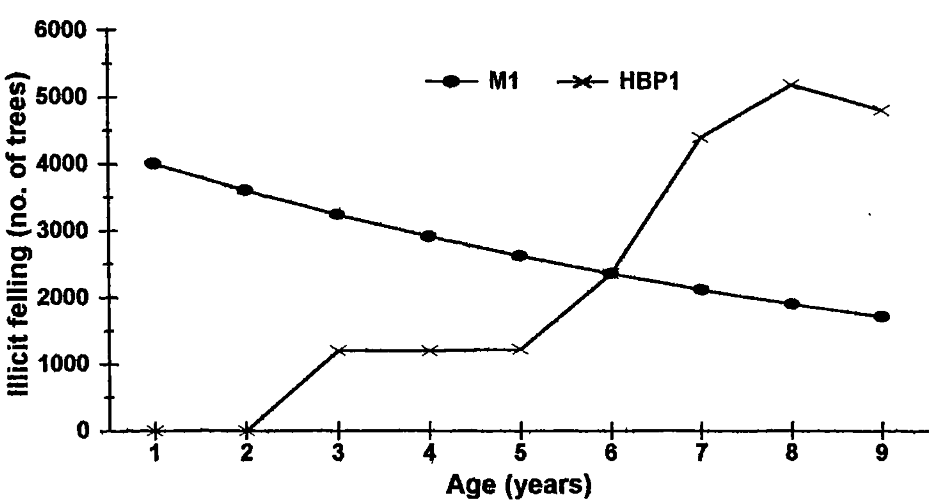

Fig. 5.1 Illicit felling in Eucalyptus plantations

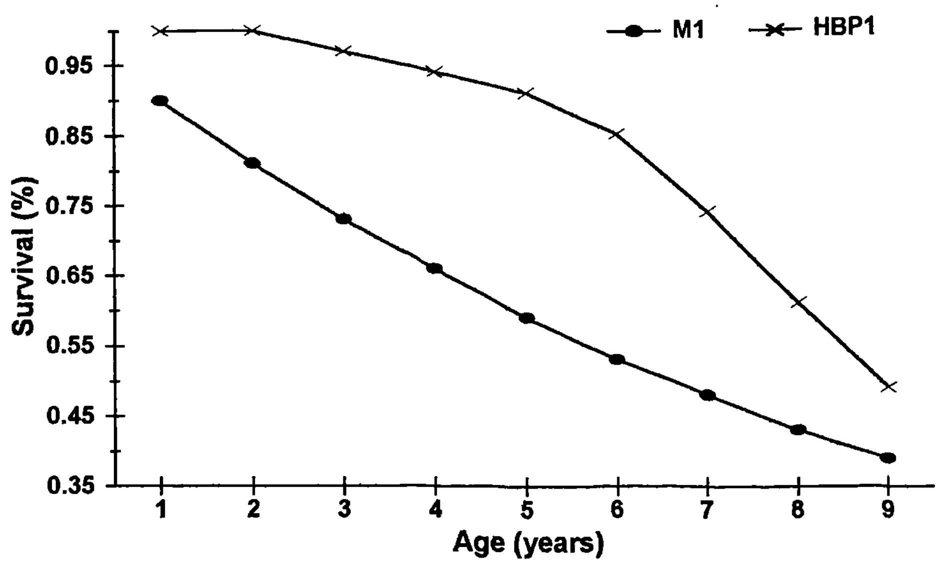

Fig. 5.2 Survival under illicit felling

The number of trees removed each year was plotted against age of the plantation (Fig. 5.1). The curve M-1 is derived from equation 5.1. The curve HBP-1 uses field data collected from the plot HBP1 (40,000 plants in 16 ha) of Hazaribagh district in Bihar, India. Fig. 5.2 shows proportional survival (expressed as a decimal) at the end of each year against age of the plantation. According to the eq. 5.1 (curve M-1 of Fig. 5.1 and Fig. 5.2), the number of trees illicitly removed was highest in the very first year of the plantation and felling during the initial three years accounts for more than 44% of the total illicit felling during the rotation (nine years). The field data (curve HBP-1 of Fig. 5.1 and Fig. 5.2) shows just the opposite. There was no illicit felling recorded in the first two years of plantation. Thereafter, illicit felling increased until the trees reached the harvesting stage and after that it went down as probably there were not many trees left at this age. Felling during the first three years accounts for only 5.9 % of the total felling. This could be attributed to the lower utility value of smaller sized plants (1 to 3 years) and alternative sources of wood from other plantations or natural forests.

5.3 Hypotheses

Based on above empirical data, it is hypothesized that:

(a) The probability of illicit felling increases temporally for a given plantation tending to be higher towards the end of rotation.

(b) The spatial variation of illicit felling is mainly explained by socioeconomic factors.

5.4 The data set

The data used in this study come from *Eucalyptus* plantations of Bihar, India. The plantations were raised in the year 1986 in blank areas (>0.4 ha) of degraded natural sal (*Shorea robusta*) forests under the Rehabilitation of Degraded Forest (RDF) scheme. The plots, spread over six districts of Bihar viz. Ranchi, Gumla, Hazaribagh, Singhbhum East, Sahebganj and Garhwa (old Palamu), were selected on a random basis representing at least two plots in each district. The data on illicit felling were taken from the Forest Department records (prosecution register) maintained by various divisions. The plots which had extreme values (very high or very low) due to some other reason (heavy grazing in initial years of the plantations) were eliminated from the sample. Plots very close to forest range or beat offices were also discarded as they did not represent the true position because these plots are better protected and are more frequently inspected. The quantum of illicit felling was also cross checked by harvesting records (1994 and 1995) for plantations of State Trading divisions and marking lists (marking lists show actual number of trees, girth class wise, available for harvesting) prepared by territorial divisions. It is found that number of trees available for harvesting by the department matches well with the number calculated from the illicit felling records [i.e. total available for harvesting = total planted - {illicit felling + mortality due to grazing etc.+other losses}]. None of these plantations were harvested yet but in the case of four plots (district Hazaribagh-2, Gumla-1, Ranchi-1) marking lists were available with territorial divisions that confirm the quantum of illicit felling obtained.

5.5 Model formulation

There are number of models for predicting both catastrophic and non-catastrophic mortality based on the logistic function (Monserud, 1976; Hamilton, 1986), power function (Hett, 1971), differential equations (Moser, 1972) and negative exponential function (Moser, 1972). This study is confined to anthropogenic mortality only.

A common approach to survival prediction has been to model the percent survival or rate of survival on the basis of the initial number of trees rather than to model the actual number of trees (Somers et al. 1980). For illicit felling modelling, the concept of 'cumulative conditional probability' of survival is used here which can be calculated from probability of survival in each year of the plantation (Price, 1989). Cumulative conditional probability of survival (CCPS) is calculated by multiplying the probability of survival of all the previous years. This can be expressed mathematically as:

$$X_i = \prod_{j=1}^{i-1} X_j$$

where X_i is the cumulative conditional probability of survival (CCPS) at the i th year and X_j is probability of survival at the j th year.

Cumulative conditional probability of illicit felling (CCPF) is obtained by multiplying the probability of illicit felling of that year with survival (cumulative probability) of the previous years and adding the cumulative felling of the previous years (Fig. 5.3).

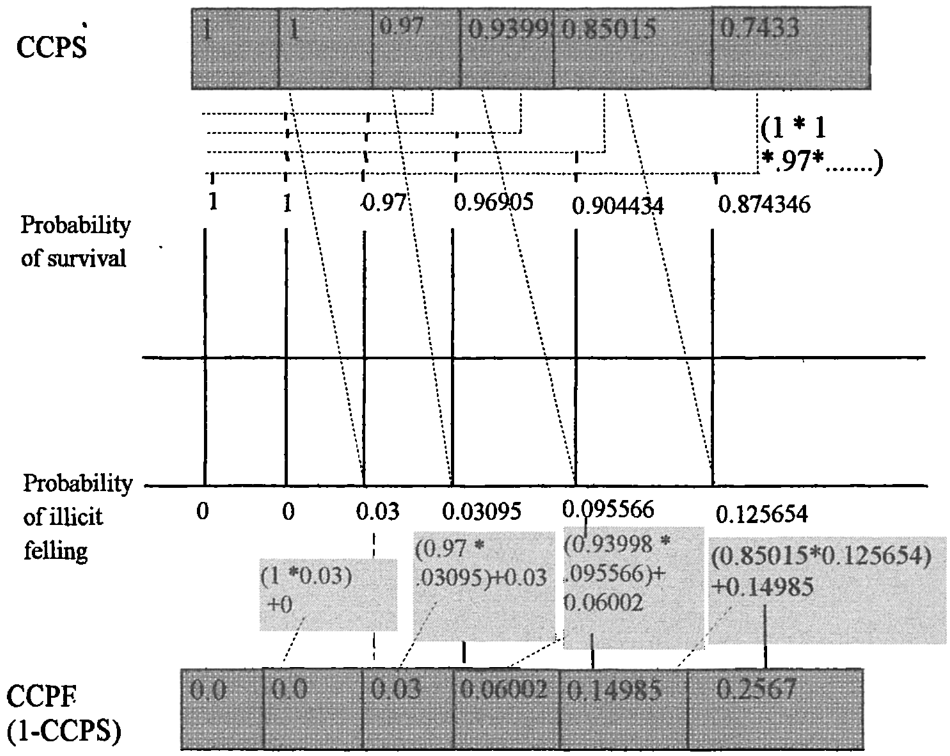

Fig. 5.3 Probability of illicit felling

The quantum of illicit felling depends upon the size (dbh) of the trees. The larger the size, the greater is the probability of illicit felling. Here, for model development, age (or time) is taken as surrogate for dbh.

The model can be written as

$N_t = N.S(x)$...eq.(5.2)

N_t stands for the number of trees at the end of year t (or age x). N is initial plantation density (number of trees per ha). S(x) is cumulative conditional probability of survival (expressed as a decimal) or proportion survived at age x.

It was observed that in the initial two years, there was no loss due to illicit felling. The loss due to natural mortality is adjusted by yield equations used to calculate volume of the stands. The equations given by Sharma (1978) for stand volume estimation of Eucalyptus plantations take account of natural mortality. So, we can take $N_2 = N$ .N_2 is number of trees surviving after two years of plantation. However, in a real situation and on the basis of data collected, loss after two years of plantation varies between 2% and

15% depending upon the climate, grazing pressure, means of protection etc. This is being modelled separately. It is assumed that there will be no grazing after two years of plantation as by that time plants would have exceeded grazing height. For the illicit felling model the equation (5.2) is modified as below:

$N_t = N_2 . S(x)$ ....eq.(5.3)

All data were adjusted so as to show $N = N_2$ i.e., if due to grazing etc. only 99% plants survived after the end of second year. The 99% figure was taken as the initial density and survival in subsequent years is adjusted accordingly to show the effect of illicit felling only. A number of modelling approaches were tried to model survival at different ages but two approaches were found most suitable as they can represent the course of illicit felling accurately and also provide scope to account for expected variations.

(a) Logistic model

(b) Weibull based model

5.5.1 Logistic model

The 'survival-age curve' of illicit felling data set shows a logistic curve pattern. Therefore, the logistic curve was chosen for nonlinear regression analysis. Cumulative conditional probability of survival as the dependent variable with age of the plantation as explanatory variable were taken for regression analysis. Several different forms of logistic model were tested. The following model gives the best prediction.

$$S(x) = A + \frac{C}{[\ 1 + \exp\{-B(x-M)\}]} \quad \text{..} \textit{eq.}\ (5.4)$$

where A, B, C, M are parameters of the regression equation and X is the age of the plantation in years and $S(x)$ is the cumulative conditional probability of survival (CCPS).

Estimates of parameters were obtained taking pooled data (N=84) of all the districts. The regression result is given below. Standard error is shown in parentheses.

Pooled data

$S(x)$= 0.3655+0.6311/[1+exp{0.699(x-7.568)}].......................................eq. (5.5)

(0.0847) (0.0996) (0.126) (0.376)

Percentage of variance accounted for 95.6.

Standard error of observations is estimated to be 0.0331.

The estimate of parameters was also obtained taking data of two regions viz. SGH (Sighbhum, Garhwa and Hazaribagh) and GRS (Gumla, Ranchi and Sahebganj) of three districts each (N=42 each) separately. The error term was reduced considerably in both the cases.

Region SGH

$S(x)$= 0.2436 + 0.7625/[1+exp{0.6894(x-7.776)}]....................................eq. (5.6)

(0.0635) (0.0725) (0.0687) (0.237)

Percentage of variance accounted for 99.4.

Standard error of observations is estimated to be 0.0145.

Region GRS

$S(x)$ = 0.4984 + 0.4863/[1+exp{0.7426(x-7.212)}]....................................eq. (5.7)

(0.0303) (0.0377) (0.0760) (0.165)

Percentage of variance accounted for 99.1.

Standard error of observations is estimated to be 0.0122.

5.5.1.1 Validation of the model

First step in model evaluation is to determine how well the model fits the data set used to develop the model. The data set was too small to set aside an independent subset to test the predictive ability of the model. The Kolmogorov-Smirnov goodness of fit test was used because it did not require an independent data set. The Kolmogorov-Smirnov goodness of fit test compares the observed distribution with a hypothesized cumulative distribution function (Conover, 1971). The difference is not significant ($P<0.05$).

Another phase of model evaluation involves determining how well the model fits biological reality. A model that is biologically illogical cannot necessarily be expected to perform well outside the range of data used to develop the model (Hamilton, 1986). Age-dbh relationship is well established for *Eucalyptus*. Price-size relationship explains well the increased felling probability towards maturity of the plantation.

5.5.2 Weibull based model

The Weibull frequency distribution is an extremely flexible frequency distribution that can possess either positive or negative skewness (Pinder, 1978). The Weibull includes the exponential distribution as a special case and is sometimes thought of as generalization of an exponential distribution (Antle and Bain, 1988). The Weibull distribution is widely used both in engineering and life sciences, from quantifying yield strength of Bofors steel and transistor reliability estimates, to stature of adult males born in the British Isles.

A random variable w follows the three parameters Weibull distribution [denoted by w~wE3(a, b, c)] if its cumulative distribution is given by

$F_W(w) = 1- \exp[- \{(w-a)/b\}^c]$ ....eq. (5.8)

where b, c > 0

$a < w < \infty$

The parameters 'a' and 'b' are location and scale parameters and 'c' is a shape parameter. The flexibility of equation (5.8) is that it describes a variety of shapes and is always nonnegative, makes it useful as the basis of a model for biological data (Somers et al., 1980; Krugg et al., 1984).

The density function is given by

$f_w(w) = [cb^{-1}((w-a)/b)^{c-1} \exp \{-[(w-a)/b]^c$..eq. (5.9)

for $a < w < \infty$

The reliability function is given by

$R_w(w) = \exp \{- [(w-a)/b]^c\}$..eq. (5.10)

for $a < w < \infty$ (Antle and Bain, 1988)

These function can be used to model the proportion of mortality for each age (x). The cumulative proportion of mortality up to age 'x' is represented by the cumulative density function

$F_{(x)} =1-\exp[-\{(x-a)/b\}^c]$..eq. (5.11)

The proportion of survival (S(x)) at age (x) is

$S(x) =1- F_{(x)}$..eq. (5.12)

By taking the value of $F_{(x)}$ from eq. (5.11), it can be written as

$S(x) = \exp[-\{(x-a)/b\}^c]$..eq. (5.13)

The location parameter 'a' indicates the beginning point of the distribution. It can either be estimated or assumed to be constant. Nevertheless, for regression analysis, the cumulative conditional probabilities of survival data were taken from three years onwards as there was no illicit felling in first two years. Substituting the value of a (a=0), the eq. (5.13) can be written as

$$S(x) = \exp[-\{(x)/b\}^c] \quad \text{......eq. (5.14)}$$

where $S(x)$ is cumulative conditional probability of survival and x is age of the plantation. 'b' and 'c' are regression parameters.

$S(x)$(cumulative conditional probability of survival) as the dependent variable was regressed against age (x) as the independent variable using the SPSS 6.0 computer package. This package requires initial values of parameters to be estimated from other sources to start iterations. The iterations stop when the relative change in a residual sum of squares between iterations is less than or equal to the convergence criterion (SSCON= 1.000E-08).

Kurg et al. (1984) advocated 'algebraic linearization' and 'quadratic comparison' to determine initial values. Berger and Lawrence (1974) have used linear regression to estimate the initial parameters. In the present study, initial values of parameters were obtained by the graphic method of making comparison of the curve with the standard curve (of known parameters) and the linear regression is used to determine the broad ranges. The estimates of regression parameters for pooled data are given below with asymptotic standard error in parentheses.

Pooled Data

$$S(x) = \exp[-\{(x)/10.4132\}^{3.0899}] \quad \text{......eq. (5.15)}$$

(0.1183) (0.1064)

R squared = 0.95888, N=84

It appears from the R^2 value of 0.95888 that the model fits the observed value well. For a nonlinear model, the tests used for linear models are not appropriate. The residual mean square is not an unbiased estimate of an error variance, even if the model is correct. The usual 'F' statistics cannot be used for testing the hypothesis (SPSS Inc., 1993b). The estimates of regression parameters for the two regions are given below with asymptotic standard error in parentheses.

Region SGH

$$S(x) = \exp[-\{(x)/9.7189\}^{3.4713}] \quad \text{......eq. (5.16)}$$

(0.431) (0.0587)

R squared = 0.99535, N=42

Region GRS

$$S(x) = \exp[-\{(x)/11.4543\}^{2.6854}] \quad \text{......eq. (5.17)}$$

(0.0928) (0.0504)

R squared = 0.99321, N=42

As expected the predictive power of regional equations is better than that of pooled data. In nonlinear regression, it is not possible to obtain exact confidence intervals for each of the parameters, only asymptotic (a large sample) approximations are given for standard error and confidence intervals. There are very large (-0.9) negative values for one region for correlation coefficients that suggest overparameterization. It means that a model with few parameters may fit the observed data as well but it is not possible in this model. One parameter ('a') is already eliminated at the stage of model formulation.

5.5.2.1 Testing of the model

As in the earlier model, the Kolmogorov-Smirnov test was adopted for testing this model. K-S statistics show that regional models performed better than the pooled data model specially in the case of predicting survival towards maturity. However, in all the cases, the difference was not significant ($P<0.05$).

5.5.3 Selection of the model

PRESS (**P**redicted **S**um of **S**quares) statistics are very important tools for model validation (Appendix 5.1) and selection of the most suitable model where the data set is small and data splitting is not practical. A model with the smallest PRESS value is preferred. The PRESS values for both the models (pooled data) are as below:

Model	PRESS Value
Logistic	0.95441
Weibull	0.98725

The PRESS values for both the models are very close. The logistic model is the preferred model as far as the PRESS statistics are concerned. However, the Weibull based model has several advantages over the logistic model which are discussed in the section 5.7.

5.6 Predicting illicit felling from socioeconomic data

To predict illicit felling at various ages of the plantation, using socioeconomic data for the district, a linear regression model was developed to relate the value of b (scale parameter) and c (shape parameter) to the socioeconomic data.

The values of b and c were calculated for pooled data, for two regions and for each of the six districts. The value of c varies from 2.5674 (for Gumla district) to 3.6295 (for Garhwa district) (Table 5.4).

Table 5.4 Values of shape and scale parameter

Districts	Value of c	Value of b
Singhbhum (SGH1)	3.2579	10.0598
Garhwa (SGH2)	3.6259	9.5239
Hazaribagh (SGH3)	3.4855	9.6493
Gumla (GRS1)	2.5674	11.5360
Ranchi (GRS2)	2.5706	11.8764
Sahebganj (GRS3)	2.9498	10.9973

The curves for each district were plotted using the universal equation (value of *b* from pooled data) (Fig. 5.4). The shape of the curves is very similar over this range (c>1) though the c is more variable. It suggests a single value of 'c' can be taken for developing the model using only b parameters.

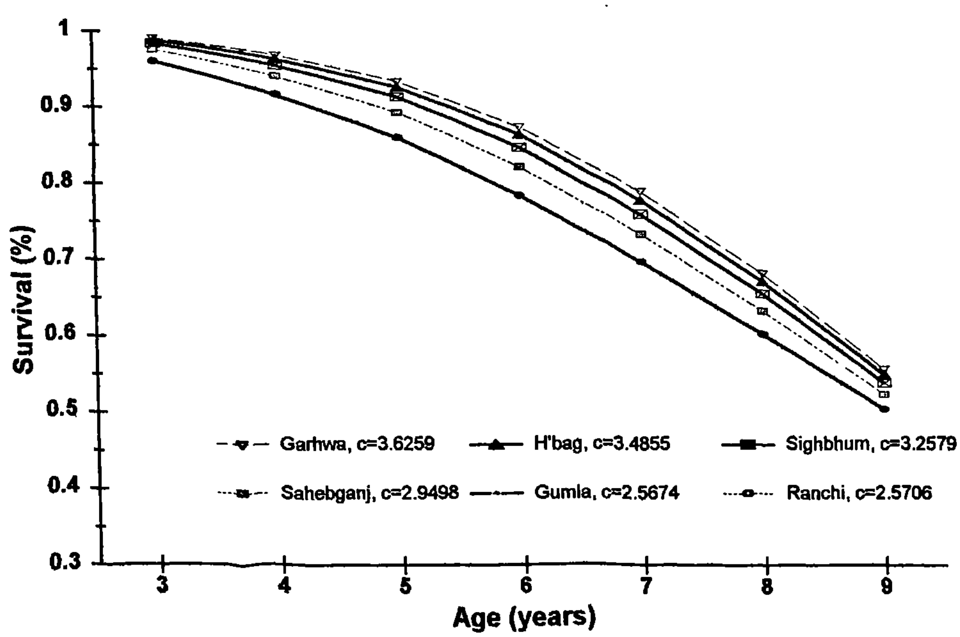

Fig. 5.4 Variable shape (c) parameter

The value of b (b is a scale parameter) for each district was obtained taking c as constant (3.0814, obtained from pooled data of all districts) The different values of b are given in Table 5.5.

Table 5.5 Values of scale parameter at constant shape parameter

Districts	Value of c c=constant	Value of b
Singhbhum (SGH1)	3.0814	10.2061
Garhwa (SGH2)	3.0814	9.8685
Hazaribagh (SGH3)	3.0814	9.9255
Gumla (GRS1)	3.0814	10.8128
Ranchi (GRS2)	3.0814	11.0845
Sahebganj (GRS3)	3.0814	10.8413

A number of socioeconomic characteristics of districts were tested to assess their predictive ability using stepwise multiple regression analysis. These include percentage of people dependent upon forests (tribal population), per capita forest area, per capita agricultural production and per capita fuelwood consumption. Fuelwood consumption data were obtained from a large survey conducted by the forest department based on interviews of people in 540 villages (Forest Department, Bihar, 1987). Government of Bihar publications were used for other district data. Each of these factors are good theoretical predictors of the illicit felling quantum but inclusion of all factors does not increase the explanatory power of the equation. Per capita forest area is not a very reliable predictor of illicit felling as forests in different districts are in various degrees of degradation. Data based on satellite imagery also only classify forests as open, dense and mangrove areas, which cannot be combined objectively to arrive at a single figure. Therefore, biomass per ha forest area (FAO, 1994) is used to calculate the total per capita biomass in forests of individual districts. Several possible equations relating the parameter 'b' with socioeconomic characteristics of districts were examined. A linear equation in the form of

$$\ln b = \beta_0 + \beta_1 \ln Fc + \beta_2 \ln Bm \qquad \text{eq. (5.18)}$$

gives the best prediction.

where b is a scale parameter of districts. β_0, β_1, β_2 are regression parameters. Fc and Bm are annual per capita fuelwood consumption (tons per capita) and total biomass per ha per person in forests (ton ha^{-1} $person^{-1}$).

Ordinary least square regression yielded the following estimates, with standard error in parentheses:

$\ln b$=2.923804 + 0.268876$\ln Fc$ - 0.060459 $\ln Bm$....................................eq. (5.19)

(0.077) (0.0490) (0.009)

Rsquare =0.96470, Standard error= 0.01209, N=6

VIF (variance inflation factor) value is 1.030 (well below the acceptable <10 limit) for both the independent variables, which suggests no multicollinearity. 'Tolerance' for each of the independent variables is also calculated for diagnosing multicollinearity. 'Tolerance' is also >0.01. But small sample size prohibits a large number of independent variables being included in the model. Inclusion of even two independent variables for this size of sample can be considered high. Fig 5.5 shows survival-age curve for one district (SGH3) based on actual and predicted data. The similar curve can also be drawn for other districts. The predicted value obtained from socioeconomic data (eq. 5.19) matches well with the actual value.

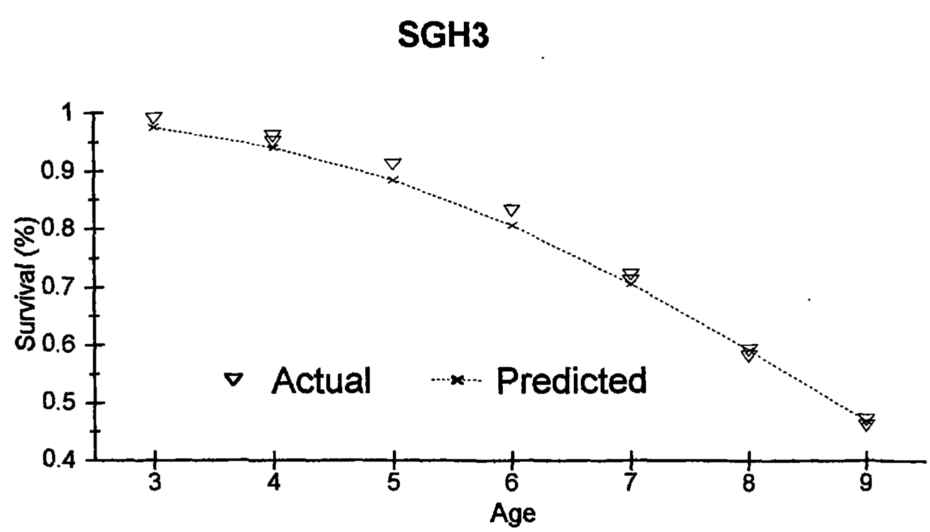

Fig. 5.5 Comparison of actual and predicted survival (SGH 3)

This model is based on the sample of six districts only. Therefore, no generalized conclusion can be drawn regarding factors contributing illicit felling but the predictive power of the model is very high which suggests these variables can be used in model formulation using a larger data set. No explicit explanation can be derived from the above model regarding socioeconomic causal factors of illicit felling. The possible explanation given below is more in the form of hypotheses or opinions rather than definitive conclusions.

Higher fuelwood consumption is not associated with higher illicit felling. It is important to note here that illicit felling in *Eucalyptus* plantations is done primarily for poles, not for fuelwood. Higher fuelwood consumption suggests availability of fuelwood at a relatively cheaper price. The availability of cheaper fuelwood is the result of cheap labour and poor market for these products. Lower wages and fewer opportunities in other sectors (viz. agriculture) seem to be the most important factors for cheap availability of labour. Under-developed agriculture also results in a poor market for poles because of (a) lower requirements for house construction, cattle shed and grain storage etc. and (b) lower purchasing power of farmers.

Lower per capita per ha biomass in forest is associated with lower illicit felling. This may be because: (a) relatively well developed agriculture in these districts yields adequate crop residues that diminish the demand of fuelwood and dependency of people on forests (b) opportunity cost of forest produce collection is high as work in agriculture offers better wages. People having opportunities of getting work in agriculture, and fell trees mainly for the purpose of selling poles in semi-urban and urban centres, only if they are assured of greater returns as compared with agriculture wages or in off seasons when there is not much work.

Some other factors like distance from urban centres, area under high yielding varieties (HYV, HYV yields less crop residue), market wage rates (mainly affected by work opportunities in the mining industry) are also important but they are not included in the model because: (a) their contributions in explaining the quantum of illicit felling are site specific and (b) a small sample does not permit inclusion of a large number of independent variables.

5.7 Illicit felling hazard function

The cumulative distribution function $F_x(x)$ and the probability distribution function

$f_x(x)$, derived from the three parameter Weibull frequency distribution, can be written as below:

$$F_x(x) = 1 - \exp[-\{(x)/b\}^c] \quad \text{eq. (5.20)}$$

$$f_x(x) = [cb^{-1}((x)/b)^{c-1} \exp\{-[(x)/b]^c \quad \text{eq. (5.21)}$$

The age specific mortality rate (symbolized as $M(x_i, x_{i+1})$), derived from the equation 5.20 & 5.21 above, may be expressed as

$$M(x_i, x_{i+1}) = 1 - \exp[(x_i / b)^c - (x_{i+1} / b)^{c-1}] \quad \text{eq. (5.22)}$$

Dividing $x_i - x_{i+1}$ and taking the limits of equation 5.22 as $(x_i - x_{i+1}) \rightarrow 0$ yields the instantaneous mortality rate (Pinder, 1970):

$$h(x) = f(x) / (1 - F(x)) \quad \text{eq.(5.23)}$$

h(x) is known as the hazard function or failure rate in engineering problems.

Probability of illicit felling at age *x* given the tree survives at age *x-1*, for two parameter Weibull distribution, h(x) has the form:

$$h(x) = (c/b)(x/b)^{c-1} \quad \text{eq. (5.24)}$$

For c=1, h(x) is constant (Trivedi and Price (1988)'s assumption of constant felling each year). The cumulative conditional probability of survival-age curve will take exponential form.

If c >1, h(x) is a monotonically increasing function of age (x). 'c' is always more than 1 as calculated from the field data. It means probability of illicit felling increases with age. It confirms the earlier formulated hypothesis.

The advantages of illicit felling modelling using the Weibull distribution are:

(a) The shape and scale parameters summarize all the information of quantum and course of illicit felling.

(b) The shape 'c' estimates of different plantations can be compared to understand the whole course of illicit felling in different socioeconomic conditions (Fig. 5.6).

(c) It can be used to model illicit felling of different species having different rotation.

Nine years (age one to nine years) survival data are used in development of the model. If plantations are not harvested at their normal rotation age, the present model is not expected to predict the survival accurately. At later years when plantation density becomes very low due to continued felling over the years, encroachment of land becomes the primary motive for illicit felling so as to clear the land for agriculture.

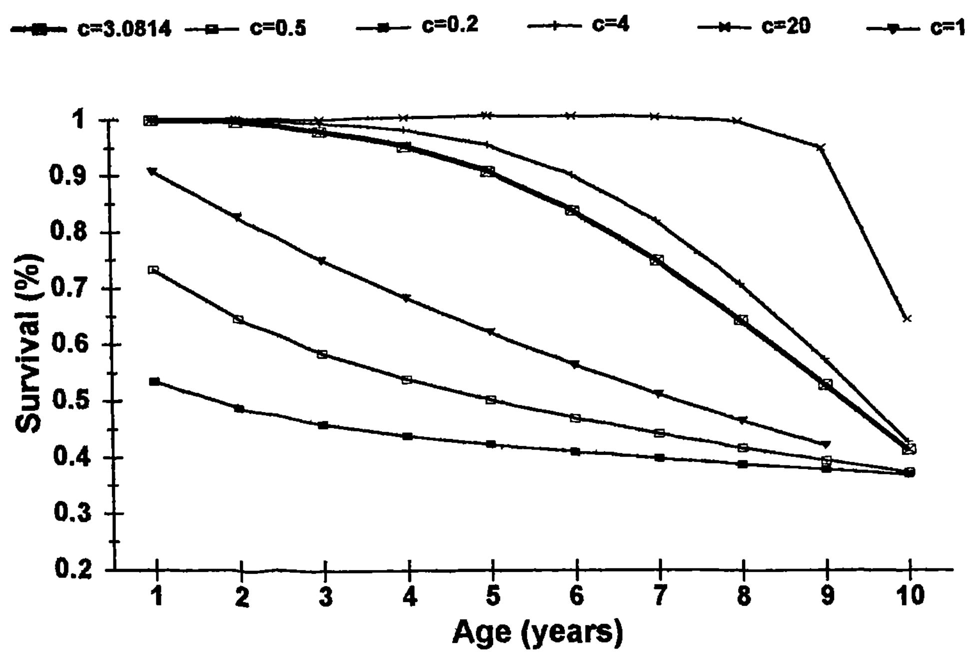

Fig. 5.6 Survivorship curves (Weibull distribution)

5.8 Application of models in physical appraisal of *Eucalyptus* plantation

The problem of evaluating the effects of forest losses as a result of fire, pests and windthrow hazard is sufficiently dealt within many forestry project analyses but the loss due to illicit felling is given inadequate attention in crucial decisions. Foresters treat plantation management as an orderly sequence of planned operations (Price and Trivedi, 1994). The determination of the optimal management approach is traditionally based on the conjecture that the outcome of selected practice is certain. This is despite the widely recognized fact of illicit felling in plantations. An uncertain outcome of plantation projects is often ignored primarily because of difficulties in evaluating it and secondarily due to preference of most funding agencies to project a certain outcome.

5.8.1 Yield estimation under illicit felling

The yield of *Eucalyptus* plantations is calculated using the following basic equation given by Sharma (1978).

$\ln V_T = b_o + b_1.(1/T) + b_2.(SI) + b_3.\ln N + b_4.(1/SI)$..................................eq. (5.25)

where V_T is the volume in $m^3 ha^{-1}$, T is the age of the plantation expressed in years, SI is the site index specific to the quality class, N is the initial number of trees per ha. The value of regression constant and coefficients are given in the Tables 4.1 and 4.2.

A yield table is generated assuming a *Eucalyptus* plantation with initial tree density of 2500 trees per ha (this corresponds to a spacing of 2mx2m) under risk-free condition using the eq. (5.25) for the district GRS1 (site quality 1). Yield tables are also generated under risk using the Weibull based model developed in section 5.5.2. The model considers the probability of survival at a particular age. It means illicit felling is quantified only in number of trees removed at specific ages of the plantation. If the illicit felling is concentrated in an area, the increment in tree volume will not be affected and the net volume will be proportionate to the trees left after illicit felling (Model WM-INA). Conversely, if illicit felling is well scattered, it will serve the purpose of a thinning and higher increment in individual tree volume is expected (WM-IA). The eq. (5.25) is based on the assumption of constant tree density for the whole rotation. However, it takes account of slight natural mortality during the rotation. The concept of variable crop density during the rotation because of illicit felling may not be compatible with the original assumption behind the equation but this is used here to illustrate the model. This has also been used in earlier studies (Trivedi and Price, 1988; Sharma, 1990) as there is no better equation available at present. The different approaches of volume estimation under variable densities are given as below:

The rate of volume increment is obtained by differentiating the equation (5.25) with respect to T as below:

$$\frac{dV_T}{dT} = -\frac{b_1.V_T}{T^2} = -\frac{b_1}{T^2}.e^{[\,b_0 + b_1.(1/T) + b_2.SI + b_3.lnN + b_4.(1/SI)]} \text{.....}eq. \ (5.26)$$

The number of trees left at mid points of each year is calculated using the illicit felling model and is used in the eq.(5.26). The volume in subsequent years is revised accordingly. This method was used by Trivedi and Price (1988) in earlier studies (Model-WMA1). But here, this method gives less than the actual volume because N_t is also a function of T, ($N_t=N_2.\exp[-\{(x)/b\}^c]$). Before differentiating eq. (5.25) with respect of time, N should be replaced by N_t. In the present study two different approaches are adopted to calculate increments in volume more precisely.

A. N in the equation (5.25) is replaced by N_t and the equation is differentiated with respect to time to give the rate of volume increment for the whole stand. The volume increment rate is calculated at the mid-point of each year and the volume of the previous year is added to get the volume of the next year. The equations are as follows:

$$\frac{dV_T}{dT}=\left[-\frac{b_1}{T^2}-\frac{cb_3}{b}.\left(\frac{T}{b}\right)^{c-1}\right]\exp\left[b_0+b_1.\left(\frac{1}{T}\right)+b_2.SI+b_3.lnN+b_4.\left(\frac{1}{SI}\right)-b_3.\left(\frac{T}{b}\right)^{c}\right] \quad \text{.......... eq. (5.27)}$$

$$\frac{dV_T}{dT}=V' \quad \text{.......... eq. (5.28)}$$

The volume in the third year is calculated as below and further volume increments are added similarly.

$$V_3=V'_{2.5}.\Delta t+V_2 \quad \text{.......... eq. (5.29)}$$

where V_3 is volume in third year, $V'_{2.5}$ is the rate of the increment in volume at 2.5 year calculated using the above equation, Δ t is the time interval (3-2=1 year), V_2 is the volume in second year.

B. The approach outlined in section A above is further improved by calculating the rate of increment of a unit volume (total stand volume/number of trees) instead of the whole stand (Model WM-IA2). Theoretically, this approach should give the same result as obtained by the previous approach but the original equation (i.e., eq. 5.25) was not initially designed to introduce variable tree number during the life of the stand. Therefore, calculation based on 'increment in unit volume' reduces the error term considerably. Both sides of the equation (5.25) are divided by the initial density of the plantation to obtain the unit volume (v_n') and N is replaced by N_t.

$\ln V_T / N_T = [\, b_o + b_1.(1/T) + b_2.\ (SI) + b_3.\ln N_T + b_4.\ (1/SI).] \,/\, N_T$ ....eq.(5.30)

Differentiating the eq. (5.30) above with respect to T gives the following equation.

$$\frac{dV_T}{dT} = \frac{\left[-\frac{b_1}{T^2} + \left(\frac{c}{b}\right).(1-b_3).\left(\frac{T}{b}\right)^{c-1}\right].\exp\left[b_0 + b_1.\left(\frac{1}{T}\right) + b_2.SI + b_3.lnN + b_4.\left(\frac{1}{SI}\right) - b_3.\left(\frac{T}{b}\right)^{c}\right]}{N\ .\exp\left[-\left(\frac{T}{b}\right)^{c}\right]}$$

....*eq.* (5.31)

$$\frac{dV_T}{dT} = v_n' \quad \text{..........} eq.\ (5.32)$$

The volume in subsequent years is obtained by applying the mean-value theorem for derivatives (Gerald and Wheatley, 1994). Let f(x) be continuous on the interval $a \leq x \leq b$, and also let it be differentiable for $a < x < b$. Then there is at least one point c in (a, b) for which

$$f'(c) = \frac{f(b) - f(a)}{b - a} \quad \text{..........} eq.\ (5.33)$$

or $f(b) = f(a) + (b-a).f'(c)$

The volume in the third year can be obtained applying eqs. 5.31 and 5.33 and the volume in subsequent years can be calculated similarly. The number of trees left at the end of second and third years are N_2 and N_3 respectively. This is calculated from the model ($N_t = N_2.\exp[-\{(x)/b\}^c]$). The volume of the stand at the second year is V_2. The unit volume (v_2) will be V_2/N_2.

$v_3 = v_2 + (3\text{-}2).v'_{2.5}$

The volume of the stand can be given as:

$V_3 = v_3 \,.\, N_3$

Table 5.6 Eucalyptus plantations under the risk of illicit felling

District: GRS1, Site Quality 1, initial plant density 2500 planta ha^{-1}

Age	Volume (without illicit felling)	Volume under the risk of illicit felling Models		
		WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27
2	11.57	11.57	11.57	11.57
3	40.51	39.26	40.04	40.23
4	75.80	70.96	72.59	73.52
5	110.38	98.20	100.93	103.51
6	141.82	117.67	121.78	127.22
7	169.61	128.54	134.26	143.79
8	193.98	131.24	138.61	153.32
9	215.33	126.91	135.77	156.35
10	234.09	117.07	127.08	153.68

Table 5.6 gives volume of the plantation under risk-free conditions and under the risk of illicit felling for district GRS1. The volume is estimated for all the districts and for three site quality classes (Annexure 5.1: Tables A5.1.1, A5.1.2, A5.1.3, A5.1.4, A5.1.5, A 5.1.6). The highest estimated volume obtained under the risk of illicit felling for each district and under three site qualities is highlighted.

5.8.2 Impact on physical rotation

The two variations of the original Weibull model as described above are :

(a) illicit felling does not affect increment in individual tree volume (WM-INA)

(b) illicit felling affects increments in individual tree volume (WM-IA)

(a) Model WM-INA

This assumes that illicit felling is localised. It results in proportional loss of area of the plantation. The increment in volume of remaining individual trees remains unaffected. The model is also applicable in some cases of scattered felling where increment in volume remains unaffected. This conforms with the observation that normal thinning does not, within wide limits of intensity, affect volume increment significantly (Trivedi and Price, 1988).

(b) Model WM-IA

This treats illicit felling as well scattered over an area, resulting in change of spacing between individual trees. The effect on net volume of the plantation will be the sum of (a) loss of individual trees due to illicit felling and (b) gain in individual tree volume due to increased spacing. The two variations WM-IA1 and WM-IA2 are due to different approaches in volume estimation of the stand.

The risk-free volume and risk incorporated volume (using all three approaches) are given in Table 5.4 for the district GRS1 (SQ1). Yield tables for other districts and for other site qualities are generated similarly (Annexure 5.1 and Fig. 5.7, 5.8, 5.9). Table 5.6 shows that risk-free volume increases with age but under the risk of illicit felling the highest yield is reduced to 131.24 m^3, 138.68 m^3, 156.35 m^3, corresponding to models WM-INA, WM-IA1, WM-IA2 respectively (rotation, 8 years for models WM-INA and WM-IA1; 9 years for model WM-INA2). On applying models WM-INA, WM-IA1 and WM-IA2, the volume reduces to 38.63 m^3, 45.57 m^3, 69.71 m^3 for site quality 2 and 12.20 m^3, 13.67 m^3, 16.10 m^3 for site quality 3 respectively for district GRS1. These corresponds to rotation of 9, 9, 12 years for site quality 2 and 10, 10, 11 years for site quality 3 respectively.

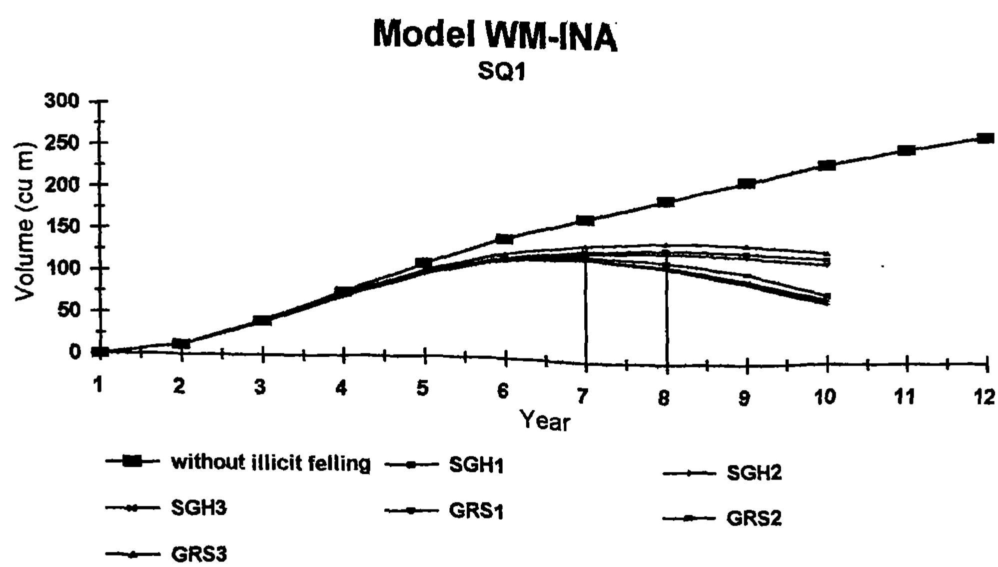

Fig.5.7 Effect of illicit felling (WM-INA) on rotations in different districts

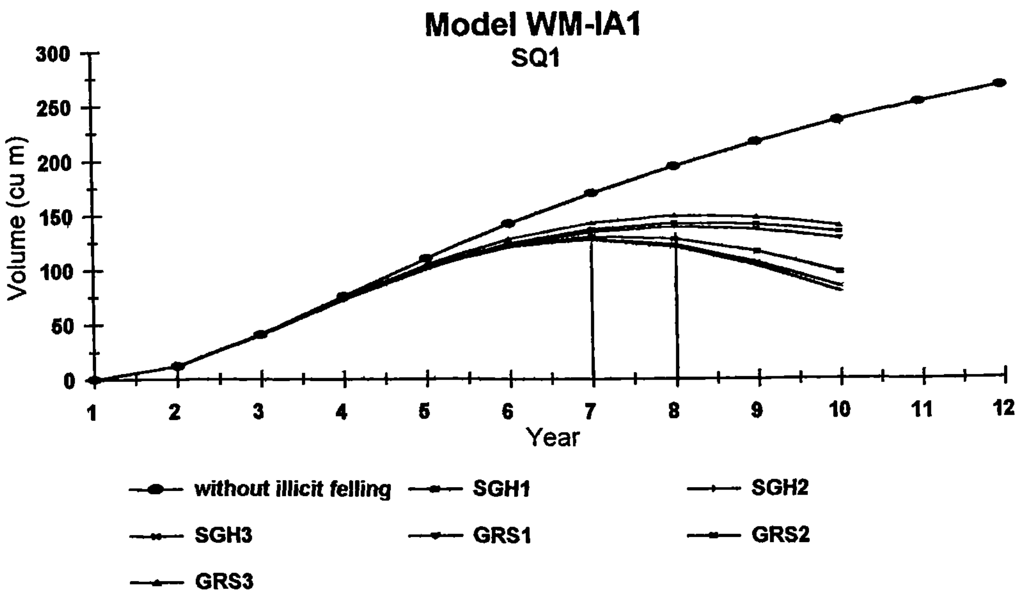

Fig.5.8 Effect of illicit felling (WM-IA1) on rotations in different districts

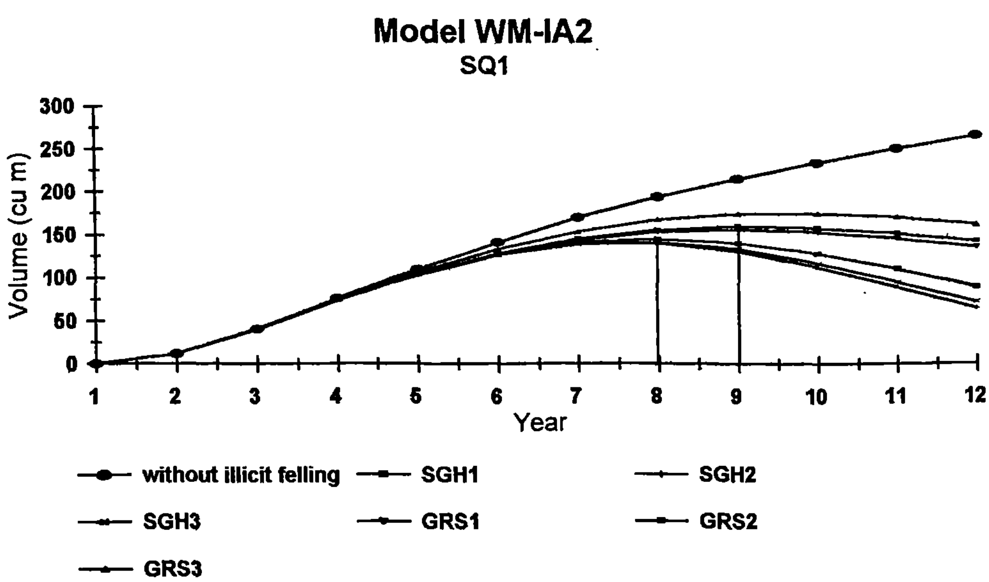

Fig.5.9 Effect of illicit felling (WM-IA2) on rotations in different districts

The illicit felling Model 1 and Model 3 given by Trivedi and Price, (1988) correspond to our models WM-INA and WM-IA1 respectively regarding pattern (concentrated or scattered) of illicit felling. They differ fundamentally in the constant loss assumption (10%) of the former. The highest yield, on applying model 1 and 3, reduces to 83.5 m^3 and 103.04 m^3 respectively at corresponding rotations of 8 and 9 years. The physical rotation is almost same as obtained by applying models WM-INA and WM-IA1. Assuming 10% compound loss due to illicit felling is nearly correct (within wide limits) for the whole rotation. But the 10% constant loss assumption is not correct for individual years.

Table 5.7 gives the various rotation ages for *Eucalyptus* plantations using maximum MAI (mean annual increment) criterion. The maximum MAI in the absence of illicit felling are 24.24 m^3, 7.43 m^3, 2.67 m^3 for site quality 1, 2, 3 respectively. Under the risk of illicit felling maximum MAI for district GRS1 (site quality 1) are 19.64 m^3, 20.30 m^3, 21.20 m^3 for models WM-INA, WM-IA1, WM-IA2 respectively. For site quality 2 (district, GRS1) the maximum expected MAI are 5.01 m^3, 5.54 m^3, 6.49 m^3 for models WM-INA, WM-IA1, WM-IA2 respectively. For site quality 3 (district, GRS1) the maximum expected MAI are 1.42 m^3, 1.53 m^3, 1.65 m^3 for models WM-INA, WM-IA1, WM-IA2 respectively. Similarly MAI for all site quality and for all districts are estimated. The corresponding rotation ages are given in the table 5.7.

It is clear from Table 5.7 and Table A5.1.1, A5.1.2, A5..3, A5.1.4, A5.1.5, A5.1.6 (Annexure 5.1) that optimum rotation in the case of maximum expected MAI are less than those in the case of maximum expected volume for all site quality classes and for all districts.

Table 5.7 Estimated rotation of *Eucalyptus* plantations based on MAI criterion

Districts	Models	Rotation (in years)		
		Site Quality 1	Site Quality 2	Site Quality 3
all districts	no illicit felling	8	11	15
SGH1	WM-INA	5	6	7
	WM-IA1	5	7	7
	WM-IA2	6	8	8
SGH2	WM-INA	5	6	7
	WM-IA1	5	6	7
	WM-IA2	6	8	8
SGH3	WM-INA	5	6	7
	WM-IA1	5	7	7
	WM-IA2	6	8	8
GRS1	WM-INA	5	7	8
	WM-IA1	6	7	8
	WM-IA2	6	9	9
GRS2	WM-INA	6	7	8
	WM-IA1	6	7	8
	WM-IA2	6	9	9
GRS3	WM-INA	6	7	8
	WM-IA1	6	7	8
	WM-IA2	6	9	9

5.9 Discussion and conclusions

The illicit felling models for *Eucalyptus* plantations shows that the expected volume of plantations depends on how losses occur. Losses as a result of localised illicit felling are more serious and shorten optimum rotations further as compared to scattered illicit felling which removes the same proportion of the stand. This has another dimension as the areas cleared by concentrated illicit felling are prone to encroachment. A detailed study of pattern of illicit felling is required to select the appropriate model for plantation appraisal. The models described above enable us to select optimum rotation in terms of wood output (volume) only. They only examine the distribution and effect of illicit felling on physical rotation of plantations. Volume is taken as proxy for utility which is not realistic as larger poles have better value per unit volume. The maximum expected MAI criterion and maximum expected volume criterion are inadequate as the decision is based on output only and input is completely ignored. However, physical appraisal is required for developing appropriate financial decision models. The model developed in this chapter will be used for financial, economic and social appraisal of the afforestation project.

Illicit felling in plantations is a serious problem in India. The dynamics of illicit felling should be properly understood before carrying out plantation project appraisals. Socioeconomic predictors of illicit felling can be used in decision making (both investment and rotation decision). The present study helps in understanding the pattern of illicit felling in a more pragmatic way. Now, the question of protection of plantations from illicit felling arises. In this context, both protection of plantations by increasing protection machinery (a stringent law and bigger law enforcing agency) and people's participation through joint forest management (JFM) need to be examined. The quantum of illegally removed wood depends largely on avoidance cost and cost of detection (Hofstad, 1992). Sometimes, it is not economically viable to control illicit felling at all at prohibitive cost of patrolling.

In terms of society, illicit felling cannot be considered as a total loss. However, it may result in desired/undesired thinning or premature (i.e. before optimum rotation) harvesting of the crop. A social cost-benefit analysis, with appropriate weights to government income and to people at different levels of consumption will be helpful in formulating projects in tune with the distribution policy of the government. In recent years, joint forest management has been put forward as a solution to the problems of illicit felling and deforestation and some success stories (Tewari, 1993) are cited in support of it. In the majority of studies (Palit, 1990), it is assumed that people are ignorant and they need to be educated about the importance of conserving the forest for future needs. However, the fact remains that no amount of motivation can make people ignore hard economic realities. Even uneducated farmers take decisions rationally. The government forests are an easy target for fulfilling their pressing demand (for additional income and forest produce). People will participate in protection only if they are assured of returns but while waiting for returns, it is not prudent to assume that they will stop illicit felling completely. Their area of operation may shift to another nearby less supervised forest. Creation of a stake in forestry returns coupled with provisions of alternative sources of energy and income are essential for the success of any participatory forest management venture. Nevertheless, JFM has some demonstration effect and it may help people to explore some alternative sources of fuelwood and other forest produce.

Chapter 6

Financial appraisal of afforestation projects

6.1 Introduction

Financial appraisal seeks to evaluate a project from the point of view of financial profitability. Financial decisions like any other decision require an assessment of alternative options to achieve the defined objective. Financial appraisal is designed to achieve efficient allocation of investment funds by maximising the net benefits to the investing agency. The concept of profitability in financial appraisal is much broader than that in usual business accounting. A financial appraisal takes account of continuous cash flow. Profit and loss at one point in time is secondary to this. The costs and benefits in financial appraisal are valued at market prices.

In the previous chapter, we have developed models for physical appraisal under the threat of illicit felling. In this chapter, we use these models to examine financial decision process under the threat of illicit felling and assess the financial profitability of the afforestation project through case studies of the FF and the RDF components of the SIDA-supported project of Bihar.

6.2 Estimation of probabilities of illicit felling

The cumulative conditional probability of survival ($CCPS_n$) is calculated using the Weibull model developed in the previous chapter ($CCPS_n=\exp[-(x/b)^c]$, where x is age in years, b=11.536, c=2.5674 for district GRS1). Cumulative conditional probability of illicit felling and other probabilities are presented in Table 6.1 and the estimation procedure is explained in accompanying notes. PIF_n is the probability of illicit felling for individual years taking PIF_n+ PS_n=1, for each year. PIF''_n is calculated for individual years, taking the sum of probabilities of illicit felling and the probability of survival for the whole production cycle as 1. These two concepts of probability estimation will be used in financial models developed in subsequent sections.

Table 6.1 Distribution of illicit felling probabilities (District: GRS1)

Year (m)	Probabilities				
	PIF_n	PS_n	$CCPS_n$	$CCPF_n$	PIF''_n
1	0.0000	1.0000	1.0000	0.0000	0.0000
2	0.0000	1.0000	1.0000	0.0000	0.0000
3	0.0310	0.9690	0.9690	0.0310	0.0310
4	0.0338	0.9662	0.9362	0.0638	0.0328
5	0.0497	0.9503	0.8897	0.1103	0.0465
6	0.0674	0.9326	0.8297	0.1703	0.0600
7	0.0867	0.9133	0.7578	0.2422	0.0719
8	0.1072	0.8928	0.6766	0.3234	0.0812
9	0.1289	0.8711	0.5894	0.4106	0.0872
10	0.1514	0.8486	0.5001	0.4999	0.0893
11	0.1748	0.8252	0.4127	0.5873	0.0874
12	0.1987	0.8013	0.3307	0.6693	0.0820
13	0.2231	0.7769	0.2569	0.7431	0.0738
14	0.2478	0.7522	0.1932	0.8068	0.0637
15	0.2728	0.7272	0.1405	0.8595	0.0527
		0.1405*			0.8595‡

Notes: 1.

$$*CCPS_m = \prod_{n=1}^{n=m-1} PS_n \qquad ‡CCPF_m = \sum_{n=1}^{n=m-1} PIF''_n$$

2. $CCPS_n$=Cumulative Conditional Probability of Survival in year *n*.
3. $CCPF_n$=Cumulative Conditional Probability of felling. $CCPF_n$=1-$CCPS_n$
4. PS_n (probability of survival in year n)=$CCPS_n/CCPS_{n-1}$
5. PIF_n (probability of illicit felling in year *n*, frame of reference: individual years)=1-PS_n
6. PIF''_n (probability of illicit felling in year *n*, frame of reference: the whole rotation)=$CCPF_n$ -$CCPF_{n-1}$
7. Strictly, PIF_n is P during the year, $CCPS_n$ is P by the end of the year.
8. The highlighted cells show interrelationships among values.

6.3 Financial models of illicit felling risk appraisal

The main objective in the financial rotation decision is to maximise profits. The optimal time to harvest a plantation is that at which the costs of letting the crop grow for one more unit of time are just compensated by the additional benefits of this action. This is simply maximisation of net present value of the crop.

The financial performance of plantations affected by illicit felling is evaluated against performance of unaffected plantations. First of all, the costs and benefits are quantified in physical terms. Then, they are valued at market prices. Finally a discounted cash flow is generated after proper adjustment of inflation and applying a suitable discount rate. For development of financial models, both costs and benefits are taken at constant price of 1993. Planting and harvesting costs are based on the Schedule of Rates of the Forest Department, Bihar (Annexure 6.1, Table A6.1.1 and Table A6.1.2). The computation of benefits involves estimation of physical yield and determination of its value. The Weibull model was used to estimate yield of plantations under different levels of illicit felling. The valuation of the crop is based on its size (diameter and height) and the end use after expected conversion (into fuel wood, timber or pole). The price of wood depends on its size. Therefore, crop diameter is calculated (using Sharma's equation (1978)) and differential price are introduced to calculate the value of the crop using depot rates of the forest department (Annexure 6.1, Table A6.1.3). The price of forest produce per m^3 for unaffected (without illicit felling) plantation is given in Table A6.1.4 (Annexure 6.1). The indirect costs which include administrative expenditure were also included in costs. All the estimates are made for 1 ha *Eucalyptus* plantation (spacing, 2m × 2m; 2500 plants per ha). A discount rate of 10% is used. Table 6.2 shows predicted net present values for one crop rotation (NPV) and net present values for an infinite series of planting and replanting (NPVinf) for rotation length from 1 to 15 years in the absence of illicit felling. The optimum rotation is indicated by highlighted cells. NPVinf indicates value of land assuming planting and replanting in perpetuity. NPVinf can be calculated as below:

$$NPV_{\infty} = \frac{NPV_{(n)}.(1 + r)^n}{(1 + r)^n - 1}$$

where $NPV_{(n)}$ is net present value for one crop rotation, r is discount rate and n is the rotation.

Table 6.2 Expected NPV (one rotation and infinite series) of *Eucalyptus* plantation in Bihar (without illicit felling)

Discount rate = 0.10

Plantation age (years)	SQ1		SQ2		SQ3	
	NPV	NPVinf	NPV	NPVinf	NPV	NPVinf
1	-8708	-95791	-8806	-96870	-8808	-96886
2	-6031	-34749	-9600	-55315	-9892	-56996
3	2441	9816	-7049	-28344	-9685	-38943
4	11100	35016	-4829	-15235	-9193	-29001
5	17905	47233	-2559	-6750	-8532	-22508
6	74622	171338	-628	-1442	-7848	-18020
7	82747	169967	840	1726	-7234	-14860
8	94644	177404	1855	3477	-6734	-12622
9	98123	170382	2475	4298	-6356	-11037
10	89069	144955	2775	4516	-6096	-9921
11	133492	205528	2823	4346	-5939	-9143
12	121139	177787	2679	3932	-5867	-8611
13	130780	184109	33834	47631	-5866	-8257
14	132266	179546	36110	49017	-5919	-8035
15	119710	157387	32215	42355	-6014	-7907

Now, we examine some financial decision models under the risk of illicit felling based on the principle of maximisation of NPV. Illicit felling affects plantations by

(a) reducing the expected revenue to the forest department

(b) increasing variability of returns depending on the pattern and quantum of illicit felling (Price and Trivedi, 1994).

We incorporate these elements in financial decision models.

6.3.1 Risk premium and discounting: the conventional approach

The discount rate premium approach is widely used in business (for details, see Bromwich, 1976). The choice of discount rate depends upon the risk in the project. The discount rate is the sum of risk-free rate of interest and a risk premium positively related to the level of project risk (Mckillop and Hutchinson, 1990). Risk premia really ought to be to do with variability of the mean expected outcome. The risk premium can be subjectively estimated depending upon project risk or more formally through the capital asset pricing model (Sharpe, 1964; Lintner, 1965). The risk adjusted discount rate (r) can be calculated as follows:

$r = \{(1+m)(1+n)\} - 1$

where m is risk free discount rate and n is the risk premium.

The Weibull model described in previous chapter showed that the risk of illicit felling varied according to age (diameter) of crop. Therefore, a constant risk premium cannot be used throughout the rotation. The risk adjusted discount rate (RADR) is calculated for each year depending on the risk of illicit felling in individual years in all the previous years .The risk of illicit felling is calculated using the Weibull model. The risk adjusted discount rate (r_t)can be given by the following equation (for mathematical derivation of the equation, see Appendix 6.1):

$$r_t = \left[(1+m) \left[\prod_{i=1}^{t} (1+n_i) \right]^{\frac{1}{t}} \right] - 1 \ldots\ldots\ldots\ldots\ldots\ldots eq.(6.1)$$

where m is risk free discount rate, n_i is probability of illicit felling in i th year

The value of n is obtained through models for each year and the value of risk adjusted discount rate (r_t) is calculated using the above equation. The values for all the districts is given in Table AP6.1.1 (Appendix 6.1) This approach is termed as RADR1.

It is not strictly correct to add together discount rate and risk premium because these factors contribute independently to the time frame (Trivedi and Price, 1988). After making deductions for loss (n), the remainder should be discounted by pure time preference rate (m). This approach is termed as RADR2. The risk adjusted discount rate for the year t ($\acute{r}_t$) can be given as (for mathematical derivation of the equation, see Appendix 6.1):

$$\acute{r}_t = \left[\frac{(1+m)}{\left[\prod_{i=1}^{t} (1-n_i) \right]^{\frac{1}{t}}} \right] - 1 \ldots\ldots\ldots\ldots\ldots\ldots eq.(6.2)$$

where m is risk free discount rate, n_i is probability of illicit felling in i th year

The factor $\prod_{i=1}^{t}(1-n_i)$ is nothing but cumulative conditional probability of survival (CCPS). Therefore, the volume calculated using model WM-INA will be exactly equal to that obtained by RADR2 approach. However, it will not remain the same if we consider the infinite series of rotations (Price, 1993)

The value of n is obtained through models for each year and the value of risk adjusted discount rate (r_t) is calculated using the above equation. The values for all the districts are given in Table AP6.1.2 (Appendix 6.1).

Table 6.3 Risk-premium approach of risk appraisal

District: GRS1, SQ1

Plantation age (years)	RADR1(eq. 6.1)		RADR2 (eq. 6.2)	
	NPV	NPVinf*	NPV	NPVinf*
1	-8708	-95791	-8708	-95791
2	-6031	-34749	-6031	-34749
3	2133	7862	2123	7807
4	9899	27559	9861	27350
5	15088	33902	14980	33469
6	61052	115770	60417	113641
7	61714	102076	60547	99076
8	63127	93475	61123	89311
9	57015	77199	54115	72149
10	43458	54762	40004	49560
11	55871	66492	49749	58162
12	40392	45959	33969	37970
13	34352	37751	26845	29003
14	26088	27919	18243	19221
15	16091	16882	9055	9370

Notes: 1. * NPVinf=NPV × $\{(1+m)^t / (1+m)^t - 1\}$, m is risk free discount rate (not risk adjusted discount rate). The derivation of the formula is presented in section 6.4.1.1.
2. The highlighted cells show optimal rotations.

Table 6.3 shows that for SQ1 (District: GRS1), the two approaches viz. RADR1 and RADR2 give the highest NPV of Rs 63127 and Rs 61123 respectively corresponding to the rotation age of 8 years each. When the net present values for the infinite series (NPVinf) are analysed, we find the highest NPVs for RADR1 and RADR2 are Rs 115770

and Rs 113641 respectively. It corresponds to the rotation age of 6 years for both the cases. All rotations are much shorter than for plantations without illicit felling (Table 6.2, SQ1). We notice a large difference in the values of NPVs at the year 15 due to the difference between Π (1-n_t) and Π 1 / (1+ n_t) approaches. It is clearly an indication that risk premium must be carefully specified. The basic difference of RADR2 and RADR1 is that RADR2 uses the (correct) subtractive method of giving CCPS. The difference is (1-n_t) ≠ 1 / (1+ n_t). The addititive / multiplicative difference is that
(1+m) × (1+ n) ≠ (m+n) (where m is risk free discount rate and n is risk premium). This is a separate error which is not treated here.

The discount rate premium approach is condemned on the following grounds:
(A) It assumes that the level of risk remains constant through the life time of a project (Markandya and Pearce, 1988).
(B) Risk is unlikely to be cumulative from one rotation to the next (Price, 1993) i.e., risk premium approach will not give correct results if we apply it for NPVinf estimates.

In the present study, we have developed the equation to incorporate variable risk premium through the life time of a project. If '(A)' above is correct, now it should give the same results as obtained by explicit models (EM). But it does not give the same result even after taking into consideration the element of variable risk because:

- All costs are discounted at risk-adjusted rates which is obviously not correct as the risk premium is related to benefits only.
- For this very reason, the risk premium approach is not appropriate even for estimation of NPV for one rotation unless we assume costs as zero - a most unlikely situation. RADR1 will give the precise estimates under this assumption (cost=0) only.
- Under usual afforestation project cash flow (most of the costs are incurred at the beginning of the project, with very little or no intermediate costs.), RADR2 gives results very near to that obtained by explicit model.

6.3.2 Explicit models of risk appraisal

We call these models explicit models because these are based on the actual quantification of the yield under risk of illicit felling. The yield of plantations is estimated using the Weibull model (WM-INA). The mean expected value of crop is the product of CCPS and the value of outcome. The cash flow is generated as described in the previous section. The NPV for one rotation and an infinite series of rotations is presented in Table

6.4. We call this model EM1.

Table 6.4 Explicit models of risk appraisal

District: GRS1, SQ1

Plantation age (years)	**EM1**		**EM2**
	NPV	**NPVinf**	**MNPVinf.**
1	-8708	-95791	-95791
2	-6031	-34749	-34749
3	2058	8275	8275
4	9759	30787	30994
5	14836	39137	39774
6	60226	138284	142305
7	60306	123871	129468
8	60826	114016	121374
9	53761	93351	101466
10	39590	64430	71647
11	49271	75860	86427
12	33426	49057	53310
13	26234	36932	44252
14	17562	23840	29291
15	8303	10916	13742

Note: The highlighted cells show optimal rotations.

This model (EM1) is based on planned rotations. It assumes replanting only after completion of planned rotation. Therefore, it underestimates the net present values when it is applied for an infinite series of rotations. The reason is that we have assumed that illict felling is concentrated by area. Price (1989) has given a general model to estimate the value of crop under risk using mean expected value of infinite series of rotation based on replanting immediately after crop damage. We use this model (EM2) to calculate mean expected value of an infinite series of rotations under risk of illicit felling. The equation is modified to include discounted value of planting cost. Probability of illicit felling in individual years is taken with reference to the total rotation (section 6.2).

$$M = CCPS\left[\left(\frac{B_t}{(1+r)^t}\right)+\left(\sum_{t=0}^{t=T}\frac{M}{(1+r)^t}\right)\right]-\left(\sum_{t=0}^{t=T}\frac{C_t}{(1+r)^t}\right)+\left(\sum_{t=0}^{t=T}\frac{M\ PIF^{*}_{t}}{(1+r)^t}\right) \quad \text{.......}eq.(6.3)$$

where CCPS is the cumulative conditional probability of survival i.e probability of achieving

planned rotation, $\left(\frac{B_I}{(1+r)^t}\right)$ gives discounted benefits from a planned rotation,

$\left(\sum_{t=1}^{t=T}\frac{M}{(1+r)^t}\right)$ is discounted M from planned successor crops, $\left(\sum_{t=1}^{t=T}\frac{C_t}{(1+r)^t}\right)$ is

discounted planting cost, *M* (or MNPVinf) is the mean expected net present value of an infinite series of rotations, *T* is rotation, PIF_t^{*} is probability of illicit felling in year *t* (frame of reference: the whole rotation) and *r* is a discount rate.

The mean expected net present value of an infinite series of rotation (MNPVinf or M) is calculated using the above formula (eq. 6.3) for all rotations and is presented in Table 6.4. The value of MNPVinf is higher as compared to that obtained by EM1, though rotation age is same (6 years) for both the models (EM1 and EM2).

6.3.3 Conclusions

The analysis of economic consequences of rotation decisions in illicit felling affected plantations exhibits the unsuitability of the conventional approach of risk adjusted discounting. The pattern of illicit felling critically affects both physical productivity and economic profitability. The financial models require an appropriate model for the physical nature of illicit felling. The effect of illicit felling on the financial rotation decision is described above according to our physical model WM-INA. For this particular case (GRS1, SQ1), the optimum rotations are the same (model EM1 and EM2) but it will not be so for all the cases. Similarly, financial rotation can be assessed employing WM-IA1 and WM-IA2. It is absolutely imperative for project appraisers to incorporate realistic estimates of the effects of illicit felling according to physical attrition and to modify the project design and management option in response to the phenomenon.

6.4 Management decision models

The financial models for plantation appraisal under the threat of illicit felling discussed above, can be applied where we have prior knowledge of the probability of illicit felling throughout the course of the rotation. Sometimes, illicit felling is done by gangs of timber smugglers resulting in severe illicit felling in a very short period. The action taken after such heavy felling depends largely on the forest officer's judgement, whether to replant the site after harvesting the remaining trees or leave the remaining trees to grow up to normal rotation. The decisions are often taken purely on administrative grounds (e.g., areas prone to encroachment by the villagers get higher priority) and the economics is rarely considered. Project managers do anticipate such risks but do not incorporate any strategy in the project itself, because of :

(a) lack of economically objective choice criterion and,

(b) assuming no shortage of land for plantation, as funds are too limited as compared to the requirements of available land for plantation.

So leaving the illicitly felled area without replanting entails no opportunity cost. It is true that plantation projects operate in a very small fraction of the area as compared to the total area available for plantation but the areas with good site quality are extremely limited. Therefore, an opportunity cost exists in either situation if the wrong replant / no-replant decision is made. After the illicit felling if the area is not replanted, a cost results as the productivity of site is underutilised by the remaining trees (or it may be beneficial due to the thinning effect depending upon distribution of illicit felling). Conversely, if the whole area is clear felled and planted again, it may not be economically desirable depending upon the opportunity cost of the funds and the productivity of the site. We attempt to provide an economically desirable choice criterion under severe illicit felling. In this study, for building the decision model, illicit felling has been assumed to be the only risk element influencing the outcome and coppice growth is not considered for the sake of simplifying the model.

If the illicit felling is concentrated over a large patch, there is no problem in decision making as no trees remain to be removed. Conversely, in the case of scattered felling, the whole area is to be clear felled and replanting has to be taken up. Plantation in small scattered patches is neither practical nor economical. Moreover, harvesting such a plantation (uneven aged) is also very difficult. Illicit felling by timber smugglers mostly takes place in concentrated patches of good growth because of:

(a) a preference for selective girth class depending upon price and available market and

(b) to facilitate quick removal of the produce from the forests.

In the case of stray felling by villagers, illicit felling assumes a scattered pattern as there is no relative advantage for concentrating over an area. The illicit felling for the purpose of encroaching forest land by the villagers takes place in a concentrated manner. Thus, the illicit felling by organised timber smugglers and illicit felling for encroachment purposes results in sudden and heavy removal of forest produce.

In both the cases, the decision will be influenced by time, quantum and pattern of illicit felling. A no-replant decision is proper when illicit felling is below some threshold level (T_f). Conversely, if the illicit felling exceeds T_f, it is prudent to replant the whole area.

6.4.1 Model for replantation decision after illicit felling

The problem of decision making (replant / no replant) is addressed by Wade and Ward (1975) and Gunter (1976). Caulfield (1987) discussed the decision making process in case of fire hazards of even-aged plantation using deterministic techniques. Routledge (1980) and Caulfield (1987) have used a stochastic formulation for determining optimum rotation. In the following section, we present both deterministic and probabilistic formulations of plant/no-plant decision models.

6.4.1.1 Plant/no-plant decision model (deterministic)

The frame of reference against which the decisions are to be made is the performance of unaffected plantations. The net present value (NPV) maximisation for an infinite series of planting and replanting (NPV_∞) is used as the decision criterion. The rationale for using NPV_∞ is discussed by Samuelson (1976) and Price (1989). NPV_∞ is the value of land for plantation in perpetuity. NPV of one rotation can be given as:

$$NPV = \sum_{t=0}^{t=n} \frac{B_t - C_t}{(1 + r)^t}$$

where B_t and C_t are the benefit and cost respectively in year t. r is the discount rate expressed in a decimal and n is the rotation. The formula for calculating NPV_∞ can be derived as below:

If $NPV_{(n)}$ is the net present value for one rotation and NPV_∞ is for the infinite series, then,

$$NPV_{\infty} = NPV_{(n)} + \frac{NPV_{(n)}}{(1+r)^{n}} + \frac{NPV_{(n)}}{(1+r)^{2n}} + \frac{NPV_{(n)}}{(1+r)^{3n}} \ldots\ldots\infty \ldots eq.\ (6.4)$$

If $NPV_{(n)}$=a, and x = 1 / $(1+r)^n$, equation 6.4 will take the form of infinite (n=∞) convergent series whose sum can be given as:

$$S = a + ax + ax^2 + ax^3 + ax^4 + ax^5 + ax^6 \ldots\ldots\ldots ax^n$$

$$S = \frac{a\,(1-x^n)}{1-x}, \text{ or } \quad S = \frac{a}{1-x} - \frac{a.x^n}{1-x}$$

If n=∞ and 0<x<1, $\quad \frac{a.x^n}{1-x} \approx 0$, then,

$$S = a / (1-x) \ldots\ldots\ldots eq.\ (6.5)$$

again by substituting the value of 'a' and 'x' in equation 6.5, the NPV_{∞} can be calculated as below:

$$NPV_{\infty} = \frac{NPV_{(n)}.(1+r)^n}{(1+r)^n - 1} \ldots\ldots\ldots eq.\ (6.6)$$

If $(1+r)^n$ = c, taking $\log_e$ of both sides, lnc = n.ln (1+r)..eq. (6.7)

If ρ = ln(1+r), eq.6.7 becomes lnc = n. ρ or c = $e^{n.\rho}$, on substituting the value of c in eq. 6.6 , we get:

$$NPV_{\infty} = \frac{NPV_{(n)}.e^{n.\rho}}{e^{n.\rho}-1} \ldots\ldots\ldots eq.\ (6.8$$

$$\rho = \ln(1+r)$$

Equation 6.8 can also be written in the following form using the binomial theorem $(1+r)^n \approx 1 + r.\,n$:

$$NPV_{\infty} = \frac{NPV_{(n)}.e^{n.r}}{e^{n.r}-1} \ldots\ldots\ldots eq.\ (6.9)$$

Most of the authors (e.g. Caulfield, 1987) have used the above form (eq. 6.9) but this does not give desired precision. Therefore, the eq. 6.8 is used in the present study. After the illicit felling, two situations can be visualised:

(a) The value of the site ($NPV_\infty(NP)$) if the stand is not planted.

(b) The value of the site ($NPV_\infty(P)$) if the whole area is planted after clear felling the remaining trees following the illicit felling.

Since the optimal rotation is shorter if there is a high opportunity cost in not replanting, the value of continuing the rotation is underestimated by the formulation based on the independent NPV_∞ assumption. The independent value of NPV_∞ assumes an undamaged optimal rotation. Therefore, NPV_∞ is estimated using the existing illicit felling data. This gives an 'expected' rotation with a given NPV_∞.

(a) The value of the site ($NPV_\infty(P)$) if the stand is planted

The value of the site will include:

(1) net present value of the infinite series of planting and replanting (NPV_∞),

(2) the value (per tree volume × price per unit volume × number of trees left) of the stand left undisturbed i.e total value of the stand at the year of illicit felling (B_X) - Illicit felling loss ($B_X.T_f$) and,

(3) value of the salvageable forest produce (from disturbed area) left by smugglers.

(b) The value of the site ($NPV_\infty(NP)$) if the stand is not planted

The value of the site will include:

(1) net present value of the infinite series of planting and replanting (NPV_∞) discounted to the year of illicit felling

(2) the value of the stand at the year of normal rotation (excluding illicit felling mortality) discounted from year of the rotation to the year of illicit felling. This normal rotation is also not independent of illicit removals.

(3) value of the salvageable forest produce (from disturbed area) left by smugglers.

Assume that the illicit felling takes place in the year 'x' of the rotation 'n' as $0 \le x \le n$, incurring removal of T_f (expressed as a decimal) trees, where $0 \le T_f \le 1$. Of T_f some proportion 'q' can be utilized.

If the area is clear felled and immediately replanted, the value of site can be given as:

$$NPV_\infty(P) = NPV_\infty + B_X - (B_X.T_f) + q.T_f.B_X \quad \text{......eq. (6.10)}$$

If the stand is not replanted following illicit felling up to the normal rotation year (n), the value of stand can be given by the following equation:

$$NPV_\infty(NP) = \frac{NPV_\infty}{e^{\rho(n-x)}} + q.T_f B_x + \frac{B_n.(1-T_f)}{e^{\rho(n-x)}} \quad \text{..........} eq.(6.11)$$

$$\rho = \ln(1+r)$$

where T_f is the loss(%) due to illicit felling for the year *x*, NPV_∞ is the net present value for the infinite series of planting and harvesting, *x* is the year in which illicit felling takes place, *n* is the normal rotation of the plantation in absence of illicit felling, B_x and B_n are the values of plantation at year *x* and *n* respectively.

Now, we can compute the threshold for the *ex post* situation. For calculating the threshold value (T_f^*), both the equations viz. 6.10 and 6.11 are set equal to one another and solved for the value for T_f^*. At the threshold value both the equations are equal to each other and this value determines replant/no-replant decision. These equations are solved by iterative process. A spreadsheet model was developed to calculate the threshold values for different discount rates (Fig. 6.1).

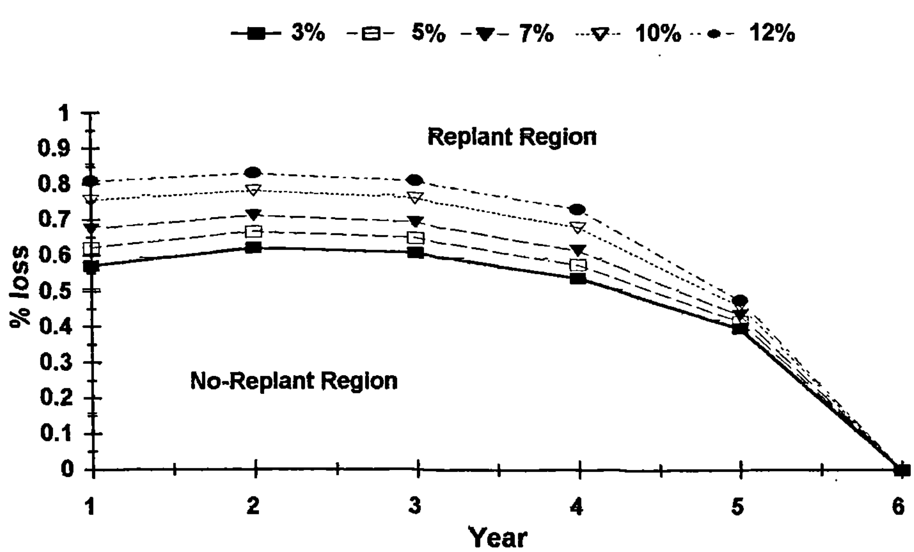

Fig. 6.1 Plant/noplant decision under the risk of illicit felling (deterministic model)

6.4.1.1 Plant/no-plant decision model (probabilistic)

We upgrade the model to a probabilistic model. % removal is the stochastic element in this model. NPV_∞ calculations are no longer valid. We use an iterative process using the concept of $MNPV_\infty$ (mean net present value for an infinite series of planting and replanting, eq. 6.3) to recompute $MNPV_\infty$ at each iteration.

Threshold levels at various ages as already computed in the deterministic model (Fig. 6.1) are combined with the PIF" (probability of illicit felling at each age, deterministic version) to give probability of illicit felling at different ages. This feeds back into recalculation of $MNPV_\infty$. Threshold values are again recalculated. Threshold values at different discount rates are presented (Fig. 6.2)

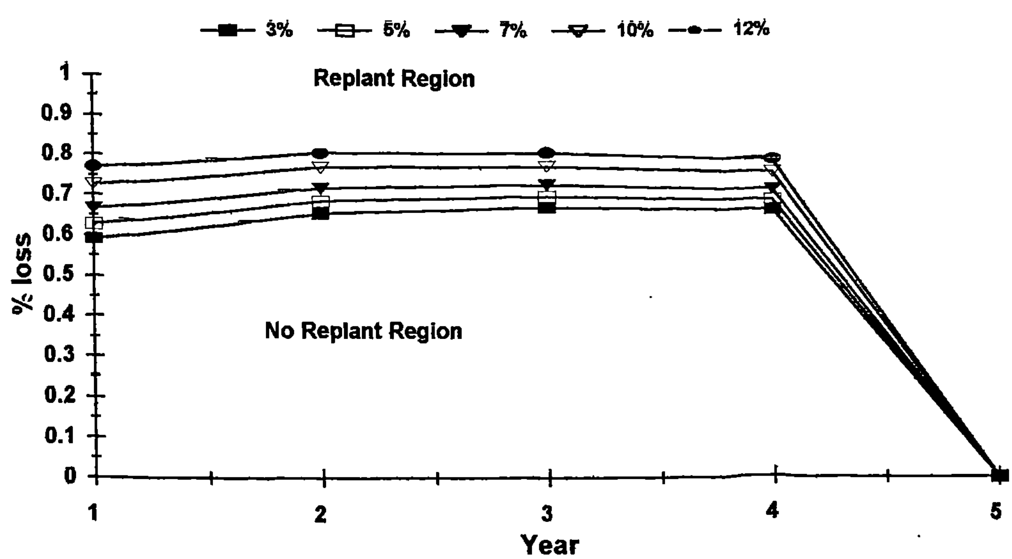

Fig. 6.2 Plant/noplant decision under the risk of illicit felling (probabilistic model)

6.4.2 Applications of the models

The above described models can be used for decision making under illicit felling as below:

- If the felling is more than T_f^*, the plantation should be clear-felled and replanting should be done.
- The salvageable forest produce left by timber smugglers does not affect the decision.

• If the illicit felling takes place in a manner as given by our model WM-IA1 or WM-IA2, the value of stand at the end of rotation can not be calculated by simply multiplying T_f by the value obtained in absence of illicit felling because illicit felling results in production of higher girth class trees by increasing tree-spacing. The higher girth class trees have higher price per unit volume.

Fig 6.1 and Fig. 6.2 shows values of T_f^* for the five discount rates (3%, 5%, 7%, 10% and 12%). The curves in the figures are break-even lines for the five discount rates. If the % loss level falls above the line (of a particular discount rate), the stand should be replanted. The values below the line suggests no-replant decision. It is obvious from the graph that for one year old plantations % loss level as high as 55% to 85% (depending on the discount rate and the model) can be economically sustained and favour no-replant decision. The % loss level increases between age one to five years because as the stands grow older the discounted value of all future rotations increases. The models also show that discount rates have little effect on planting/no-planting decisions. This is because of the high levels of illicit felling which dominates the effect of discounting.

This model can also be used for decision analysis (gap-filling decisions) in case of severe grazing of plantations (in initial years of establishment) or high mortality of plantations due to failure of the monsoon. This can be incorporated in the project itself. It also suggests that the protection strategy should be formulated taking into consideration the discount rate. In this particular case the discount rate seems to have little effect but at low levels of removals the effect of discounting on decision will be more apparent. This model can only be used in decision analysis after damages occurred at one point in time.

6.5 Financial appraisal of RDF component: a case study

The financial appraisal is based on actual details of costs and estimated benefits for a total of 18 plots of RDF component of SIDA-supported social forestry project of Bihar.

6.5.1 Computation of costs

6.5.1.1 Planting costs

All the plantations were taken up in PFs. Therefore, there is no direct cost involved for land. The details of costs for the plantation are given in Table A6.2.1 (Annexure 6.2). It covers all the operations from advance work to maintenance. The costs are based on the schedule of rates prescribed by the forest department of Bihar for various items of work. The wage rate was constant (Rs 21) for all three years and planting and maintenance costs are envisaged only up to three years. The operations involving cutting back of degenerated growth of sal (*Shorea robusta*) were carried out in some areas during the second phase of the project. We have not included this in our analysis because our selected plantations (of 1986) were raised in very degraded forests. So any expenditure in cutting back operations was not required. The expenditure in 'site clearance' covered this operation also.

6.5.1.2 Harvesting costs

The harvesting cost is given in Table A6.1.2 (Annexure 6.1). It includes actual costs for felling trees, conversion, transportation and other miscellaneous costs. Most financial appraisals of afforestation projects are based on stumpage price of forest produce which is estimated by deducting a fixed harvesting and post-harvesting cost from the auction price of the forest produce. We find that elements of variability in post-harvesting operations are very high and it involves a substantial amount of expenditure depending on crop size and quantum. Therefore, we have included all costs from planting to actual auctions of the produce.

6.5.1.3 Indirect costs

The costs of supervision and administrative expenditure are included in indirect costs. It is difficult to quantify individual indirect costs for each plantation. Therefore, the details of total expenditure on the project were obtained from the office of the Chief Conservator of Forests (Development), Bihar, and the indirect costs were calculated proportionate to the direct expenditure for each component of the project (Table A6.2.2, Annexure 6.2). In most of the earlier studies, the estimation of indirect costs was either avoided (Arnold et al., 1987; World Bank, 1990) or a fixed indirect cost was assumed (Verma, 1988).

6.5.2 Computation of benefits

The accrual of benefits depends on the physical yield and the price of the produce. The physical yield of individual plantations is estimated using equation 5.25. Sharma's (1978) yield table gives yield figures for 800 to 1800 plants per ha. Our case study is related to an initial density of 2500 plants per ha. Therefore, we need to extrapolate it to include estimates for 2500 plants which though theoretically inaccurate, is empirically justifiable because of the reduction in number of plants due to illicit felling in subsequent years.

The value of the crop is estimated according to the predicted size of converted (ready to auction) material. The conventional estimation of the value of the crop, based on diameter or diameter-class, may underestimate or overestimate the value because diameter size class or diameter may or may not correspond to the merchantable price-size schedule (e.g. for poles both the diameter and the length are considered for valuation). The rates for fuelwood used in our analysis are per m^3 stacked volume rates. Therefore, the estimated solid volume is converted into stacked volume (stacked volume = 1.5 × solid volume, Chaturvedi, 1983).

Twigs and branches (diameter < 5 cm OB) contribute considerably to total biomass of a tree. Conventional yield tables do not include these in their estimates. We have quantified these components from biomass studies of *Eucalyptus* and *Acacia* plantations of Bihar and after appropriate correction for moisture contents (Table A6.2.3, Annexure 6.2) stacked volume is estimated. The percentage contribution of various components in total biomass is presented for *Eucalyptus* and *Acacia* (Table A6.2.3, Annexure 6.2). This correction is important because:

(a) It affects the total profitability of the project.

(b) Twigs and branches (and sometimes leaves) are generally consumed locally. Ignoring their contribution in total fuelwood production results in underestimating the value of plantations for local needs. It is often argued that *Eucalyptus* plantation caters only for the needs of the mining industry (the mining industry requires a huge quantity of poles) and local fuel wood needs are completely ignored.

Eucalyptus is a good coppicer in early ages. Therefore, several coppice crops can be obtained when plantations are worked on short rotations. The coppice yield in the first generation and subsequent generations depends on a number of factors which includes soil moisture, timing of coppice, site quality etc. (Chaturvedi, 1983). At present, there is no growth and yield equation available to predict coppice yield in plantations for Bihar. Therefore, we have not considered coppice crops in the present study. Though some studies (Sharma, 1979; Neelay et al., 1984) are available for other states, these studies are based on a very small sample and relate to first generation coppice only. These studies also fail to establish any yield relationship between main crop and subsequent coppice generations. The yield from the first generation coppice crop will be two to three times higher than the seedling crop of the same age (Neelay et al., 1984). Chaturvedi (1983) reports that there is no fall in the yield of the first generation coppice crop compared with main crop while there is reduction in yield of the second generation coppice crop.

6.5.3 Computations for real costs and real benefits

The costs and benefits of the project occur at different points in time. To make them comparable, they should be expressed in real terms. The real values for costs and benefits are computed by adjusting market values for the effect of inflation. The most widely used price indices for indicating the degree of inflation in the economy as a whole are the Implicit Price Index (or GDP deflator) and the Wholesale Price Index (WPI). The former takes into account all production in the economy while WPI reflects changes in the price of (at wholesale level[1]) 447 commodities covering all traded items in the economy with 37.61% weight to articles of agriculture origin (GOI, 1993). WPI (average of weeks) is found most suitable and is used in the present study. The deflating/inflating factor for each year is presented in Table A6.2.4 (Annexure 6.2). The deflating/inflating factors are applied for converting the values of costs and benefits to the constant price of 1993. Now, cost and benefits at different points in time are comparable and can be used for cash flow generation.

1

Consumer Price Index (CPI) measures changes in the retail prices. Since retail prices affect different sections of the society differently, the CPI's are calculated separately for (i) industrial workers, (ii) urban non-manual employees and (iii) agriculture labourers.

6.5.4 Profitability criteria

The discussion in section 3.3.3 suggests that out of three indicators viz. NPV, BCA and IRR, NPV per unit area seems to be the most suitable criterion for FCBA. However, we use all three criteria in our analysis to examine their relative merits.

6.5.5 Choice of a discount rate

The discount rate used in financial cost-benefit analysis is the market rate of interest. But it is difficult to find a single rate of interest. Table A6.2.5 (Annexure 6.2) gives the various interest rates used by different financial institutions . These rates are nominal. As we have expressed costs and benefits in real terms, discount rates should also be expressed in real terms after adjusting for inflation. To estimate inflation rate in the economy, a time series of GDP deflators for the year 1965-91 is compiled (Table A6.2.4, Annexure 6.2). A log-lin (or semilog) model in the form:

$\ln Y=\beta_0+\beta_1 X_t+u_t$..eq. (6.13)

(where *Y* is GDP deflator and X_t is time trend and u_t is error term) is used for regression analysis. From the regression results of eq. 6.13, we notice (DW statistic, 0.88008) the presence of positive serial correlation (≤ 0.01). The series also has a unit root (DF: -2.5395>DF_{26} (-3.5943) $P\geq 0.05$ and ADF(1): -4.3034>ADF_{25} t (-3.6027) $P\geq 0.05$).

To arrive at an unbiased estimate of eq. 6.13, we transform eq. 6.13 according to the Cochrane-Orcutt procedure assuming that the error term follows first order autoregression (AR(1) process: subsequently we test it for AR(2) and AR(3) etc.).

$u_t=\rho u_{t-1}+\epsilon_t,\ \rho<1$

where ρ is coefficient of autocorrelation and u_t has no autocorrelation.

The eq. 6.13 is transformed as below:

$(\ln Y_t - \rho \ln Y_{t-1}) = \beta_0 (1-\rho) + \beta_1 (X_t - \rho X_{t-1}) + \epsilon_t$..eq. (6.14)

or

$Y_t^* = \beta_0^* + \beta_1^* X_t^* + \epsilon_t$..eq. (6.15)

where $\beta_0^*=\beta_0(1-\rho)$, $X_t^*=(X_t-\rho X_{t-1})$ and $Y_t^*=(Y_t-\rho Y_{t-1})$

It yields estimates that are asymptotically equivalent to the exact ML (maximum likelihood) estimators. The results are as below with t-value in parentheses:

$\ln Y^*=3.3081+0.080669 X_t^*$...eq. (6.16)

(75.4329) (31.8874)

R^2=0.99610 Adjusted R^2=0.99577 SE=0.039741 Maximum of log-likelihood=48.56 DW-statistic=1.3368, ρ=0.56859

In equation 6.13, β_1 is the slope coefficient and gives instantaneous[2] (at a point in time) inflation rate which is estimated as 0.080669 or 8.07%.

But the inflation rate over a period of time will be more meaningful for our study as we are interested to estimate a discount rate over a period of time. To estimate overall annual compound rate of inflation for the Indian economy, we formulate an alternative model as below:

$Y_t=Y_0(1+i)^{X_t}.e^{u_t}$ ....eq. (6.17)

Taking ln of eq. 6.17, we get,

$\ln Y_t=\ln Y_0+\ln(1+i)X_t+u_t$..eq. (6.18)

where Y_t is GDP deflator at time X_t, Y_0 is initial value of GDP deflator and *i* is inflation rate, *u* is stochastic error term and X_t is time trend.

If $\ln Y_0=\beta_0$, $\ln(1+i)=\beta_1$, the equation 6.18 can be written as:

$\ln Y=\beta_0+\beta_1X_t+u_t$..eq. (6.19)

Both equations 6.13 and 6.19 are the same. Therefore, the coefficient of time (i.e. β_1) estimated above (eq. 6.13 and eq. 6.16) can be used for eq. 6.18 also.

ln(1+i)= 0.080669, i=0.084012 or 8.4%

The average annual inflation rate for the referenced period is 8.4% and we assume, on the basis of rates given in Table A6.2.5 (Annexure 6.2), market rate of interest (nominal interest rate) as 19%.The discount rate in real terms can be given as below:

r=[{(1+m)/(1+i)} -1]

where *m* is money interest rate, *r* is real interest rate and *i* is inflation rate.

r=0.97786 or 9.8% or approx. 10%

Therefore, we take 10% discount rate in our financial analysis but we also test the impact of other discount rates on profitability of woodlots in sensitivity analysis.

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[2] $\beta_1=\dfrac{d\ln Y}{dX_t}$ or $\beta_1=\left(\dfrac{1}{Y}\right)\dfrac{dY}{dX_t}$, $=\dfrac{dY/y}{dX_t}$

i.e., relative change in GDP Deflator/absolute change in time

6.5.6 Results of financial appraisal (RDF)

Table 6.5 presents results of financial appraisal. NPV/ha in two districts viz. Gumla and Ranchi is quite high as compared to other districts. This is due to less incidence of illicit felling and better growth conditions (site quality and rainfall) in these areas. Out of the remaining four districts, E.Sighbhum and Garhwa show negative values for NPVs. The other profitability criteria also indicate the same results. All the calculations are based on the assumption that the distribution of illicit removals follows the model - WM-INA.

Table 6.5 Results of financial cost-benefit analysis (RDF)

	Profitability criteria		
	NPV/ha (Rs/ha)	IRR	BCR
Districts			
Gumla (GRS1)	33149	0.24	1.83
Ranchi (GRS2)	36662	0.25	1.89
Sahebganj (GRS3)	3844	0.13	1.15
E.Singhbhum (SGH1)	-6334	0.05	0.73
Garhwa (SGH2)	-9775	0.01	0.58
Hazaribagh (SGH3)	3445	0.12	1.12
Regions			
GRS	25156	0.22	1.70
SGH	-2843	0.08	0.89
All plots (N=18)	9825	0.16	1.32

Notes: 1. A discount rate of 10% is used.
2. Figures under different profitability criteria are weighted (according to the area of plantation) average of corresponding plots.

The range of IRR indicates that out of 18 woodlots only 4 woodlots show IRR of less than zero (Table 6.6). The estimated IRR of more than 16% in 8 woodlots can be considered quite satisfactory keeping in view the illicit felling incidence in these forests.

Table 6.6 Range of IRR in different regions (RDF)

Regions	Number of plots			
	IRR (range)			
	≤0	≤0.10	≤0.15	>0.16
GRS	0	1	1	7
SGH	4	2	2	1

6.5.7 Sensitivity analysis

A sensitivity analysis is undertaken to examine the effect of discount rate on profitability of RDF woodlots (Table 6.7). NPV and BCR are used as criteria. At the discount rate of 20%, only 3 woodlots are profitable. In RDF woodlots indirect costs are as high as 34.8%, 35.8% and 41.5% (of the total costs) in year 0 (advance work), year 1 (completion) and year 2 (maintenance) respectively. However, a reduction in indirect costs does not result in the marked increase in number of profitable woodlots (0% reduction in indirect cost, profitable plots, 8; 100% reduction in indirect cost, profitable plots, 9: Profitability criterion, NPV/ha; discount rate 0.15).

Table 6.7 Profitability of RDF woodlots under different discount rates

Regions	N	Profitability criteria	Number of plots			
			Discount rates			
			0%	10%	15%	20%
GRS	9	NPV>1	9	8	7	6
SGH	9	NPV>1	5	3	1	0
GRS	9	BCR<1	0	1	2	3
		BCR≥1	2	7	7	6
		BCR≥2	7	1	0	0
SGH	9	BCR<1	4	6	8	9
		BCR≥1	4	3	1	0
		BCR≥2	1	0	0	0

N=total number of plots

6.6 Financial appraisal of FF component: a case study

The primary aim of financial appraisal is to find out profitability of FF component but in FF farmers' participation is critical. Therefore, financial appraisal of FF component is undertaken with two perspectives, farmers' perspective and project's perspective. In project's perspective, all costs incurred whether by farmers or by the Forest Department are considered as the total project costs. In farmers' perspective, costs incurred by farmers only are considered as costs. Benefits in both the cases, however, go to farmers only.

6.6.1 Computation of costs

In FF component, plantations were raised in farmers' land. The details of cash and material given to farmers are presented in Table A6.2.6 (Annexure 6.2). It is assumed that farmers utilized all materials and cash in raising the plantations. A cash incentive for protection of plantations in the form of 'societal compensation' was also disbursed to farmers depending upon survival of plants after two years of plantation. All these costs are included in total costs of the project.

Plantations have not yet been harvested. Therefore, no data for harvesting costs in farmers' plot were available. The schedule of rates for harvesting (Table A6.2.7, Annexure 6.2) used by the forest department is found appropriate in the case of farmers' plot also. Transportation costs, however, are calculated on the basis of actual distance from the village to nearest state trading central depot as most farmers sell their produce in the forest department's depots.

6.6.2 Computation of benefits

Eucalyptus 'hybrid' and *Acacia auriculiformis* dominate the planting in farmers' plots because of their suitability to the site conditions and their resistance to grazing and browsing. Most of the farmers have not yet harvested their plantations. Therefore, the yields of FF woodlots were estimated using equations 4.3, 4.4 and 4.5. Some farmers have harvested a small number of trees for domestic use. But most of them were not able to tell the exact volume (or weight in case of fuelwood) and value of the harvested trees as harvested trees were used mainly for domestic consumption. The values of intermediate extractions were also estimated following the earlier described procedure. The estimation of survival in individual plots was not difficult as farmers knew very well the exact amount paid as societal compensation. Later, it was also verified from the government records. About 40% of the farmers had grown some fruit bearing species (<5% of the total plantation). The market price of different fruits were taken from the World Bank's Plateau Project document in absence of any reliable information.

FCBA is also undertaken from the farmers' perspective. The calculations are based on the assumption that farmers have not invested their own money for plantation. All the operations were completed from the cash and material received from the department. Only weeding costs (if any) were incurred by farmers. The expenditure on the protection of plantation by farmers were incurred in the first and second year but they had received societal compensation at the end of third year of planting.

6.6.3 Computations for real costs and real benefits

The real costs and benefits were calculated by adjusting the figures for costs and benefits for inflation. The cash flow for each plot is generated at constant price of 1993. NPV, NPV per ha, BCR and IRR are calculated taking 10% as a discount rate.

6.6.4 Results of financial appraisal (FF)

The region-wise and the district-wise results of FCBA are summarised in Table 6.8.

Table 6.8 Results of financial appraisal of FF: project perspective

		Profitability criteria		
	N	NPV/ha (Rs/ha)	IRR	BCR
Districts				
Gumla (GRS1)	12	9058	0.24	1.79
Ranchi (GRS2)	12	35463	NA	3.24
Sahebganj (GRS3)	12	-5761	-0.04	0.37
E.Singhbhum (SGH1)	12	20441	0.32	2.38
Garhwa (SGH2)	12	33954	0.47	3.22
Hazaribagh (SGH3)	12	23220	0.34	2.66
Regions				
GRS	36	9834	0.25	1.84
SGH	36	25797	0.37	2.76
Total all plots	72	16824	0.31	2.29

Notes: 1. A discount rate of 10% is used. 2. Average values for districts, regions and for all plots are calculated from pooled data of respective categories. 3. N=number of plots. NA= IRR could not be calculated.

The average NPV per ha is positive in five out of six sampled districts. Only one district Sahebganj shows negative NPV. This is because of very low survival rate in this district. Some plots have even registered 0% survival. SGH region shows higher profitability according to all the three criteria.

Table 6.9 shows results of financial IRR. It is observed that IRR in 25% of woodlots are zero or below zero and about 46% of plots have more than 26% IRR.

As expected all the woodlots except four were found to be profitable based on analysis from farmers' perspective at the discount rate of 10%. The results are summarised in table 6.10. All other tables in this case study are based on calculations from projects' perspective only, which is our primary concern in the present study.

Table 6.9 Range of IRR in different regions (FF)

Regions	Number of plots			
	IRR (range)			
	≤0	≤0.26	>0.26	NA
GRS	14	6	9	7
SGH	4	6	24	2

N=36 in both the regions, NA= IRR could not be calculated.

Table 6.10 Results of financial appraisal of FF: farmers' perspective

Regions	N	Profitability criteria	Number of plots		
			Discount rates		
			10%	15%	20%
GRS	36	NPV≤0	9	9	9
		NPV≤30000	14	19	24
		NPV≤60000	10	8	3
		NPV>60000	3	0	0
SGH	36	NPV≤0	0	0	0
		NPV≤30000	14	22	32
		NPV≤60000	19	14	4
		NPV>60000	3	0	0

6.6.5 Sensitivity analysis

A sensitivity analysis has been carried out to observe the effect of discount rate.

The results of financial NPV at various discount rates are presented in Table 6.11. At 20% discount rate about 39% woodlots become unprofitable. A significant observation is that even at 0% discount rate 25% woodlots are unprofitable. A possible reason may be the lack of attention by the farmers, with the reason for adoption of FF possibly being a pecuniary gain, rather than real intention to grow the trees. The scheme of Kissan nursery was an added advantage to some of these farmers as they had raised seedlings also for their own plantation from the project money.

Table 6.11 Profitability of FF woodlots under different discount rates

Regions	N	Profitability criteria (Rs/ha)	Number of plots			
			Discount rates			
			0%	10%	15%	20%
GRS	36	NPV≤0	14	16	17	19
		NPV≤30000	6	10	15	17
		NPV≤60000	4	8	4	0
		NPV>60000	2	2	0	0
SGH	36	NPV≤0	4	5	6	9
		NPV≤30000	6	12	24	27
		NPV≤60000	4	18	6	0
		NPV>60000	24	1	0	0

These results should be viewed in light of intra-regional variability in the outcome which we discuss in following paragraph. We will examine some of these aspects in chapter 8.

The findings of financial appraisal indicates that the variations (inter district and inter region) in profitability both in RDF and FF components are quite significant. Table 6.12 presents some indicators to show variability in FF and RDF component.

Table 6.12 Variations in per ha NPV (Rs/ha) in FF

	N	NPV per ha		
		SD	CV (%)	95% CI
FF				
GRS	36	23048	177	5216, 20813
SGH	36	20517	78	19220, 33104
All plots	72	22654	116	14265, 24912
RDF				
GRS	9	18180	74	10593, 38542
SGH	9	12715	219	-15573, 3975
All plots	18	21811	232	-1462, 20230

SD=standard deviation, CV=coefficient of variation, CI=confidence interval, Discount rate=0.1

6.7 Discussion and conclusions

The financial analysis of RDF and FF components reveals the following two main conclusions.

A. The financial outcome of both RDF and FF components is characterised by high variability, both inter-regionally and intra-regionally (Table 6.12).

B. The performance of the two components shows that RDF seems to be profitable in GRS region while FF seems to be relatively profitable in SGH region (Table 6.5 and Table 6.8).

Most afforestation projects have two main components - FF and RDF, and their role is perceived as complementary to each other. RDF is confined to the government forests while FF focuses on raising of plantations outside the boundaries of the government forests. Financial appraisal of FF and RDF components demonstrates that in districts where FF shows good profitability, RDF is marred by poor performance and vice versa, the exception being Ranchi district where both FF and RDF are moderately profitable. A possible explanation to this phenomenon is given as below:

(a) FF is successful in areas where agriculture is well developed because:

- Farmers require forest produce for their own domestic consumption and for sale in forest produce scarce region.
- FF serves as a labour saving option. Farmers can concentrate in terms of investment

and supervision in their more productive areas leaving marginal areas to farm forestry.

(b) RDF woodlots have better chances of success in areas rich in natural forests because:

- People prefer sal (*Shorea robusta*) poles as compared to *Eucalyptus* poles resulting in relatively less illicit felling in *Eucalyptus* plantation.
- Population density is also low in these areas as compared to areas where agriculture is well developed (population density (persons per km^2): Gumla, 150; Ranchi, 240; Sahebganj, 157; E.Sighbhum, 325; Garhwa, 187; Hazribagh, 190).

Therefore, it is unlikely that both FF and RDF component of the project will be successful in same area.

Ranchi district is unique in several respects e.g. (a) a well developed irrigation system(cropping intensity (gross cropped area/net sown area) being 120%), (b) high mean annual rainfall: 1454mm, 82.5 rainy days, (c) intensive cultivation of high value (and high risk also) vegetable crops and finally (d) being the headquarters of the Forest Department, Bihar, RDF woodlots get better supervision and protection as compared to other districts.

NPV per ha for pooled data and for the two regions (both for FF and RDF) are represented in the form of box-and-whisker plot (Fig. 6.3). The horizontal line in the middle of the box represents the median value, the upper and lower line of the box represents Q_3 (third quartile) and Q_1 (first quartile) respectively. The length of upper and lower whisker show the range of upper 25% and lower 25% values respectively.

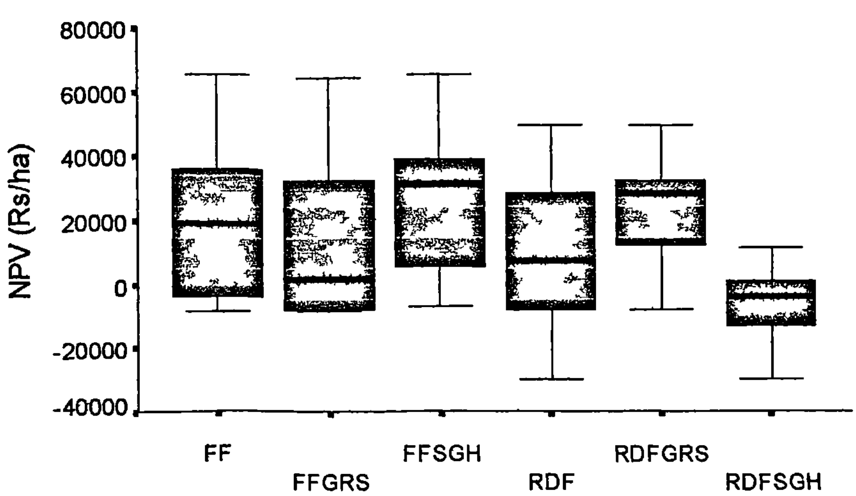

Fig. 6.3 Box and whisker plot showing range of outcome in FF (Region: FFGRS and FFSGH) and RDF (Region: RDFGRS and RDFSGH)

Considering the variations in outcome both in FF and RDF, it is difficult to arrive at a definitive conclusion about the profitability of the project in totality or even for individual components. The reasons for variations range from physical threat like illicit felling and biotic pressure to biological elements of variations like site conditions, genetic stock etc. The financial models of illicit felling attempt to find out an optimum strategy to maximize profitability and to minimize the uncertainty in outcome. Financial appraisal is an indispensable part for any project appraisal because all investment and estimates in government are based on market prices only. In subsequent chapters, we will examine profitability of these components from a broader perspective of the general welfare of the different sections of the society and to the economy as a whole.

Chapter 7

Economic Appraisal of Afforestation Projects

7.1 Role of projects in developing economy

India, like many other developing countries, has adopted a planned economy to achieve speedy economic growth with social justice. Planning has been one of India's important key policies since independence. Projects provide an important means by which investment envisaged in plans can be realized. Sound development plans require good projects and good projects are meaningless without sound planning (Gittinger, 1982). In developing countries resources available to the economy are scarce and the planners have to decide optimum use of limited resources among competing uses. Therefore, the economic appraisal of a project is of vital importance to assess projects' performance from a broader framework of the country's economy. The economic appraisal of a project takes the viewpoint of the whole economy as compared to financial appraisal (Chapter 6) which is taken from the point of view of the individual participants or the total project itself.

7.2 Economic cost-benefit analysis: an overview

The objective of ECBA (economic cost-benefit analysis) is to evaluate the project in terms of its contribution to the whole economy. Individual financial profitability from the point of view of the farmers and the investing agency are not considered. ECBA is concerned with the efficiency with which the project creates net utility. The efficiency is measured as willingness to pay for benefits and willingness to accept compensation for benefits forgone (Mishan, 1975).

In the economic appraisal, the market values of costs and benefits are suitably adjusted to represent their opportunity costs. The economic appraisal requires the following adjustment in financial value of costs and benefits.

- It involves valuation of non-market goods e.g., land, non-market benefits.
- All costs and benefits are adjusted to reflect their opportunity costs

- Subsidies and taxes are not considerd as they are simply transfer payments.
- Economic discoumt rate is used to reflect society's temporal preference for income.

ECBA is concerned with the efficiency with which a project creates net utility while SCBA (social cost-benefit analysis) considers efficiency and distribution together.

7.3 Economic Discount Rate

The selection of a suitable discount rate is the most controversial issue in the application of CBA for forestry project appraisals (Harou, 1985: Price, 1988) as the selection of discount rate affects viability and profitability of projects more than anything else. The economic reasons for discounting are widely debated. The Forestry Commission in the UK uses different discount rates for appraising different types (e.g. silviculture, plantation and harvesting) of projects. The arguments for and implications of discounting are discussed by Price (1973, 1993). The discount rate used in ECBA is the marginal productivity of capital in the public sector (Squire and Van der Tak, 1975). The market interest rate reflects the opportunity cost of investments and can be used for determining economic discount rate but it is extremely difficult to find out a single market rate of interest for India. It varies from 15% to 22% (nominal) depending on the lending agency and borrower. Generally the poorest people borrow at the highest rate of interest. The stock returns also do not reflect the true returns because of various controls in the economy. The funds for social forestry projects are drawn from investment funds. So the rate of return to government investment measures opportunity cost of capital.Economic Discount Rate for project appraisals in developing countries is taken in the range of 8% and 12% (in real terms) (ODA, 1988). Gittinger (1982) has suggested 12% for most projects. The discount rates used by various bilateral and multilateral agencies for social forestry project appraisals in India vary between 10% and 12% (real) (World Bank, 1985; ODA, 1992).

7.4 Estimation of economic discount rate

There are two main approaches used in estimation of discount rate.

(a) the social opportunity cost of investment (SOC), and

(b) social time preference (STP).

The SOC (or economic discount rate) measures the value to the society of the next best alternative investment. The STP measures the society's trade off for present consumption in order to improve future consumption.

In this section, we examines different methods of estimation of an economic discount rate (EDR) for the afforestation project appraisal and attempt to derive objective estimates of EDR.

7.4.1 The data

The data used in this study come from secondary sources. The preparation of national accounts statistics in India is undertaken by the Central Statistical Organisation (CSO), Ministry of Planning, New Delhi. The CSO follows the classifications and definitions recommended in the United Nations System of National Accounts (SNA). The main sources of data are International Monetary Fund's (IMF) International Financial Statistics (IFS) and Government Finance Statistics Yearbook (GFSY), United Nations' (UN) National Accounts Statistics: main aggregates and detailed tables (NAS) and Economic Survey by the Government of India (GOI). The problem in using these data is that sometimes they are not consistent, for instance IFS, Oct., 1988 gives India's Gross National Product (GNP at current prices) for the year 1986 as Rs 2913.6 billion (10^9) while IFS Dec. 1993 gives Rs 2911.4 billion for the same year. The data acquired from different sources also show some variations. To overcome this problem, the data given in the latest published source are assumed to be correct and we attempt to use the complete data set for a particular model from the same data source. The period of time series is selected to minimize any manipulation of data. All the estimates (except population) relate to fiscal years beginning 1 April. Population figures are midyear (30 June) estimates.

There are various approaches to estimate opportunity cost of capital or opportunity cost of investment funds. The EDR can be estimated using either microeconomic or macroeconomic data. The methods suggested so far include production function estimation (both static and dynamic) , incremental capital output ratios (ICOR) determination, growth models, analysis of market rates of interest, national plan objectives, cost of borrowing from external and internal sources (Adhikari, 1987; Trivedi, 1987). The average or weighted average returns to the investment of a number of successful and unsuccessful projects can also be examined to arrive at a suitable EDR for proposed projects.

7.4.2 Production Function Approach

The marginal product of capital is difficult to estimate because of:

(a) obscurity regarding the concept of capital and,

(b) lack of statistics about the total capital stock itself for India.

None of the national and international level data sources gives the estimate of a total quantum of capital stock. However, some estimates by non-government agencies are available, but they cannot be used because of under-estimation of some components of capital stock (Pant, 1984).

The following Cobb-Douglas production function is used for the estimation of a marginal product of capital.

$$Y = AK^{\beta_1}L^{\beta_2}e^{u} \qquad \text{eq. (7.1)}$$

where Y is the output, K is capital, L is labour, A is constant, β_1 is the elasticity of Y with respect to K, β_2 is the elasticity of Y with respect to L and u is a stochastic disturbance term.

On assuming the elasticity of substitution for the above model is constant and unity, i.e. $\beta_1 + \beta_2 = 1$, eq. (7.1) can be written in the following form.

$$Y = AK^{\beta_1}L^{1-\beta_1}e^{u} \qquad \text{eq. (7.2)}$$

On dividing both sides by L and after log transformation the function can be written in the log-linear model as;

$$\ln(Y/L) = \ln A + \beta_1 \ln(K/L) + u \qquad \text{or}$$

$$\ln(Y/L) = \beta_0 + \beta_1 \ln(K/L) + u \qquad \text{eq. (7.3)}$$

where $\beta_0 = \ln A$

For the analysis of the whole economy, we take Y, K and L as gross domestic product (GDP), the gross capital stock (K) and the economically active population (EAP) respectively. The following equation for estimation of a marginal product of capital (q) can be obtained by partial differentiation of the eq. (7.2) with respect to K.

$$q = \partial Y/\partial K = \beta_1 (Y/K) \qquad \text{eq. (7.4)}$$

The data for the total population for each year were obtained from IMF (1995). The ratio of total workers (main and marginal workers) to the total population was calculated from the data given in Mukhopadhyay (1994) and GOI (1993) which are 0.367 and 0.3746 for the periods 1971-1981 and 1982-1992 respectively. The EAP is obtained by multiplying the above ratio by the total population of respective years. The estimation of work participation in the 1981 census and the 1991 census are comparable but the

1971 census follows the 'secondary worker' concept (Mathur, 1994). Some of earlier studies (e.g. Trivedi, 1987 and Sharma, 1991) are based on the assumption that the labour force remains static over time which is obviously not correct. To estimate capital (K) the figure for annual capital formation is compiled at constant prices (1980 price) for the period 1965 to 1988. The initial figure or benchmark capital is determined by finding out the amount which, on addition to the series (cumulative series of capital formation), gives the best fit of the eq. (7.3) with the highest R-Square. The justification for finding the benchmark lies in the argument that one has to measure the capital input which corresponds as closely as possible to the capital output it produces (Trivedi, 1987). The benchmark capital is estimated as Rs 2876 billion at 1980 price. The regression results are as below with t-ratio in the parenthesis:

$$\ln(Y/L) = -0.70017 + 0.76159 \ln(K/L) \quad \text{............eq. (7.5)}$$

$$(-5.9892) \qquad (20.3718)$$

S.E.=0.035951 R-Squared =0.94966 DW-Statistics =1.3494 n=24

The model has no heteroscedasticity in the error variance ($F=0.0644 > F_{(1,\ 22)}$, 0.802, $P<0.01$). The value of β_1 is estimated as 0.76159. The value of β_2 $(1-\beta_1)$ will be 0.23841. The production function can be written as:

$$Y = 0.4965 K^{0.76159} L^{0.23841} \quad \text{............eq. (7.6)}$$

where, $\ln A = \beta_0$ $\beta_0 = -0.70017$

The marginal product of capital is obtained by substituting the value of β_1 into the eq.(7.4)

$$q = 0.76159(Y/K)$$

The average value of a marginal product of capital (q) is 0.17998 (CV=6.00%; 95% CI of mean, 0.1754, 0.1846) (Annexure 7.1, Table A7.1.1). Therefore, an economic discount rate (EDR) for India is approximately 18%.

7.4.2.1 Constant returns to scale

The above estimation is based on our earlier assumption of constant returns to scale (i.e. $\beta_1 + \beta_2 = 1$). Now, we proceed to test this assumption by making three different restrictions in the original form. This is essential for validation of our function because many developing economies are showing increasing returns to scale. For the purpose of testing constant returns to scale, we formulate restricted models and then test the improvement of fit. The details of test procedure are given in Appendix 7.1. All the tests indicate that it is correct to assume constant returns to scale.

7.4.3 Dynamic Production Function

The static production function (as described above) is not able to capture improvements in technology. The output is likely to be affected by technological development. To capture this effect, it is common to include a time trend referred to as the technological coefficient (ψ) in the model. Time can be used as a proxy for technological progress. Both exponential ($e^{\psi t}$) and linear (t^{ψ}) forms are tested. A linear time trend gives meaningful results. The function can be written as

$$Y = AK^{\beta_1}L^{\beta_2}t^{\psi}e^{\epsilon}$$

By taking logarithms and dividing both sides by L, we get:

$$\ln(Y/L)=\beta_0+\beta_1\ln(K/L)+\psi\ln t+\epsilon$$

where $\beta_0=\ln A$. Y, K, L and t are gross domestic product (GDP), the gross capital stock (K), the economically active population (EAP) and a time trend respectively. ϵ is an error term.

The following best fit for this model is obtained by multiple regression analysis (time series data 1965-1988, Annexure 7.1 Table 7.1.1). The t-ratio is given in parentheses:

$$\ln(Y/L)= -0.68826+ 0.75689 \ln(K/L) + 0.0012193\ln t \quad \text{.......eq. (7.7)}$$

(-2.4819) (7.1384) (0.04763)

S.E.=0.036795 R-Squared =0.94966 DW-Statistics =1.3510 n=24

The error terms are independent. The model has no heteroscedasticity in the error variance (P<0.01). The VIF (variance inflation factor=7.678) and 'tolerance' (=0.1302) shows no sign of multicollinearity. The value of β_1 is estimated as 0.75689. The value of ψ is positive that shows technological progress. Since, the value of ψ (0.0012193) is very small, β_2 can be approximated as 1- β_1. The value of β_2 will be 0.24311. The production function can be written as:

$$Y=0.5024K^{0.75689}L^{0.24311}$$

where $\beta_0=\ln A$ β_0 =-0.68826

The marginal product of capital is obtained by substituting the value of β_1 into the eq. (7.4).

$$q=0.75689(Y/K)$$

The average value of a marginal product of capital (q) is 0.17887 (coefficient of variance, CV=5.98%; 95% CI of mean, 0.1743, 0.1834) (Annexure 7.1, Table A7.1.11). Therefore, an economic discount rate (EDR) for India is approximately 18%.

Now, we test the significance of the addition of the time trend variable. The coefficient for time is not significant in the eq. (7.7) even at 10% significance level. The R^2 is exactly the same (=0.94966) in both the models (eq. 7.5 and eq. 7.7). The adjusted R^2 for the models are 0.94737 (eq. 7.5) and 0.94487 (eq. 7.7) suggesting the inclusion of time variable is not significant at least for this data set. The significance can be tested formally using F statistic (or t statistic as $F=t^2$):

$$F=\frac{\{ESS_{tt}-ESS_{wtt}\}/(n)}{RSS_{tt}/(N-k)} \quad \text{.......eq.(7.8)}$$

where ESS_{tt} and ESS_{wtt} are the sum of squares due to regression, with time trend model (tt, i.e., eq. 7.7) and without time trend model (wtt, i.e., eq. 7.5). RSS_{tt} is the sum of squares due to residuals of time trend model. N, n and k are number of observations, number of regressors in tt model and number of parameters in tt model respectively. On putting the respective values in the eq. (7.8), we get the F statistic as 0.0077 which is less than critical value ($P<0.05$). So we can conclude that addition of the time trend in the model is not significant. Sharma (1991) had also used a dynamic production function for estimation of EDR taking an exponential form of time trend. The time variable was not significant in his study and R^2 was in fact, reduced from 85.0% (model without a time trend) to 84.9% (model with a time trend) by the inclusion of a time variable in the model.

7.4.4 Incremental Capital Output Ratio

The incremental capital output ratio adjusted for contribution of labour gives an approximation of opportunity cost of capital or investment (Squire and Van der Tak, 1975). The main advantage in this approach is that ICOR can be calculated directly from national income statistics and it does not require estimation of capital stock. The implicit incremental capital output ratio (ICOR) is the ratio of the investment rate (ratio of the development expenditure to the GDP) to the growth rate (rate of growth of GDP) of the economy. It can be expressed as:

$$ICOR_t=I_t/\Delta Y_t=[I_t/Y_t][\Delta Y_t/Y_t]^{-1} \quad \text{.......eq. (7.9)}$$

where I_t is investment in year t and ΔY_t is the increase in output in year t. $[I_t/Y_t]$ is the current investment output ratio and $[\Delta Y_t/Y_t]$ is the rate of growth of output.

The ICOR for the year 1951-1991 is given in the Table 7.1 which shows wide fluctuations. It is expected because the agriculture sector contributes a sizeable portion of GDP of India although the share of agriculture sector in total GDP of India has decreased from 56% in the year 1950-51 to 33% in the year 1990-91. The dependency of agriculture on monsoon and contribution of agriculture towards GDP, cause these wide fluctuations.

Table 7.1 Growth Rate of GDP (at factor cost), Savings, Investments and ICOR

Year	GDP(%)	Savings(%)	Investment(%)	ICOR
1951-56	3.61	10.28	10.66	2.96
1956-61	4.27	11.73	14.52	3.50
1961-66	2.84	13.21	15.45	5.44
1966-71	4.66	14.35	15.99	3.43
1971-76	3.08	17.27	17.87	5.80
1976-81	3.24	21.65	21.47	6.63
1981-86	5.06	19.36	20.98	4.15
1985-90	5.81	20.37	22.70	3.91
1985-92	5.31	20.70	23.17	4.36

Source: GOI, 1992

The equation (eq. 7.9) can be also written as:

$$1/\,ICOR=(Y_1-Y_0)/I_0 = \Delta\, Y_1/\Delta\, K_0$$

where Y_1, Y_0, I_0 and K_0 are output in year 1, output in year 0, investment in year 0 and capital in year 0 respectively. Investment in year 0, i.e. I_0 can be approximated to $\Delta\, K_0$ (change in capital). The correlation between ΔY_t (increment in output in year t) and ΔK_{t-1} (capital formation in the year t-1) can be used to estimate ICOR (Phillips, 1986). Trivedi (1987) has used ΔK_{t-x} (time lags up to 12 years) to arrive at a consistent (least standard deviation) estimate of dY/dK but by increasing time lags we lose a corresponding number of observations and therefore, it may yield consistent results, because of working on fewer observations rather than because of any real lag relations. These methods have several drawbacks listed by Price (1993). The approach adopted in this study eliminates some of the shortcomings of the earlier approaches as ICOR is used to estimate benchmark capital only. The lagged effect from capital formation is also tested using an infinite lagged model in the form:

$Y_t = \beta_0 + \beta_1 X_t + \beta_2 X_{t-1} + \beta_3 X_{t-2} + \beta_4 X_{t-3} + ... + u_t$ with appropriate transformation (Koyck transformation) to eliminate the problem of multicollinearity. Labour's share has to be excluded to find true opportunity cost of capital (Irvin, 1984; UNIDO, 1978).The proposed model for estimation of marginal productivity of capital can be written in the form:

$Y_t = \beta_0 + \beta_1 X_t + u_t$ .... eq. (7.10)

where Y_t and X_t are GDP and capital. u_t is an error term.

The time series data (1965-1988) are used for estimation of the coefficients of eq. (7.10). The DW statistic shows the problem of serial correlation. We assume the error term (u_t) follows first order autoregression (AR(1)), (subsequently, we test it for AR(2), AR(3) etc.), i.e.

$u_t = \rho u_{t-1} + \epsilon_t, \quad \rho<1$

where ρ is coefficient of autocorrelation and ϵ_t has no autocorrelation.

The eq. (7.10) is transformed according to the Cochrane-Orcutt procedure as below:

$(Y_t - \rho Y_{t-1}) = \beta_0(1-\rho) + \beta_1(X_t - \rho X_{t-1}) + \epsilon_t$ .... eq. (7.11)

or $\quad Y_t^* = \beta_0^* + \beta_1^* X_t^* + \epsilon_t$

where $\beta_0^* = \beta_0(1-\rho)$, $X_t^* = (X_t - \rho X_{t-1})$ and $Y_t^* = (Y_t - \rho Y_{t-1})$

This transformation results in loss of the first observation. This can be avoided using the Prais-Winsten transformation $(Y_1(1-\rho^2)^{1/2};\ X(1-\rho^2)^{1/2})$. The loss of one observation may not be of much effect for large time series. The capital stock for the year 1964 is calculated by multiplying GDP by ICOR (ICOR for the period 1961-66; Table 7.1). This method can give only an approximate value of the capital stock. This is used in the absence of reliable estimates of the capital stock of India. Then, we generate the whole time series (K_R; Annexure 7.1, Table A7.1.1) by adding the net capital formation in previous years' capital stock. The results of the regression (eq. 7.11) are as below with t-ratio in parenthesis:

$Y_t^* = -164.3201 + 0.20716 X_t^* + \epsilon_t$

(-2.8996) (26.8648)

S.E.=43.6542 R-Squared =0.98849 DW-Statistics =1.7974 n=24

So, the marginal productivity is 0.20716. We have already estimated capital's share as 0.76159 (eq. 7.6). The adjusted (for labour) Incremental Output Capital Ratio (IOCR, i.e. 1/ICOR) will be: IOCR=0.20716 × 0.76159=0.1577 or 15.77%. Therefore, an economic discount rate (EDR) for India is approximately 16%.

The IOCR adjusted for labour's share can also be estimated directly using data from Table 7.1. The average ICOR value for the period 1961-1992 is 4.83. The adjusted IOCR will be: IOCR=(1/4.83) x 0.76159=0.1576 or 15.76%.

7.4.5 Growth models

The growth model approach is used by Rao (1983), Kumar (1988) and Sharma (1990) for estimation of EDR. A fully articulated economic growth model requires us to specify functions relating to the labour, saving, investment, production, technical progress, distribution of income etc. (Hahn and Matthews, 1964) but our choice of model is constrained by the inadequate data base. The present study differs from the above-mentioned studies mainly in methodology for estimation of marginal propensity to save. We use an autoregressive consumption model. This method is also free from some of the shortcomings of earlier methods which require estimation of capital stock of the economy. The annual net output (Y_t) can be written in the Harrod-Domar model form (for a particular year t, the capital K_t combines with other resource, including labour, and produces net output Y_t) as (Kogiku, 1968):

$$Y_t = A_t . K_t$$

where, A_t is net output to net capital ratio.

It shows net output is directly proportional to capital invested. If out of total net annual output Y_t, some proportion (i.e., s) is saved and reinvested to generate a new capital stock K_{t+1} in the year t+1, the function can be written as:

$$K_{t+1} = K_t + sY_t$$

where s is the marginal propensity to save.

We assume that capital is the only variable (with t) and other inputs of production are constant. The net product from a new capital asset can be given as:

$Y_{t+1} = Y_t + qsY_t$ or after including intercept β_0

$$Y_{t+1} = \beta_0 + (1+qs)Y_t \quad \text{.........eq. (7.12)}$$

The term qs is the proportion of marginal product which is saved and, in fact, it is productivity of savings. The model will be used for autoregression analysis of NDP (Net Domestic Product) lagged by one year with only capital changing. The land input is assumed to be constant as there will not be much change in land, and change in labour input will be adjusted suitably. This model does not take account of technological progress explicitly but since the model is autoregressive, it can take account of time dependent changes. To estimate the value of 1+qs, we generate the time series of NDP in real terms and for constant labour. The NDP of individual years is calculated by subtracting CFC (consumption of fixed capital=gross national product-net national product) from GDP. The NDP series at current price (NDP_C) is converted to that at constant price of 1980 (NDP_T) using appropriate deflators for respective years. Since NDP at constant labour (i.e. only change in capital) for India is not available in any of the national or international data sources, we assume that private consumption expenditure (PCE) is the payment for labour. The PCE current price time series is converted to that at constant price (1980 price) and the difference in PCE (ΔPCE) for individual years is calculated from year 1 (1965 as base year). ΔPCE of individual years is deducted from NDP_T to arrive at the estimates of NDP_{TL} (NDP at constant price and constant labour) (Annexure 7.1, Table A7.1.2). The best fit model for the eq. 7.12 is as below:

$$Y_{t+1}=7.3646+1.0198Y_t \quad \text{eq. (7.13)}$$

(0.128) (16.853)

S.E=46.3399 R-Squared =0.92811 DW-Statistics =2.2316 n=24

Now, we proceed to estimate marginal propensity to save (s). The savings for individual years are calculated by subtracting total consumption (government consumption+private consumption) of respective years from GNP of that year. The marginal propensity to save is calculated for each year by taking incremental difference of savings to that of GNP (i.e. s=ΔSavings/ΔGNP). The average value of marginal propensity to save is 0.2056 (Annexure 7.1, Table A7.1.3). The average value for marginal propensity to consume will be, 0.7954 (1-0.2056). The simple econometric model ($S=\alpha+sY$) based on regression of savings (S) on GNP (Y) is used in estimation of marginal propensity to save (Kumar, 1988). This type of model is too simple to interpret the real situation because it cannot capture the long term aspect of savings. A dynamic model in the form of a distributed-lag model or autoregressive model is required to explain the time path of the variable because the dependence of savings on GNP may not be instantaneous. The lapse time for response has to be considered to estimate the marginal propensity to save. We formulate the model for estimation of marginal propensity to consume and then calculate the marginal propensity to save. The model (eq. 7.14) is based on the assumption that consumption is linearly related to permanent income. This is basically the adaptive expectations (AE) or progressive expectations hypothesis. It means that instantaneous increases in income will not be consumed immediately. On the other hand, the rational expectations (RE) hypothesis assumes that individual economic agents do not purely decide on past experience, and current available information is equally important. The model (AE) can be written in the following form:

$C_t=\delta\beta_0+\delta\beta_1Y_t+(_1-\delta)C_{t-1}+u_t-(1-\delta)u_{t-1}$ or

$C_t=\hat{\alpha}_0+\hat{\alpha}_1Y_t+\hat{\alpha}_2C_{t-1}+\hat{\varepsilon}_t$ ....eq. (7.14)

where $\hat{\alpha}_0=\delta\beta_0$; $\hat{\alpha}_1=\delta\beta_1$; $\hat{\alpha}_2=(_1-\delta)$, and $\hat{\varepsilon}_t=[u_t-(1-\delta)u_{t-1}]$

C_t is consumption in the year t, C_{t-1} is consumption in the year t-1 and Y_t is GNP in the year t. The time series viz. C_t, C_{t-1} and Y_t, are tested for stationarity. All the series are found stationary following unit root tests (τ statistics, Dickey-Fuller and augmented Dickey-Fuller (ADF(1)) tests, Dickey and Fuller, 1981). This test is important because generally national level time series data show a 'random walk' and this may result in spurious regression. If these types of time series are nonstationary and are cointegrated, it will not result in spurious regression (Engle and Granger, 1987). We can use error correction models (ECMs) for nonstationary time series showing presence of stochastic trends.

The regression results are as below:

$C_t=17.4616+0.66899Y_t+0.17067C_{t-1}$

(1.8396) (7.2907) (1.2781)

S.E.=25.8022 R-Squared =0.99914 DW-Statistics =1.9419 n=23

The marginal propensity to consume can be calculated as $\beta_1=\hat{\alpha}_1/1-\hat{\alpha}2$, i.e. 0.8067. Therefore, the marginal propensity to save (s) will be 0.1933 ($1-\beta_1$).

The major problem in this model is detection of autocorrelation because the usual Durbin-Watson d statistic is not applicable. However h-statistic (Durbin, 1970) can be used.

$$h=\hat{\rho}\sqrt{\frac{N}{1-N[var(\hat{\alpha}_2)]}} \quad \text{...} eq.(7.15)$$

$$\hat{\rho}=1-\frac{1}{2}d$$

where N is number of observations, d is the usual DW statistic, $var(\hat{\alpha}_2)$ is the variance of the lagged dependent variable. On substituting the value of $\hat{\alpha}_2$ (0.017836), N (23) and d (1.9419) in the eq. (7.15), we get the value of h as 0.1833. Since h=0.1833 is between ±1.96 ($P<0.05$), we do not reject the null hypothesis (H_0: no positive or negative AR(1)).

EDR is calculated as below:

1+qs=1.0198 (from eq. 7.13) and s=0.1933 calculated above, EDR will be 10.24%.

7.4.5.1 Non-linear consumption model

The model (eq. 7.14 or simply $C_t=\alpha + \beta Y_t + \epsilon_t$) is a restricted form of the general consumption model assuming $\gamma=1$. A nonlinear form can be written as:

$$C_t=\alpha + \beta(Y_t)^{\gamma} + \epsilon_t$$

The marginal propensity to consume (MPC) can be given as:

$$MPC=dC_t/dY_t=\beta\gamma(Y_t)^{\gamma -1}$$

Here, the value of MPC varies according to the value of Y_t.

An asymptotic test ($Z=(\gamma-1)/S.E.$ of γ) based on standard normal distribution is carried out to test the hypothesis that γ is different from 1. Since, $Z=-0.3319<Z_{crit.}=1.96$, $P<0.05$, we reject the nonlinear model in favour of the linear model.

7.4.6 Market Interest Rates

In most developing countries including India, commercial banks and government financial institutions play a dominant role as a source of funds both for working capital and long term fixed capital formation. The interest rate on advances of schedule and commercial banks in India was 11.5 to 17% (nominal) in 1992 depending on the size of credit and the sector (priority or others) (GOI, 1993). As a consequence of the government control, like in many other developing countries, both on interest rate and cash reserve ratios (CRR), an unorganised or 'informal' money market has developed in India where borrowing and lending rates tend to be determined by respective markets. The interest rates in informal rural credit markets were around 22% (nominal) in 1981 (Montiel et al. 1993). All India debt and investment survey (AIDIS) shows that the share of 'informal' (or non-institutional) source of credit declined from 92.8% (of total rural credit) in 1951 to 38.8% in 1981 (Gothoskar, 1988). These figures are before economic liberalisation. Interest rates in the informal markets now exhibit a declining trend and will be comparable to those of the formal sector. Only then, the market interest rates will demonstrate the real opportunity cost of investment fund and can be objectively converted to a single EDR.

7.4.7 Discussion

The use of an appropriate discount rate for forestry project appraisals is a widely discussed issue. The estimated values of EDR using different approaches attempted in the present study are summarised in the Table 7.2.

Table 7.2 Estimates of EDR for India (time series: 1965-1988)

Method	EDR (%)
Production Function	17.99
Dynamic Production Function	17.89
Incremental Output Capital Ratio	15.77
Incremental Output Capital Ratio (1962-92)	15.76
Growth Model	10.24

The suitable application of the above discussed methods for estimation of EDR largely depends on availability of data required for a particular model. Apart from data the other most important aspect in estimation of EDR is employment of suitable econometric methods. The statistical problems commonly associated with time series national data like stationarity, serial correlation etc. are to be appropriately tackled to arrive at an unbiased estimate of EDR. The production function approach gives a higher value probably because of the underestimation of capital. The Cobb-Douglas production function is based on conventional growth theory. It means output increases because of either capital increases or labour increases, or because current technology improves. Scott (1976) argues that rate of increase in income depends only on total savings and growth in labour force and there is no influence of independent technical progress. The other problem is the estimation of capital stock itself, which comprises both organised sectors (transport, communications etc.) and non organised sectors (informal markets etc.), and their aggregation to arrive at a single figure. The ICOR method can be useful in estimation of EDR but estimation of labour's share for the Indian economy is difficult. The total wage bill can be assumed to be the approximate share of labour. The marginal efficiency of investment decreases as the magnitude of investment increases because initial investment goes to the best available opportunities that yield the highest rate of returns.

The growth model is free from some of the shortcomings of the above described models but it assumes the monopoly power and risk neutrality of public sectors. The estimated value of EDR using the growth model is fairly close to the interest rates applicable in Indian economy. These range from 0.10 to 0.175 (nominal) (RBI, 1988; GOI, 1993).

The growth model gives plausible results and is free from the problem of inadequate data base. On this basis, we can recommend that the value EDR should be 10.2% (real) for social forestry projects' appraisal in India. Despite several theoretical and practical problems in estimating EDR, an objective estimate is required not only for comparing social forestry projects with other land use projects but also selecting different management options within social forestry projects. The EDR derived in the present study can serve the purpose (Shukla, 1997).

7.5 Economic pricing in ECBA

In economic appraisal, goods are valued in terms of their contribution to the economy. Economic prices are also called efficiency prices or shadow prices. The economic prices in competitive markets are determined by the demand and supply mechanism. But market prices do not reflect economic value due to distortion in domestic and international markets.

If the good is an export good, then its economic price is the f.o.b (free on board) price i.e. the price of the good at the port of the exporting country. For an import good, the economic price is c.i.f (cost, insurance and freight) price i.e. price at the port of importing country. Taxes to curb unwarranted imports and subsidies to boost export are not considered in economic prices as they are simply transfer of payments which are neither loss or gain to the economy. For non-traded goods, the economic price would be the marginal cost of production. If there is no distortion of the market, the market price reflecting the consumers' willingness to pay, is a good estimate of the economic price. A detailed discussion on shadow pricing has been given in Chapter 3.

7.5.1 Shadow pricing of land

Land used in raising woodlots is valued in terms of its alternative use. We first consider the case of potential agricultural land earmarked for tree growing, and then examine land which has no agricultural potential. The economic value of land depends on its opportunity cost i.e. the net value of production forgone when the land is put for alternative use. If agricultural land is to be set aside for tree-growing, its economic value would be in accordance with the agricultural output forgone. If the land used for tree growing has no alternative use, its opportunity cost may be taken as zero - both from the farmer and economic points of view. The economic value of land will be reflected in price of land in a perfect competitive market. But in India, the market price of agriculture land does not reflect its true value because:

(a) land is not frequently sold or purchased

(b) land is associated with a feeling of security by farmers which may push its price (security premium) well above its opportunity cost.

In the absence of a competitive functioning market for land sale, a rental value of the land is a good indicator of its true value. In the study region of Bihar, though there is no competitive rental market, the principles of share cropping (owner of land takes half the produce as rent and he does not invest anything for crop growing) are well established. The rent varies depending upon crop grown.

In Farm Forestry (henceforth, FF) component, most of the farmers have grown tree crops in their fallow lands. These fallow lands were used as common grazing land and are unsuitable for agriculture because of low productivity. The usage of these lands as common grazing grounds has further deteriorated their productivity due to frequent and uncontrolled grazing. Hence, the benefits from these lands would be negligible. Therefore, the opportunity cost of these land is estimated as zero. The second category of farmers were absentee landlords. Their average (of past four to five years) annual returns (at constant price of 1985) from share cropping were calculated and the present value is estimated using equation 7.16.

$$P=A\frac{(1+r)^n-1}{r(1+r)^n} \quad \text{..........} \quad eq.(7.16)$$

where *P* is the present worth of an annuity factor, *A* is annual return, *n* is rotation length of FF woodlot and *r* is economic discount rate.

For NPV_{∞} calculations, P can be calculated as P= A / r.

In LM methodology, the present value is multiplied by the standard conversion factor to allow for the foreign exchange premium. But it is not required in the present study (UNIDO methodology).

The third category of farmers (< than 5 % of total sample) are those farmers who have diverted their land from agriculture to tree-growing. In this case, the estimate of the value of production forgone for adopting farm forestry is required. This can simply be estimated by deducting all costs from all benefits both taken at market price. The value can be taken as the opportunity costs of land in financial terms. This can be converted into economic terms by taking the economic value of each of the inputs and outputs (including labour). The annual return is expressed in present worth (eq. 7.16) and added in to the cost stream. An example for calculation is given in Table A7.2.1 (Annexure 7.2). A production function approach would provide a more accurate estimate of the output (Gittinger, 1982).

In the present study, the main crops grown by the farmers were fodder crops and coarse grains (khesari). The produce from these crops are consumed locally. Therefore, their economic price is assumed as the same as the market price. For the labour component, shadow wage rate is estimated according to the procedure given in the next section. The data for the agricultural input component were taken from Plateau Agricultural Development Project as farmers were not able to recall the exact input for their crops. Therefore, the production function approach for valuation of output could not be adopted.

The shadow pricing of land is not required in most forestry projects taken up in forest land. CBA should simply assess net economic benefit from alternative land-uses (Price, 1989). In India generally forest land cannot be diverted for non-forestry purposes (Forest Conservation Act.,1980). Therefore, there is no opportunity cost of the land used other than that of alternative forestry uses. In the Rehabilitation of Degraded Forests (RDF) component, the plantation is taken up in small patches (> 0.4 ha) in existing forest areas. These areas are already degraded and they were used as common grazing lands before the project. It can be assumed that such land would have provided only negligible alternative use in the absence of the project. Therefore the opportunity cost of land is taken as zero.

7.5.2 Shadow pricing of labour

Shadow price of labour or shadow wage rate (SWR) is measured in terms of the opportunity cost of labour i.e., the marginal value product forgone elsewhere in the economy by employing labour in the project. The wage rate of labour in a perfect competitive market would be determined by its marginal value product (Gittinger, 1982). But wage rates paid to labour do not represent their actual value because of

(a) widespread unemployment and underemployment, and,

(b) enforcement of the Minimum Wages Act.

Both in FF and RDF the labour's share can be divided into two components - skilled and unskilled. The skilled labour (mainly department staff) are in short supply and their wages reflect their opportunity costs. This is based on the fact that these skilled workers would be fully employed even without the project. But there is severe unemployment and under-employment in the case of unskilled labour as they are largely dependent on seasonal employment in agriculture. In afforestation projects most of the works are carried out in the agricultural off-season when there is no shortage of labour. Only the planting operation is carried out in the rainy season. It coincides with the agricultural peak season. The agricultural wages of the peak season can be taken as the opportunity cost of scarce labour.

7.5.2.1 SWR on the basis of scarce and surplus labour (SWR_{SS})

The total labour force is divided into scarce labour and surplus labour depending upon seasonal requirement of labour in the afforestation project. All the operations (survey, fencing, nursery, soil work etc) in zero year (Table A7.2.2 and A7.2.3; Annexure 7.2) were carried out in the agricultural off season. Therefore, it is assumed that surplus labour would have been used for completion of these works. The planting operation is assumed to be carried out by scarce labour as the timing of planting concides with the agricultural peak season. This approach is used to estimate shadow wage rate separately for plantation and harvesting activity both for FF and RDF (Table A7.2.4 and A7.2.5, Annexure 7.2).

7.5.2.2 SWR on the basis off season and peak season wage rate (SWR_{op})

The market wage rate in the agricultural peak season (June, July, August and September) is high as compared to the off season rate. The market wage rates represent opportunity cost of labour. But to get an aggregate figure market wage rate both in peak season and off season are to be weighted according to employment generation in respective seasons through the afforestation project. The average market wage rate (of six districts) at constant price is estimated to calculate average peak season and average off season rate (Table A7.2.6 Annexure 7.2). The rest of the months are grouped into agricultural off season. It is estimated that in the afforestation project 31.28% of the total labour was employed in peak season (68.72% in off season). SWR_{OP} can be given as:

$$SWR_{OP}=\frac{(WR_P.E_P+WR_O.E_O)}{WR_A}\text{..}eq.(7.17)$$

where, WR_P is wage rate in the peak season, WR_O is wage rate in the off season, E_P is employment in the peak season, E_O is employment in off season and WR_A is average wage rate.

The SWR_{OP} for planting activity will be:

[(34.24 × 0.3128)+(22.02 × 0.6872)]/28.13 =0.85072 or 0.85

This method does not give accurate results because:

(a) our sample is restricted to wage rates of only one year

(b) peak season and off season market wage rates are influenced by a number of employment guarantee schemes (Jawahar Rozgar Yojana and Rural Landless Employment Guarantee Programme).

7.5.2.3 SWR_{PT} on the basis of productivity and time criteria of employment

According to surplus labour theory, unemployment and underemployment exists when withdrawal of a labourer from a sector does not affect the total production. The time criterion regards a labourer as unemployed or underemployed if he or she is not gainfully employed for some specific period in a reference week. In India a person working 8 hours a day for 273 days of the year is regarded as employed on a 'standard person' basis. There is no agreed methodology for measuring unemployment in India. The quinquennial surveys of the National Sample Survey Organisation (NSSO) provide the most comprehensive source. It classifies unemployment status into three categories.

(1) Usual Principal Status unemployment (UPS)

A person is considered unemployed on UPS basis, if he/she was not working, but was either seeking or was available for work for a 'relatively longer time' during the reference period (2.81 % in Bihar, 1987-88 : GOI, 1992a). This is also referred as 'chronic unemployment or open unemployment'.

(2) Current Weekly Status unemployment (CWS)

On the basis of a week as the reference peiod, a person is considered unemployed by CWS, if he/she had not worked even for one hour during the week but was seeking or available for work (3.77 % of total labour force in Bihar, in 1987-88, GOI, 1992)

(3) Current Daily Status unemployment (CDS)

CDS measures unemployment in terms of the total person days of unemployment i.e., the aggregate of all the unemployment days of all persons in the labour force during the week (4.04 % of total labour force in Bihar, 1987-88:GOI, 1992)

The above described criteria for measuring unemployment are based on conventional and most commonly used concept i.e 'period for involuntary idleness'. It does not include 'invisible' unemployment or under employment i.e., a situation of work with very low levels of productivity and income. The later is a problem of much larger magnitude in India, than conventionally measured unemployment. Persons belonging to low income households can hardly afford to remain unemployed. Therefore, they may engage themselves in any low productive or low income work.

In this section we estimate SWR_{PT} on the basis of CWS taking time and productivity criteria of unemployment.

The NSSO classifies workers into two groups, main worker (who have worked for > 3.5 days in the reference week) and subsidiary workers (who have either worked $\leq$ 3.5 days in the reference week or did not work at all) (Table A7.2.7, Annexure 7.2). We assume that in afforestation projects, workers will be drawn in proportion to unemployment in each category (subsidiary, main worker). The latest census data (1991) gives the following figures about work participation in Bihar (Mukhopadhyay, 1994).

(A) Total population of Bihar 86374465

(B) % of main worker to total population 29.66 %

(C) Economically active population 32.16 %

(D) % subsidiary worker to total population 2.50 %

$$\frac{SWD}{MWD} = \frac{S_{\%}.S_U}{M_{\%}.M_U} \quad \text{.......} eq.(7.18)$$

where *SWD* is subsidiary worker days, *MWD* is main worker days, $S_{\%}$ is % of subsidiary worker to the total population, $M_{\%}$ is the % of main worker to the total population, S_U is the average number of days unemployed for subsidiary worker and M_U is the number of days unemployed for main worker.

On substituting the values in equation 7.18, we get,

(2.50 × 3.2015) / (29.66 × 0.1246) = 2.16573 or 2.17

The ratio of SWD/MWD is 2.17. It means if total 3.17 (2.17 +1) days are required in the afforestation projects, 2.17 days go to main workers i.e., 31.55 % (1/3.17) and 68.45 % (2.17/3.17) go to subsidiary worker. Table A7.2.7 (Annexure 7.2) shows that on an average main workers and subsidiary workers were employed for 6.7264 days and 1.9440 days respectively in the reference week. If daily wage rate is w, the marginal product of main worker will be 0.96w (6.7264/7.00) and the marginal product for subsidiary worker will be 0.28w (1.9440/7.00). Hence, the total value of the marginal product forgone by society by drawing one labour in to an afforestation project would be (weighted average according to number of workers drawn) will be:

SWR_{PT}=[(0.3155 × 0.96w)+(0.6845 × 0.28w)]=0.4945w or 0.49w

7.5.2.4 Conclusions

The shadow wage rate estimated above ranges from 0.313w to 0.85w. As we have already stated SWR_{OP} (0.85w) is based on data of only one year. The other two methods (SWR_{PT} and SWR_{SS}) give plausible estimates. The SWR for Bihar has been estimated by Trivedi (1987) as 0.44w which is very close to our estimates. Therefore, we use SWR_{SS} method in the present study. But we will examine the effects of change in SWR through sensitivity analysis

7.5.3 Shadow pricing of fertilizer

Fertilzer and insecticide are two important material inputs in the FF and the RDF component. Pesticides (Aldrex 5 % powder and Aldrex 30 % EC liquid) were used only in the nursery in very small quantities. There is no subsidy by the government on pesticides. Therefore their market price can be assumed as their economic price.

Fertilizers (urea and single superphosphate) were used in both the FF and the RDF plantations. The rates of these two fertilisers before 1991 were fixed by the government for the whole country, after substantially subsidizing the prices. The domestic production of nitrogenous and phosphatic fertilizers is not sufficient to meet demand. Therefore both N and P fertilizers are imported by the government and government provides subsidy at different rates for domestically produced fertilzers and imported fertilizers (Table A7.2.8, Annexure 7.2). Thus the market price of fertilizers (N & P) does not reflect their economic value.

The total subsidy per kg (weighted by their origin viz., domestic or imported) is calculated and the economic price is estimated (Table A7.2.8, Annexure 7.2). The accounting ratio ($A_i = P_i^s / P_i^m$, where P_i^s is social price and P_i^m is market price) for fertilizer for India is estimated as 1.00 (Lal, 1980) but this does not seem plausible in light of the recent data. The economic price of fertilizer will be 1.778m (where m is the market price).

7.5.4 Shadow pricing of output

The main outputs in FF and RDF components are fuelwood, poles and fencing posts. The values of these products used in FCBA are based on the depot rates which in turn depend upon auction price received by the forest department. The auction rates can be taken as economic value because they are determined by free and open market competition.

If the fuelwood and other forest produce are available to the farmers by some allocation mechanism (e.g. Joint Forest Management), the economic value can be estimated in terms of:

(a) time saved in collection of wood from the forests and,

(b) the opportunity cost of labour saved in peak and off seasons.

The economic value of fuelwood can also be derived by using the values of imported (or domestic) fuel substitution such as kerosene. A replacement for kerosene

value at border price (Rs 5.78/litre) would value fuelwood (economic value) at Rs 354/m^3 as against a financial value of Rs 250/m^3 (l m^3 fuelwood≡61.25 litres of kerosene, Price, 1989). The economic value (Rs 354/m^3) requires further adjustment to include premium on foreign exchange and adjustment for transportation input. However, in practice shortages of fuelwood may result in more dung and coal being burnt. The use of dung as domestic fuel may affect dung availability to crops adversely which in turn results in:
(a) a possibe decrease in food production, and
(b) increase in imported fertilizer consumption (due to heavy subsidy on nitrogenous fertilizer, the consumption of chemcal fertilizer is well above optimal level, which is altogether another matter) which has both economic and environmental consequences. At present, in the study area kerosene is used by farmers for lighting and for protection of their life and property against elephant herds. Kerosene is unlikely to be used as domestic fuel by most of the farmers as it requires initial investment (equivalent to 20-25 workdays) in stoves.

The local market price for coal is Rs 2/kg which is more or less equivalent to current price of fuelwood in energy equivalent. The f.o.b export value of coal is Rs 1250/tonne. Although little or no coal is currently exported, an export parity price of Bihar coal in Bihar would be less than this to allow for transport.

Based on these considerations, the depot rates of fuelwood, poles and fencing post are taken as their respective economic values.

7.5.5 Estimation of standard conversion factor (SCF)

It is not envisaged that important commodities (except fertilizer) will be used as inputs or that outputs of the afforestation projects will be exported. Therefore, the use of a standard conversion factor (SCF) is not required. However, the SCF is widely used by the World Bank for appraising the afforestation projects in developing countries. It can be estimated using a simplified form of equation 3.9 as the estimation of the elasticity of supply of exported goods and elasticity of demand of imported goods is difficult. Squire and van der Tak (1975) have taken average export supply elasticity and average import demand elasticity instead of taking elasticities (of supply and demand) of individual commodities. We assume the both the elasticities are the same. The equation 3.9 can be written as follows:

$$SCF = \frac{M+X}{(M+T_m)+(X-T_x)} \quad \text{......} eq. (7.19)$$

where X is f.o.b value of all exported goods at border price, M is c.i.f value of all important goods at border prices, $(M+T_m)$ is the value of domestic price (T_m is imort tax) and $(X-T_x)$ is the value of export at domestic price (T_x is the subsidy)

A time series (1965-1992) of X, M, $M+T_m$ and $X-T_x$ is generated and the estimates of SCF is calculated for each year using eq. 7.19 (Table A7.2.9 , Annexure 7.2). The average value of SCF is estimated as 0.8316 or 0.83 (CV=5.78%).

7.6 Economic appraisal of RDF: a case study

7.6.1 Computation of economic costs and benefits

All inputs and outputs are evaluated in terms of their economic and opportunity costs. To evaluate shadow wage rate of labour, SWR_{ss} is used because it gives flexibility of quantifying SWR_{ss} according to different project operations. The afforestation project draws largely on unemployed labourers. Such labourers have zero opportunity costs. Most operations in the project are not rigidly (except nursery and planting) time bound. Therefore, it is reasonable to assume that the large section of the afforestation work is done by surplus labourers.

All forest roads remain closed for vehicular movement in the monsoon season to protect unsurfaced roads. The harvesting operation is generally carried out in the agricultural off season resulting in no opportunity costs of surplus labour. Therefore, the direct cost and loading costs (see Table A7.2.4, Annexure 7.2) in harvesting are taken as zero.

As we have discussed in Chapter 5 and Chapter 6, the yields of RDF plantations are affected by the incidence of illicit felling. This non-market benefit is directly available to the people. The financial appraisal does not account for the value of forest produce directly available to the people due to illicit felling. This has to be accounted for in an economic appraisal because it is an additional benefit to the economy. The effect on the yield of forest produce depends on the specific model according to which illicit felling takes place. In this case study, we assume that the illicit felling follows the model - WM-

INA. The value of illicitly removed timber is obtained by multiplying the volume during the year by the average price applicable for the year.

7.6.2 Results of economic appraisal (RDF)

Table 7.3 presents the results of economic appraisal. All the districts show positive values of NPVs. NPV/ha in GRS region is quite high as compared to SGH regions. The volume loss (to the government) in illicit felling is included in the analysis considering it as gain to the economy. The other profitability criteria also indicate the same results.

Table 7.3 Results of economic cost-benefit analysis (RDF)

	Profitability criteria			
	NPV/ha (Rs/ha)	IRR	BCR	% plots profitable
Districts				
Gumla (GRS1)	66283	0.47	3.89	100
Ranchi (GRS2)	68897	0.47	3.90	100
Sahebganj (GRS3)	28848	0.34	2.81	100
E.Singhbhum (SGH1)	22917	0.34	2.80	100
Garhwa (SGH2)	20192	0.32	2.62	100
Hazaribagh (SGH3)	34693	0.38	3.27	100
Regions				
GRS	55483	0.44	3.64	100
SGH	27591	0.36	3.00	100
All plots (N=18)	40201	0.40	3.35	100

Notes: 1. An economic discount rate of 10.24% is used.
2. SWR_{SS} is used for shadow pricing labour wages
3. Figures under different profitability criteria are weighted (according to the area of plantation) average of corresponding plots.

The range of IRR indicates that IRR is above zero in all the woodlots (Table 7.4). The estimated IRR is more than 20% in 95% of total woodlot. This can be considered quite satisfactory.

Table 7.4 Range of IRR in different regions (RDF)

Regions	Number of plots					
	IRR (range)					
	≤0	≤0.10	≤0.20	≤0.30	≤0.40	>0.40
GRS	0	0	0	0	3	6
SGH	0	0	1	0	7	1

7.6.3 Sensitivity analysis

A sensitivity analysis is undertaken to examine the effect of discount rate on profitability of RDF woodlot (Table 7.5). NPV , IRR and BCR are used as criteria. The economic discount rate estimates using growth model, IOCR model and production function model are used in calculations.

Table 7.5 Profitability of RDF woodlot under different discount rates

Regions	N	Profitability criteria	Number of plots		
			Economic discount rates		
			10.24%[a]	15.77%[b]	17.94%[c]
GRS	9	NPV>0	9	9	9
SGH	9	NPV>0	9	9	8
GRS	9	BCR<1	0	0	0
		BCR≥1	0	0	2
		BCR≥2	9	9	7
SGH	9	BCR<1	0	0	1
		BCR≥1	1	1	4
		BCR≥2	8	8	4
GRS	9	IRR<0.1	0	0	0
		IRR≥0.1	1	1	1
		IRR≥0.2	8	8	8
SGH	9	IRR<0.1	0	0	0
		IRR≥0.1	1	1	1
		IRR≥0.2	8	8	8

N=total number of plots, [a] growth model, [b] IOCR (Incremental Output Capital Ratio) model and [c] production function model

We examine the effect of shadow wage rate on profitability (Table 7.6). In section 7.7.2, we have estimated shadow wage rate (SWR_{SS}) by quantifying scarce labour and surplus labour for each of the plantation operations. Here, we have used pooled data of total labour (scarce labour and surplus labour separately) input in RDF component to estimate shadow wage rate ($SWR_{SS'}$).

Table 7.6 Profitability of RDF woodlot under different economic discount rates (EDR) and shadow wage rates (SWR)

EDR	Shadow wage rate	NPV Rs/ha			
		Regions			% plot
		GRS	SGH	All plots	profitable
10.24%[a]	$SWR_{SS'}$	53733	26159	38624	100
	SWR_{PT}	50070	23284	35393	100
	SWR_{OP}	43279	17984	29419	94
15.77%[b]	$SWR_{SS'}$	33063	15205	23278	94
	SWR_{PT}	29906	12547	20394	94
	SWR_{OP}	24096	7655	15087	94
17.94%[c]	$SWR_{SS'}$	27218	12050	18907	94
	SWR_{PT}	24207	9457	16125	94
	SWR_{OP}	18677	4686	11011	89

Notes: 1. [a] growth model; [b] IOCR (Incremental Output Capital Ratio) model and [c]production function model are used for estimation of EDR
2. $SWR_{SS'}$ is SWR on the basis of surplus and scarce labour. The estimation is based on total labour required in the RDF component ($SWR_{SS'}$=0.313).
3. SWR_{PT} is SWR on the basis of productivity and time criteria (SWR_{PT}=0.495).
4. SWR_{OP} is SWR on the basis of peak season and off season wage rates (SWR_{OP}=0.85)

Now, we examine the profitability of woodlots without including the benefits of illicit felling in benefit streams (Table 7.7 and Table 7.8). We call it as assumption S-1. This is also required to compare the economic profitability of RDF to the financial profitability, as in FCBA the benefits due to illicit felling were not included. The net present values show remarkable decrease at all the discount rates. The main reasons for such low net present values are:

a. The benefits due to illicit felling are not included in benefit streams.

b. The benefits due to illicit felling start accruing in the relatively early stages of plantation cycle.

c. The rate of illicit felling in some districts is relatively higher as compared to other districts. This variable rate of illicit felling becomes less important by considering illicit felling in benefit streams.

Thus, inclusion of illicit felling in benefit streams results in:

- increase in profitability
- decrease in variability
- lesser effect of change in discount rate on overall profitability

Table 7.7 Results of economic cost benefit analysis (RDF)

Assumption: S-I (Forest produce due to illicit felling is not considered as a benefit)

	Profitability criteria			% plots
	NPV/ha (Rs/ha)	IRR	BCR	profitable
Districts				
Gumla (GRS1)	48752	0.36	3.13	100
Ranchi (GRS2)	52689	0.38	3.22	100
Sahebganj (GRS3)	12619	0.21	1.79	100
E.Singhbhum (SGH1)	3991	0.15	1.32	33
Garhwa (SGH2)	685	0.11	1.06	33
Hazaribagh (SGH3)	15150	0.23	1.99	100
Regions				
GRS	38774	0.33	2.84	100
SGH	8192	0.19	1.59	56
All plots (N=18)	22017	0.27	2.29	78

Notes: 1. An economic discount rate of 10.24% is used.
2. SWR_{SS} is used for shadow pricing labour wages
3. Figures under different profitability criteria are weighted (according to the area of plantation) average of corresponding plots.

Table 7.8 Profitability of RDF woodlot under different economic discount rates (EDR) and shadow wage rates (SWR)

Assumption: S-I (Forest produce due to illicit felling is not considered as benefit)

EDR	Shadow wage rate	NPV Rs/ha			
		Regions			% plots
		GRS	SGH	All plots	profitable
10.24%[a]	$SWR_{SS'}$	37022	6759	20440	78
	SWR_{PT}	33359	3885	17209	72
	SWR_{OP}	26568	-1416	11235	67
15.77%[b]	$SWR_{SS'}$	20350	751	9611	67
	SWR_{PT}	17193	-1907	6727	61
	SWR_{OP}	11595	-6620	1614	50
17.94%[c]	$SWR_{SS'}$	15735	-898	6621	67
	SWR_{PT}	12724	-3491	3839	56
	SWR_{OP}	7403	-8086	-1084	39

Notes: 1. [a] growth model,[b] IOCR (Incremental Output Capital Ratio) model and [c]production function model are used for estimation of EDR
2. $SWR_{SS'}$ is SWR on the basis of surplus and scarce labour. The estimation is based on total labour required in the RDF component ($SWR_{SS'}$=0.313).
3. SWR_{PT} is SWR on the basis of productivity and time criteria (SWR_{PT}=0.495).
4. SWR_{OP} is SWR on the basis of peak season and off season wage rates (SWR_{OP}=0.85)

7.7 Economic appraisal of FF: a case study

7.7.1 Computation of economic costs and benefits

In determining economic cost and benefits in FF component, there are two main areas of concern, non-market inputs and indirect outputs. In previous sections, we have already discussed the detailed methodology of economic pricing of costs and benefits. The economic valuation of land varies from farmer to farmer according to previous land use. It is often argued that in FF project peak season labour should be valued in terms of forgone agricultural output assuming that the value of lost agricultural output is the same to the village as it is to the society. This approach is not attempted because of lack of village level data. Therefore, the FF component also uses the SWR_{SS} . All the direct and intermediate benefits included in the financial appraisal are given the same value in the economic analysis. The externalities (e.g. soil conservation, increase in fertility due to nitrogen fixation) of the project have not been considerd due to lack of pertinent data. Economic value of harvesting costs are given in Table A7.2.5 (Annexure 7.2). A discount rate of 10.24% is used in the analysis. The calculations are illustrated through derivation of discounted cash flow of FF plot 1A1 (Table A7.2.10, Annexure 7.2). The effect of change in discount rate is examined in the sensitivity analysis.

7.7.2 Results of economic appraisal (FF)

The region-wise and the district-wise results of ECBA are summarised in Table 7.9. The average NPV per ha is positive in five out of six sampled districts. Only one district, Sahebganj, shows negative NPV. This is because of the very low survival rate in this district. Some plots have even registered 0% survival. SGH region shows the highest profitability according to all the three criteria.

Table 7.9 Results of economic appraisal of FF

		Profitability criteria		
	N	NPV/ha (Rs/ha)	IRR	BCR
Districts				
Gumla (GRS1)	12	14766	0.42	3.72
Ranchi (GRS2)	12	44259	NA	8.13
Sahebganj (GRS3)	12	-1663	0.05	0.67
E.Singhbhum (SGH1)	12	27854	0.48	5.14
Garhwa (SGH2)	12	42534	NA	8.29
Hazaribagh (SGH3)	12	30722	0.49	6.29
Regions				
GRS	36	15687	0.41	3.87
SGH	36	33623	0.57	6.48
Total all plots	72	23541	0.57	5.09

Notes: 1. An economic discount rate of 10.24% is used.
2. Average values for districts, regions and for all plots are calculated from pooled data of respective categories.
3. N=number of plots. NA= IRR could not be calculated.
4. SWR_{SS} is used in all the calculation in this table.

Table 7.10 shows results of economic IRR. It is observed that IRR in 18% of woodlots is zero or below zero.

Table 7.10 Range of IRR in different regions (FF)

Regions	Number of plots			
	IRR (range)			
	≤0	≤0.25	>0.25	NA
GRS	11	5	8	12
SGH	2	3	21	10

N=36 in both the regions, NA= IRR could not be calculated.

7.7.3 Sensitivity analysis

A sensitivity analysis has been carried out to observe the effect of discount rate and shadow wage rate. The results of economic NPV at three discount rates are presented in Table 7.11. At a 17.94% discount rate about 21% of woodlots become unprofitable.

Table 7.11 Profitability of FF woodlots under different economic discount rates

Regions	N	Profitability criteria	Number of plots		
			Economic discount rates		
			10.24%[a]	15.77%[b]	17.94%[c]
GRS	36	NPV≤0	14	15	15
		NPV≤30000	10	15	17
		NPV≤60000	9	6	4
		NPV>60000	3	0	0
SGH	36	NPV≤0	4	5	5
		NPV≤30000	10	20	24
		NPV≤60000	17	11	7
		NPV>60000	5	0	0

Table 7.12 shows the effect on profitability (criterion: NPV/ha) of FF under different discount rates and shadow wage rates.

Table 7.12 Profitability of FF woodlots under different economic discount rates (EDR) and shadow wage rates (SWR)

EDR	Shadow wage rate	NPV/ha (Rs/ha)		
		Regions		
		GRS	SGH	All plots
10.24%[a]	$SWR_{SS'}$	14351	30754	21534
	SWR_{PT}	15312	32137	22679
	SWR_{OP}	13469	29483	20482
15.77%[b]	$SWR_{SS'}$	8604	19359	13341
	SWR_{PT}	9410	20447	14243
	SWR_{OP}	7864	19359	12460
17.94%[c]	$SWR_{SS'}$	7004	16177	11021
	SWR_{PT}	7765	17181	11888
	SWR_{OP}	6305	15255	10244

Notes: 1. [a] growth model;[b] IOCR (Incremental Output Capital Ratio) model and [c]production function model are used for estimation of EDR
2. $SWR_{SS'}$ is SWR on the basis of surplus and scarce labour. The estimation is based on total labour required in the RDF component ($SWR_{SS'}$=0.313).
3. SWR_{PT} is SWR on the basis of productivity and time criteria (SWR_{PT}=0.495).
4. SWR_{OP} is SWR on the basis of peak season and off season wage rates (SWR_{OP}=0.85)

7.8 Discussion and conclusions

The results of ECBA of FF and RDF exhibits that the estimation of EDR is vital in assessing profitability of the afforestation project. Generally, project analysts choose to ignore this aspect in project appraisal and select an arbitrary EDR ranging from 10% to 20%. On the other hand, SWR is measured in most of the projects with great sophistication (including migration effect in labour wages and incorporating 'high cost of living' in urban areas). The relative effect of SWR and EDR (assumption: S-1) are shown for district GRS3 (Fig. 7.1). Realistic assumptions about projects' inputs and outputs generally lead to plausible estimation of shadow prices.

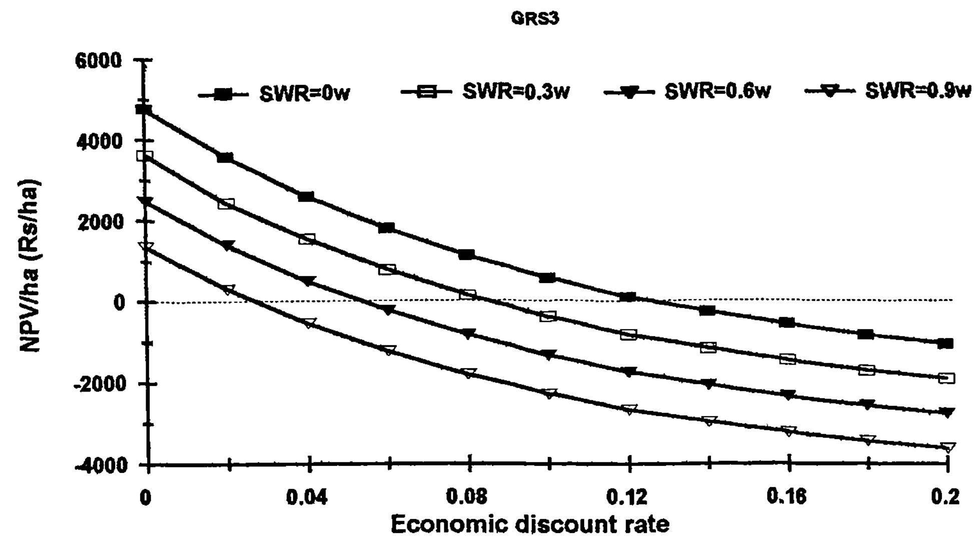

Fig. 7.1 Profitability at different Economic Discount Rates and Shadow Wage Rates

In section 7.6.5 we have estimated the standard conversion factors but this approach is not used in the present study. This can be used to compare the results obtained by the World Bank for the projects in other states. In the LM methodology, different conversion factor for different commodities or groups of commodities are required to be estimated and inputs and outputs are expressed in convertible foreign exchange. The valuation of non-traded commodities in convertible foreign exchange or border rupees is questioned by Sen (1970) and Joshi (1972). It is more appropriate to express their value based on internal market prices which reflects domestic 'willingness to pay'. In this chapter, we have considered profitability mainly from 'efficiency' point of view, the distributional and other socioeconomic aspects will be explored in subsequent chapters.

Chapter 8

Patterns of farmer tree growing: a socioeconomic analysis of farm forestry

8.1 Sources of variability in Farm Forestry

The demand for forest produce cannot be tackled by the government forests only. So, tree-growing outside the boundaries of government forests has become a very important component in most of the afforestation projects. The farm forestry (FF) component was initially designed to promote private plantations on marginal land unfit for agriculture. The primary objective was to provide fuelwood and other forest produce (mainly poles) for domestic use, thereby reducing pressure on natural forest. Farmers were to plant trees on their own land with their own choice of species. Therefore, they have a vested interest in protection. FF has achieved good success in some regions but has failed in many regions. The financial CBA and economic CBA (Chapter 6 and 7) of FF show that profitability levels of farm forestry investments vary from farmer to farmer. The variability in returns is very high even in the same region or in the same district. A systematic appraisal of FF performance, an analysis of factors governing decision making for adoption and non-adoption of FF practice and identification of constraints confronting it is very much desired for an objective appraisal of FF component. It is in this perspective that there is a need to sort out fundamental concerns centring around FF development. In this chapter, we attempt to explore why farmers plant tree, what factors constrain FF adoption and what factors affect FF returns most. We examine the following elements of farmers tree-growing patterns in detail as these elements determine success or failure of FF:

1. Socioeconomic characteristic of farmers and tree growing.
2. Adoption of tree growing by farmers.
3. Determinants of survival of plants in FF.

8.2 The Data

The data used in this study were collected through a questionnaire-based survey of 288 farmers of Bihar, India. Both adopters of farm forestry (between 1980 and 1992) and non-adopters (up to the year 1992) were included in the survey. The details of sampling methodology and survey procedure are described in Chapter 4. The questionnaire is presented in Annexure 4.2 and Annexure 4.3. A summary of variables used in all the analyses in this chapter is presented in Table 8.1.

Table 8.1 Summary of variables for factor analysis, discriminant analysis, the logistic regression model and multiple regression analysis

Variable code	Description of the variables
ADOPTDGR	Interval, % of land (to the total land) under tree cover
ADOPTIME	Nominal, adoption time - not adopters, early and late adopters, measured on a scale from 0 to 2
ADOPTION	Dummy, adoption of FF and non-adoption, coded 0 for non-adopters, 1 for adopters
ADVICE	Interval, advice (no. of times) from different departments measured on 0 to 8 scale
AGASSET	Ordinal, value of agriculture machinery measured on 1 to 4 scale
AGASSET1	Dummy, value of agriculture machinery, coded 0 if less, 1 if more
AGE	Interval, age of farmer in years
AGGRI	Interval, income from agriculture in Rs
AGUPTINC	Interval, agriculture income/total income
APROLAND	Dummy, suitability of land for tree growing, coded 0 if not suitable, 1 if suitable.
AWARINDX	Ordinal, awareness about forestry activity, measured on 0 to 4 scale
CASTE	Dummy, caste, coded 1 if SC and ST, 0 if others
COWEEP	Interval, number of cattle owned by a household
DISTRICT	Nominal, districts
EXPERNS	Dummy, experience in tree growing, coded 0 if no experience, 1 if adopted FF before 1985
EXTNSN	Interval, advice on silviculture, measured on 0 to 5 scale
FORPROD	Dummy, adequacy of forest produce for domestic needs, coded 1 if adequate, 0 if not adequate
FWWOODKM	Interval, distance to collect firewood measured in km

GOVFORTP	Interval, % fuel from government forest
HHPOP	Interval, number of members in the household
HIRLBR	Dummy, engagement of hired labour in plantation, coded 1 if hired labour used, 0 if not
INCOME	Interval, total income from all sources
INTPROD	Nominal, disposal of intermediate products, four categories
IRRFTL	Ordinal, adequacy of irrigation facilities, measured on 1 to 3 scale
IRRFTL1	Dummy, adequacy of irrigation facilities, coded 0 if inadequate, 1 if adequate
LAND	Interval, land ownership in ha
LANDOWN	Dummy, land ownership, coded 0 if $\leq$1.90 ha, 1 if >1.90
LANDOWN3	Ordinal, land ownership, measured on 0 to 2 scale
LITERACY	Dummy, literacy, coded 1 if literate, 0 if illiterate
OCCUP	Nominal, occupation, 1 to 7 categories
OCCUP1	Nominal, occupation, four categories
OCCUP2	Dummy, occupation, coded 0 if agriculture is the main occupation, 1 if other
PCFLWOOD	Interval, per capita weekly fuelwood requirement in quintals
PCPOLES	Interval, per capita annual pole requirement in number
PCTIMBER	Interval, per capita annual timber requirement in cft
PLANTLOC	Ordinal, quality of planting site, measured on a scale 0 to 3
PLTSPACE	Dummy, spacing in plantation, coded 1 if regular, 0 if irregular
PLTTRP	Interval, distance from nursery to plantation site in km
PROTECT	Ordinal, degree of plantation protection, measured on a scale from 1 to 3
PROTECT1	Ordinal, degree of plantation protection, measured on a scale from 0 to 3
PROTHLP	Dummy, help required from the FD in protection, coded 1 if help required, 0 if not required
PURWOODP	Interval, proportion of purchased wood used in %
REGION	Dummy, region, coded 0 if GRS and 1 SGH
SEX	Dummy, sex, coded 1 if male, 0 if female
SPSLECT	Nominal, selection of species, three categories
SURVIVAL	Interval, no. survived/no. planted
URBAN	Interval, urban income in Rs
WEEDNO	Interval, weeding number
YRSCOL	Interval, number of years in school

Note: The questionnaires are given in Annexure 4.2 and 4.3.The measurements of variables are presented in Annexure 4.4.

8.3 Socioeconomic characteristics of farmers and tree growing

In most of the FF programmes tree-growing by farmers was not considered fundamentally different from growing trees in forests and tree growing in farmers' field was considered to address the same concerns as deforestation, environmental degradation and meeting forest produce requirements. Each of these perspectives provides useful information regarding the role of trees in rural household livelihood strategies, but, without recognition of a broader framework, they are unlikely to explain farmers' adoption behaviour (Arnold, 1995). There are a number of factors likely to influence farmers' decisions. Knowledge about their interactions with other factors is helpful in analysing the adoption process and can provide valuable insight into understanding farmers' tree growing strategies in a broader context. The question of interrelated variables has important implications in statistical modelling of adoption and also in developing efficient strategies for interventions (if required). In this section, we confine ourselves to adopters only. We will also examine characteristics of non-adopters in the two sections that follow. The main objectives are:

(1) To determine if the factors viz. socioeconomic characteristics of farmers, management practices, extension and training, farmers' asset status, forest produce procurement etc., are interrelated and if so,

(2) To determine the type of relationship among different factors.

8.3.1 The factor analysis model

It is useful to obtain some idea of measures of association of the various variables considered to impinge on patterns of tree growing. Factor analysis is well suited to identify a relatively small number of factors that can be used to represent large numbers of interrelated variables. The basic assumption of factor analysis is that observed correlation between variables results from their sharing these factors. Factor analysis refers to a number of statistical data reduction techniques (principal component analysis (PCA), exploratory factor analysis (EFA), confirmatory factor analysis (CFA), LISREL etc.). The common objective is to represent complex data in terms of a smaller number of hypothetical variables. Transformations (e.g. orthogonal) of a set of variables can be used to reduce the number of variables in the analysis. PCA has no underlying statistical model of the observed variables. It explains the total variance (i.e. common variance+unique variance) in the observed variables on the basis of maximum variance properties of principal components (Dunteman, 1994) while factor analysis focuses on explaining the common variance. In the present study, the principal components analysis method is used. This method uses standardized values of variables for analysis. Thus, problems associated with unequal variance are avoided. In principal components analysis, linear combinations of the observed variables are formed. The first principal component (or factor) accounts for the largest amount of variance. Successive components explain progressively smaller portions of the total sample variance.

The mathematical model for factor analysis appears somewhat similar to a multiple regression equation. Each variable is expressed as a linear combination of factors that are not actually observed. Instead, they are labels for groups of variables that characterize these concepts. The general model for the ith standardized variable is wriiten as (SPSS Inc., 1993a):

$$X_i = A_{i1}F_1 + A_{i2}F_2 + \ldots\ldots\ldots\ldots A_{ik}F_k + U_i$$

where F_1.......F_k are common factors, U_i is the unique factor and A_{i1}....A_{ik} are the coefficients used to combine the k factors.

The general expression for the estimate of the jth factor, F_j, is

$$F_j = \sum_{i=1}^{p} W_{ji}.X_i$$

where W_i's are factor score coefficients and p is the number of variables.

8.3.2 Methodology

The study considers 24 variables. Factor analysis proceeds in the following steps (Lowley and Maxwell, 1971; Mulaik, 1972).

1. Computation of a correlation matrix for all variables and evaluation of the model.
2. Factor extraction - the number of factors necessary to represent data.
3. Rotation - transforming the factors to make them more interpretable.
4. Calculation of scores for each factor and for each case.

Since one of the goals of factor analysis is to obtain factors that help to explain correlations, the variables must be related to each other for the factor models to be appropriate. First, the correlation matrix for all twenty-four variables is computed. The correlation matrix shows half the coefficients are greater than 0.3 in absolute value which suggests that they share common factors. We test the hypothesis that the correlation matrix is an 'identity matrix' (i.e. all diagonal terms are 1 and all off diagonal terms are 0) using the Bartlett test of sphericity. We reject the hypothesis on the basis of this test (Bartlett test of sphericity=5507.4680, significance=0.0000). 'Anti-image correlation' (negative of the partial correlation coefficients) matrix of all the variables is small (<0.01 in 76% of the cases) as the linear effects of other variables are eliminated and they (variables) share a common factor. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.822226 (It can be termed as 'meritorious' in the words of Kaiser, 1974). KMO value close to 1 suggests correlation between pairs of variables can be explained by the other variables.

The five factors (based on eigenvalue >1 criterion) explain 73.1% total variance. The scree plot (plot of a total variance associated with each factor) suggests that the five-factor model is appropriate. The proportion of variance explained by the common factor is called communality. Table A8.1.1 (Annexure 8.1) shows communalities for all the variables with the percentage of variance accounted for by each of the retained (five) factors. For example, 72.172% of variance of variable ADVICE is explained by our five-factor model. The communality is >0.5 for all the variables. We can conclude that the factors in the model adequately described the data. The initial unrelated factor loading is difficult to interpret, hence rotation of factor is employed. We used orthogonal rotation (the axes are maintained at right angels) so as to maximize a varimax criterion. The varimax criterion attempts to minimize the number of variables that have high loadings on a factor by maximizing the sum of the variances of the squared loadings within each column of the loading matrix (Duteman, 1994). The rotated factor patterns' matrix is given in the Table 8.2. The rotated factor matrix pattern is now apparent.

8.3.3 Factor analysis results

The principal component analysis exhibits that the twenty-four variables can be summarised in five principal components or factors.

Table 8.2 Rotated factor patterns (varimax) matrix

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
WEEDNO	0.83915	0.25852	0.8146	0.05086	-0.06653
APROLAND	0.81912	0.22209	0.18730	0.04019	0.20010
EXTNSN	0.80817	0.28983	0.24627	-0.02407	0.15349
PLTTRP	-0.77381	-0.18932	-0.15011	0.10185	-0.05149
ADVICE	0.75180	0.12973	0.23794	0.00905	-0.28808
AWARINDX	0.73374	0.45744	0.26261	-0.03237	0.04997
PROTECT1	0.71397	0.32012	0.21344	0.13932	-0.01763
FWWOODKM	0.69366	0.16073	-0.18915	-0.19601	0.35687
PLANTLOC	0.60417	0.17289	0.05362	0.30098	0.17314
YRSCOL	0.48035	0.38082	0.04056	0.30867	0.22250
AGGRI	0.27769	0.84033	0.08611	-0.32952	0.03588
INCOME	0.32858	0.77348	0.04005	0.28897	0.10460
LAND	0.23663	0.75621	0.00459	-0.17539	-0.05627
IRRFTL1	0.27925	0.73922	0.11944	0.13356	0.22549
AGASSET	0.54849	0.65251	0.02755	0.07012	0.16472
COWEEP	0.22684	0.62560	0.19645	-0.23679	-0.29313
PCFLWOOD	0.24078	0.10413	0.88278	-0.02837	-0.05148
PCTIMBER	0.44263	0.21440	0.71123	0.16295	0.16580
PCPOLES	0.11775	0.06523	0.58978	-0.40126	0.02038
URBAN	0.15884	0.02471	0.03071	0.86520	0.15899
AGUPTINC	0.14080	0.38235	0.23753	-0.74345	0.06353
HHPOP	-0.07228	0.17623	-0.42005	0.02609	-0.74398
GOVFORTP	-0.13267	-0.33235	0.40544	-0.28556	-0.67767
PURWOODP	0.24008	0.42954	-0.04136	0.45054	0.49889
% variance explained	40.9	12.5	9.0	5.8	4.9

Note: All the variables are explained in Table 8.1

The complete data set can broadly be represented in five factors. The five factors are represented as five indices of farmers' characteristics in relation to tree-growing. They are referred to as 1. Planting technologies, 2. Farmers' asset, 3. Forest produce requirements, 4. Sources of income and 5. Forest produce procurement.

1. Factor 1: Planting technologies

This index explains 41% of total variance. The variables, explaining three important characteristics viz. awareness, extension services and management practices are heavily loaded on this index. All variables except one (PLTTRP i.e., distance from nursery to farmers' plot) have a positive sign. The negative sign of the variable PLTTRP is expected as the long distance from nursery to plantation sites is a disincentive to tree-growing. The extension services' impact on tree-management practices is also implied from the common index and both in turn are influenced by farmers' awareness and education level.

2. Factor 2: Farmers' asset status

This index explains 12.5% of total variance. Farmers' total income, income from agriculture, land holding, irrigation facilities and farm machinery all have positive signs.

3. Factor 3: Forest produce requirements

This index explains 9% of total variance. Per capita timber, poles and fuelwood requirement are loaded heavily on this index and all three variables have a common sign (positive). It is contrary to the expectation of association of large per capita timber requirement with large urban income.

4. Factor 4: Sources of Income

It explains 5.8% of total variance. Urban income has a positive sign and the ratio of agriculture income to urban income has negative sign.

5. Factor 5: Forest produce procurement

This factor explains 4.9% of total variance. The dependency on government forest and purchased wood have opposite signs. Farmers' family size (HHPOP) and dependency on government forest both have a common (negative) sign.

The factor analysis shows that the variables explaining tree growing can be summarised by 5 independent and distinct indices. The inter-factor correlation is very weak ('r' ranges from -0.2 to 0.46). The weak inter-factor correlation does not support the sequential pattern of variables. It means INCOME (i.e., farmers' total income, factor 2) is independent of AWARINDX (i.e., index of farmers' awareness about the project, factor 1). It also suggests, for example, procurement of wood from forests is not conditioned by income level of farmers but household population. The important points which emerge from the above analysis are:

1. The extension service has significant influence upon management practice and awareness about the programme.
2. Forest produce consumption is independent of farmers' asset status.
3. Dependency on the government forests for fuelwood is related to family size.
4. In developing an adoption decision model, the variables grouped in different factors are to be considered explicitly (or by the factor score) to avoid misspecification of the model.

8.4 Adoption of tree growing innovations

Trees have always been an integral part of the rural landscape in this region of Chotanagpur and Santhal Pargana. But tree growing was confined to a few wealthy farmers. The selection of the species was also limited to long rotation timber species (*Dalbergia sissoo, Tectona grandis*), fruit trees (*Mangifera indica*) and shade bearing species (*Azadirachta indica, Melia* spp.). The free distribution of seedlings programme started by the Forest Department in the late seventies has encouraged farmers to grow some non-traditional and exotic species. But this programme has met with only partial success. The constraints to the rapid adoption of tree growing innovations were limited access to information, opportunity cost of land for alternative use, inadequate farm size, availability of seedlings etc.

8.4.1 Adoption: the process

The process of adoption is the result of disequilibrium which stems from inefficient utilisation of resource at the farm level. The equilibrium can be attained through a process of learning new innovations (Schultz, 1975). Feder et al. (1985) define adoption as 'the degree of use of a new technology in long-run equilibrium when the farmer had full information about the new technology and its potential'. Tree-growing adoption can be viewed as a continuous process at the aggregate level influenced by a number of factors outlined in the next section. At the farmers' level it may be a discrete adopt/non-adopt choice. Rogers (1983) has identified a five-stage adoption/rejection decision process which includes

(1) awareness of existence of innovation,
(2) persuasion by external agency,
(3) adoption/rejection decision,
(4) implementation of the decision and
(5) adopter seeking information to confirm his decision.

The tree-growing adoption process differs from other farm-technology innovations in a number of ways which emanate from the unique characteristics of a tree crop.

- Long gestation period for returns
- Tree-growing does not require high capital investment like other farm innovations (mainly technology adoption).

- Most farm innovations involve high risk but tree-growing innovation has relatively small risk (less effect of the monsoon, the price fluctuations in wood markets are relatively less as compared to agriculture markets and risk of disease affecting crop yields is extremely low)
- Trees can grow in marginal and less productive land which is biologically unsuitable and economically unprofitable for agriculture.
- A tree crop requires less labour.
- A tree crop provides the option of continuous or one time returns on one time investment.
- There is no urgency either to harvest or to sell forest produce immediately. This gives advantage to farmers to plan their harvesting or selling schedule depending upon a good market, availability of labour (agricultural off season) or according to their capital needs.
- Part of a tree (or single tree in a plantation) can be cut and sold separately. It can be equated to small units of currency (Chambers and Leach, 1989).

So, the conventional theories explaining adoption of farm level innovations are not coprehensive enought to explain tree-growing innovations.

8.4.2 Theory and Hypotheses

Tree growing by people may be looked upon as an evolutionary process in land use patterns. The evolution of tree growing patterns and definable stages therein have been identified by a number of authors (e.g. FAO, 1985; Raintree and Warner, 1986; Warner, 1993). Arnold (1995) has distinguished five stages in tree growing practice. These stages emerge in response to land use intensification. Gilmour (1995) has postulated that the afforestation process on private lands in central Nepal has been evolving through a series of evolutionary stages. The whole adoption process is to be considered in the context of farmers' 'livelihood strategies'. The adoption of tree-growing is a dynamic process and is dependent upon several factors, many of which relate to the characteristic of the investors, their resource endowment status, alternative opportunities for land use available and constraints being faced. These factors can determine the evolution of land use patterns. At least four evolutionary stages in tree growing patterns can be identified.

(i) Tree growing mainly by large farmers, mostly fruit-yielding trees grown for consumption (not for commercial returns). In some cases, it could include growing of fast growing species where there are wood markets.

(ii) Increased participation of all or major categories of farmers in tree growing. Technology input and information play an important role here. The motive for adoption could be different for different categories of farmers (large farmers, >1.90 ha land; small farmers, $\leq$1.90 ha land).

(A) Large farmers:

- profit maximization from farm land
- solution to factor constraints, particularly labour and supervision
- circumvent land reform and tenancy laws
- opportunity to use marginal land

(B) Small farmers:

- better return from a tree crop compared to low return agricultural crops in marginal lands
- opportunity to use marginal land
- risk management
  - a. substitution of a less uncertain crop in place of a less productive and uncertain crop
  - b. as a saving bank for emergencies or insurance against drought or flood
- trees as a capital asset meet large productive and unproductive expenditure
- the possibility of lump sum return coupled with off-farm employment opportunities (primarily in mining industry) could facilitate the adoption of tree cropping by small farmers.

(iii) A shift to a more intensive form of tree cultivation, such as irrigated orchards involving fruit-yielding species for sale in good quality of land, and timber species with perception of high return in marginal land. Wealthy farmers may remain at this stage possibly because of sufficient enterprise diversification or because of supervision and labour constraints.

(iv) A complete or partial (depending on quality of land and market access) shift from growing trees to growing high value, high input, high risk and very short rotation crops such as vegetables on land developed through capital investments earned from fast growing trees, mainly by small farmers.

At any point in time, it may be possible to find all four stages in a given setting.

Such differential behavioural response by farmers may possibly be determined by:
(a) individual enterprenuership, perception (of returns) and attitude,
(b) socioeconomic characteristics of the farmer,
(c) access to information, technology and credit,
(d) factor constraints,
(e) opportunity costs of available technological options on different qualities of land,
(f) institutional framework and law (transit permit system), and
(g) development support (subsidies, accessibility to market, and demand for outputs).

Trees promotional interventions (free seedlings and cash for planting and maintenance) in the form of the FF component of the project have been designed and sought to promote private tree growing, under a premise of the need for fuelwood and other forest produce (mainly poles), and as a motivating factor for people faced with increasing wood scarcities. However, our preliminary analysis indicates that the motives for farmer tree growing are many and stem from distinct contextual factors. The opportunities and constraints vary among different groups and in turn influence the decision making process regarding land uses.

We hypothesize that:
(a) farmers' tree growing adoption can be explained in a broader framework of evolution of land use patterns and,
(b) tree-growing is an integral part of farmers' land use strategies adopted in response of their 'livelihood strategies' and is determined by alternative uses of land, capital and labour in a socioeconomic context.

The hypothesis (a) has two parts:
(i) historical changes in land use patterns,
(ii) the role of tree crop in changed (evolved) land use.

If the hypothesis (a) is true, the study of change in land use patterns and major factors attributed to changes in land use should demonstrate a significant shift in cropping patterns, agricultural production, irrigated area, credit and technological development etc. All these factors are to be viewed in the context of unique characteristics of tree crop (section 8.4.1). The hypothesis (b) explains adoption of a tree crop in the evolved situation. The theory of 'livelihood strategy' assumes that all farmers are 'welfare (utility) maximizers' rather than 'profit maximisers' (Chambers and Leach, 1989). It focuses on multiple household objectives which include secure provision of food, savings to meet planned and unplanned expenditures, risk management and income generation (Arnold, 1995; Scherr, 1995). Farmers may adopt FF to get a lumpy return if they do not have any superior strategy for getting a lump sum return and their daily requirements for income are fulfilled by other sources, e.g. agriculture, dairying, urban income etc. Similarly, farmers may be interested in growing trees for savings if they find difficulty in getting credit in the market for the purpose they require, and at the interest rate they can afford.

8.4.3 Adoption of FF in socioeconomic context

8.4.3.1 Changing patterns of rural land use

In last two to three decades a number of factors have influenced change in cropping patterns, and tree growing has emerged as an important option in response to changes. We have used primarily national level data to identify broad trends. It is plausible to assume that these trends will be very similar in the case of the state of Bihar. The relevance of these factors in tree growing adoption in the study area will be examined in the next section.

8.4.3.1.1 Change in irrigated area

The country's irrigation potential has increased from 38.2 million ha in year 1971 to 83.4 million ha at the end of year 1992. As a consequence of irrigation development 33.3% of the net cropped area was irrigated in 1990-91 as compared to 22.1% in the year 1970-71 (GOI, 1993). The major effects of this development are:

- intensification of management which requires heavy investment both in capital and labour
- supervisory constraints in the case of large farmers

8.4.3.1.2 Change in technology

The reforms in techniques of production in agriculture started in the early 1970's after the introduction of high yielding varieties in wheat. The major trends which emerged from the data are:

- The consumption of fertilizers which was only 0.13 million tonnes of nutrient in 1955-56 and 8.5 million tonnes of nutrient in 1985-86 increased to 13.8 million tonnes of nutrient in 1993-94 (GOI, 1993).

• The percentage of area under high yielding varieties to the total area under the crop was increased from 2.6% and 3.9% in the case of paddy and wheat respectively in 1966-67 to 68% and 90.8% in the case of paddy and wheat respectively in 1992-93 (GOI, 1993; Mukhopadhya, 1994).

8.4.3.1.3 Change in land holdings

Land reforms in India have envisaged that beyond a specified limit (for the state of Bihar, the statutory limits are 6.07 to 7.28 ha, 10.12 ha and 12.14 to 18.21 ha for land irrigated with two crops, land irrigated with one crop and dry land respectively) all the lands are be taken over by the government and distributed to landless and other farmers having uneconomical land holdings. The law provided a number of exceptions for sugarcane farms, orchards and religious trusts. This explains partially the growth of orchards in the early 1970's (Stage i, section 8.3.2).

The average size of 'operational holding'[1] has been steadily declining in Bihar from 1.50 ha in 1970-71 to 0.87 ha in 1985-86. The effect of shrinkage of land holdings is two-fold:

• Farmers find labour selling a better option than working on an uneconomical size of land holding for agriculture,

• Farmers start growing vegetable crops. The area under vegetable crops is limited by credit availability and market for the produce.

Trees find a place in the above setting because they require less supervision and less capital.

8.4.3.1.4 Agricultural profitability

We will examine the following aspects of agricultural profitability in relation to tree growing:

a. agricultural output-input ratios,

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[1] Operational holding is defined as 'all land which is used wholly or partly for agricultural production and is operated as one technical unit by one person alone or with others without regard to the title, legal form, size or allocation'.

b. terms of trade in agriculture

c. price of agricultural commodities

a. Agricultural output-input ratios

The output-input ratio for agricultural and allied activities showed a declining trend (-21.10%) from 1970-71 to 1984-85. Nadkarni (1988) has observed that output-input ratios at constant (1970-71) price declined between 1970-71 and 1984-85 from 4.59 to 3.62. The new technological development requires use of increased quantity of inputs (fertilizer, pesticide and water), but contradictory to expectations, it resulted in a decrease in profitability. A farmer using high doses of fertilizer (N:P:K; 125:75:50 kg) in paddy achieved BCR of 1.88 as compared to another farmer using relatively low doses of fertilizer (N:P:K; 69:42:28 kg) who reached BCR of 2.84 (calculations are based on data of a single example given by Nadkarni, 1988). It shows that higher agricultural yield (higher quantity of inputs) generally results in higher returns but it may not necessarily result in higher profitability. We cannot generalize this for the entire study area but we expect similar results in most cases. This analysis is undertaken purely from a financial point of view. If we include the subsidy on fertilizer and water (ECBA), the gap between two BCRs will be much wider.

b. Terms of trade in agriculture

The proportion of industrial output (pesticide and diesel) in agriculture has increased sharply since late 1970's. The net barter terms of trade improved at an annual compond rate of 2.38% during 1961-62 to 1973-74 and deteriorated at an annual compound rate of 1.07% during 1973-74 to 1987-88 (Table 8.3). These aggregate terms of trade may affect farmers' production decisions and consequently adoption of tree growing in some areas.

Table 8.3 Inter-sectoral terms of trade of agriculture in India

1978-79=100

Year	1951-52	1961-62	1970-71	1973-74	1980-81	1987-88
Index*	86.9	86.9	109.9	115.7	89.7	98.5

Note: * The index is based on 'net barter terms of trade' using the value of intersectoral transactions for current production and current consumption in 1978-79 as weights. If Px and Pm are prices of exports from, and import to, the agriculture sector, the net barter terms of trade (i.e., relative price) can be expressed as Px / Pm.
Source:Thamarajakshi, 1990

c. Production and price of agricultural commodities

Agricultural prices have shown a continuous tendency to increase (both in money and real terms) over the last four decades (wholesale price index of agricultural commodities, 1950-51=100; 1960-61=112.7; 1970-71=211.9; 1980-81=446.0; 1990-91=993.7) (Shetty, 1978; GOI, 1993). But the price fluctuations in the case of rice and pulses (rice is the main crop in Bihar and pulses are grown in drier areas) are relatively high (GOI, 1991). However, the fluctuation in total yields is quite high. Although overall per capita availability of food grains has increased in the last four decades, the availability of 'other cereals' (mainly coarse cereals consumed by the poorer section of the farmers) and pulses has decreased marginally (Fig. 8.1).

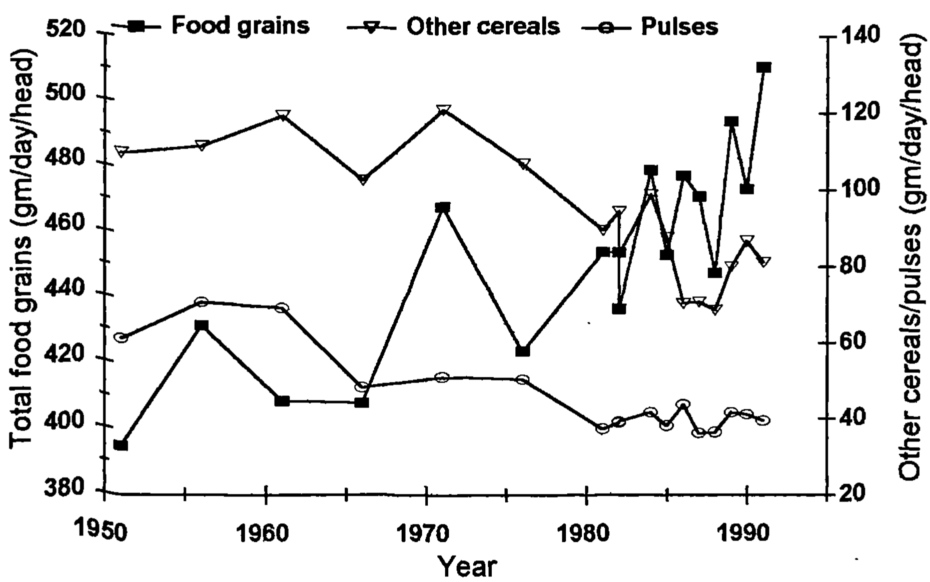

Fig. 8.1 Per capita availability of food grains in India

8.4.3.1.5 Rural credit

The credit needs of farmers have two dimensions:

a. the period required to repay the loan

- short term, e.g., loan for fertilizer, seeds etc.
- medium term, e.g., cattle purchase

- long term, e.g. purchase of tractor, borewell

b. The purpose of the loan is:

- productive, e.g. loans for agricultural input etc.
- consumption, e.g. loan in case of floods, drought etc.
- unproductive (marriage, funeral etc.)

With the adoption of new technology and development of irrigation, farmers require a large amount of money to procure agricultural input. A large sum of money is also required to meet social obligations of marriage, funeral and litigations. The regular income from the farm is generally used to meet daily requirements. The requirement of a lump sum amount of money, in the absence of adequate savings, can only be met by borrowing from institutional and non-institutional sectors.

Table 8.4 Debt owned by rural households to different credit agencies

(Per cent)

Credit agency	Years			
	1951	**1961**	**1971**	**1981**
1. Institutional	7.2	17.3	29.2	61.2
2. Non-institutional (a+b+c)	92.8	82.7	70.8	38.8
a Agricultural money lenders	25.2	47.0	23.1	8.6
b. Professional money lenders	46.4	13.8	13.8	8.3
c. Others (landlords, traders, relatives etc.)	21.2	21.9	33.9	21.9

Source: Ghothoskar, 1988

Table 8.4 shows that credit from institutional finance has increased significantly and the share of money lenders in providing rural credit has reduced considerably in the last three decades. The all India Debt and Investment Survey-1981 and the 37th Round of the National Sample Survey show that rural indebtedness grew by 97% and 60% (nominal) between 1961-71 and between 1971-81 respectively. The rate of growth of indebtedness was much faster for cultivators (102%, 1961-71) and (71%, 1971-81) as compared to non cultivators.

The availability of institutional credit to priority sectors (mainly agriculture and allied activities) in Bihar has increased phenomenally in the last 25 years (Table 8.5).

Table 8.5 Institutional credit in Bihar

No. of offices		Bank credit (Rs in million)		Share of priority sector in bank credit (%)	
June 1969	Sept. 1993	June 1969	Sept. 1993	June 1969	Sept. 1993
269	3004	520.5	38260	9.1	61.2

Source: GOI, 1993

Financial institutions, such as Cooperative banks and *Gramin* banks are not approachable for consumption loans or for loans to meet social or familial obligations. Moreover, since the interest rates for agricultural loans are fixed by the government, banks have to ration their loans among potential borrowers. This gives rise to a segmentation of credit markets and results in complicated inter-linkages between credit, tenancy and labour (Bell and Srinivasan, 1989).

At the time of collective crises, poor farmers are especially hurt because they have little to offer as collateral (sometimes, working for a fixed period during the peak season on money lenders' farms is accepted as a collateral in absence of any asset) and they cannot get loans even if they are willing to pay a higher rate of interest. The expected return to a lender depends on the probability of repayment and the expected return is a declining function of the interest rates he charges. Therefore, lenders would prefer to ration the credit rather than raise the interest rate (for mathematical proof; see, Eswaran and Kotwal, 1990).

The above analysis addresses the following important issues:

- increasing needs of finance by farmers.
- increased share of institutional credit and consequently provision of loans for production and consumption purposes.
- reduction in the role of non-institutional sources of finance which results in a decrease in availability of credit for unproductive or social purposes.
- non-availability of loans at time of crises even if borrowers are ready to pay a higher rate of interest
- the availability of credit for agriculture prompts farmers to go for intensification of cultivation in small irrigated plots and grow a tree crop in remote, relatively less supervised unirrigated areas.

8.4.3.2 Farmers' response to the change: the development of tree growing strategies

In recent years, tree growing has emerged as an important option in response to the changes outlined in section 8.4.3.1. The unique characteristics of a tree crop render trees an important option. The response varies depending upon farmers' resource endowment, family size, credit facilities etc.

Land is the most valued possession of farmers. Most transactions in land in Bihar are in tenancy, not in outright sales or purchases. A large proportion of sales of agricultural land are distress sales (food crises, death etc.). In contrast, the market for livestock (mainly bullocks in Hazaribagh and Garhwa districts, and goats in East Singhbhum, Sahebganj and Ranchi districts) is relatively buoyant. The livestock are typically bought and sold in *Hats* (regional market), not in village markets. This provides smoothing of consumption against village-specific risks. Thus, livestock, traditionally, are perceived as a capital asset and serve as a collateral on loans. With technological progress and the development of urban markets for livestock products, the role of livestock has shifted from 'store of wealth' to 'generators of income'. Farm forestry tends to fill this gap of 'store of wealth'.

The farmers aim to smooth their consumption in the face of uncertain income. The motive for savings is a precautionary one which is different from the life-cycle savings motive (Meade, 1966; Farrell, 1970). Consumption credit for the poor farmer enables him to smooth consumption without having to engage in *precautionary savings* and permits him to grow risky crops. The unavailability of consumption credit forces poor farmers to invest in safe and low return activities (Eswaran and Kotwal, 1989).

The role of trees as 'poor people's assets' has been identified by several authors (Chambers and Leach, 1989). The role of trees in providing a capital asset with easy liquidity has been recognised by farmers in the study area. More than 41% of small farmers and 64% of large farmers have planned to utilize money from plantations for lump sum expenditure (Table 8.6). Adoption of tree growing to meet lump sum requirements of capital (marriage, litigation, education, dowry etc.) is observed by a number of authors in other states of India (Slater, 1918; Hill, 1982; Shah, 1988 cited in Chambers and Leach, 1989). Farmers in Karnataka state have also used the lump sum money realised from tree farming in irrigation and other development activities (Bisaliah, 1990).

Chambers and Leach (1989), after noting needs to reduce poor farmers' vulnerability to contingencies, concluded:

"India's large-scale Integrated Rural Development Programme (IRDP) does provide poor people with economic assets, but these are intended to generate income which will raise them above the poverty line, not give them lump sums to meet contingencies."

Poor and small farmers with fewer opportunities (due to loss by encroachment and settlement of common grazing land viz. *Garmazurva Am* and *Garmazurva Khas*) for the traditional mode of savings (e.g. livestock), adopt tree growing to meet contingencies and lump sum investment needs. This is evident from the fact that:

- No farmer has harvested his complete plantation yet, though trees have reached above their normal rotation age.
- More than 39% of small farmers are not sure how would they utilize the money obtained from plantations. Obviously, they wish to keep plantations to meet any unforeseen expenditure (Table 8.6).

Table 8.6 Proposed utilization of plantation money

Utilization	Small farmer (n=135)	Large farmer (n=117)
Purchase of land	3.7%	8.5%
Loan repayment	8.1%	6.8%
Plant more trees	7.4%	8.5%
Don't know	39.6%	12.0%
Others*	41.2%	64.2%

Notes: 1. * marriage, education, dowry, borewell etc.
2. The utilization categories are significantly ($p<0.0005$) different both in small farmer and in large farmer separately following χ^2 test.

Ease of marketing and perception of good returns are essential for growing long gestation crops like trees. The role of trees to meet contingencies needs and as a capital asset (security needs) depends on ease in liquidity. Unlike many other states viz. Gujarat, Haryana and Karnataka where *Eucalyptus* is primarily used as raw material for paper pulp, in Bihar it is mainly used as mining props and poles. The disposal of produce from the plantation does not seem to be a problem because the Forest Department, Bihar is purchasing poles and props (of *Eucalyptus* and other species) from farmers at reasonable and competitive prices (pole price has increased in real terms over the last six years in Bihar while in northwestern India the price has dropped after a boom) to meet ever-growing demands of the mining industry and the Irrigation Department (poles are used to reinforce bunds - a flood control measure) (Table 8.7).

Table 8.7 Proposed disposal of plantations

Disposal	Small farmer (n=135)	Large farmer (n=117)
Sell in the market	37.0%	10.3%
Sell to the forest department	29.6%	59.8%
Own consumption	7.4%	17.1%
Other*	25.9%	12.8%

Notes: 1. *dowry, security for loans etc.
2.The disposal options are significantly ($p<0.0005$) different both in small farmer and in large farmer separately following χ^2 test.

Food security or feeling of food security is of vital importance to farmers in the study area. Even relatively rich farmers were found to grow some agricultural crop of cereals (mainly rice or maize) and pulses for household consumption even though they have sufficient sources of income to buy these from the market. Other farmers ('small' and poor) consider food grain production for consumption as their first priority. This (food security) may be an important reason for farmers to grow low remunerative food crops in some part of their lands and adopt tree crops in the rest.

8.4.4 Analysis of farmers' adoption decision

When a new technology is introduced, it is not accepted by all farmers instantaneously. A few people adopt the new technology at very early stages but the majority observe early adopters before taking the decision to adopt or reject. There may be many social and economic factors that can significantly affect the adoption decision. The adoption of tree growing is expected to be influenced by farmers' socioeconomic characteristics (like gender, caste, age, literacy, number of persons in the family etc.) and by external factors (e.g., farm size, irrigation facility, market, information and extension services etc.). Most of the adopters are expected to be educated, large farm holding, younger and belong to higher income groups. The non-adopters are expected to be older, poor, illiterate and belong to scheduled caste and scheduled tribe categories

(Feder, 1980, 1982 and Mann, 1989). We examine farmers' tree-growing adoption decisions in both spatial and temporal context.

8.4.4.1 Tree growing innovation: adoption decision, a temporal analysis

Tree growing innovation, like any other technology adoption, takes time to be accepted by all potential adopters. The time lag in the adoption decision divides farmers into early adopters and late adopters. The adoption time is influenced by
(a) informational externalities which include acquisition of information, and
(b) individual farmers' decision making capabilities (Pomp and Burger, 1995).

The diffusion of tree growing innovation among farmers spreads by copying by late adopters of early adopters. We examine whether early adopters of tree growing innovation were different in their characteristics from non-adopters or late adopters. We classify farmers who have planted 50 or more trees between 1980 and1985 as early adopters and farmers who had planted 50 or more after 1986 as late adopters. The non-adopters are those farmers who had either not planted any tree or planted fewer than 50 trees between 1980 and 1993. The choice of the number 50 is judged from experience.

We use discriminant analysis to investigate factors influencing adoption timing (early or late) and to devise criteria for classifying farmers into the above categories (non-adopters, early adopters and late adopters). In discriminant analysis, linear combinations of independent variables are formed and used in classification of two or more groups. We have included some dummy variables in the analysis, though linear discriminant function requires that independent variables have a multivariate normal distribution. But it can give fairly good result in the situation where the normality assumption is violated also (Gilbert, 1968; Moore, 1973). The theory of discriminant analysis is described in section 4.4.3.4.1.1 (Chapter 4).

A stepwise variable selection (criterion: probability of F, entry 0.05, out 0.10) algorithm is used which combines the features of forward selection and backward elimination. The significance level of all the selected variables is small (<0.05). So, we reject the hypothesis that all group (non-adopters, early adopters and late adopters) means are equal. Wilk's Lambda for all the variables is also <1 which confirms inequality among group means for individual variables.

We have included three groups (k) in the analysis so two (k-1) discriminant functions can be calculated. The first function has the largest ratio of between groups to within groups sum of squares. The second function is uncorrelated with the first and has the next largest ratio. Table 8.8 gives unstandardized discriminant function coefficients. The final statistics are presented in Table 8.1.1 (Annexure 8.1).

Table 8.8 Discriminant function coefficients

Variables	Unstandardized canonical discriminant function coefficients	
	Function 1	Function 2
Constant	-1.2168	-5.4782
FORPROD	-0.4248	0.9653
FWOODKM	-0.0566	0.0919
HHPOP	-0.0655	0.2276
INCOME	2.6001E-04	-2.6583E-04
IRRFTL	-0.7591	0.7882
PCFLWOOD	2.1267	2.6072
PCPOLES	-0.0719	0.0501
PCTIMBER	-1.7235	-0.2712
SEX	1.5383	0.4653
LANDOWN	1.7874	0.2617
AGASSET1	0.7382	-0.2089

Note: The description of the variables is given in Table 8.1.

These coefficients are used to calculate discriminant scores for each case. We get two scores (D_1 and D_2) per case, one for each function. The linear discriminant equation is given below:

$$D_1=B_0+B_1X_1+B_2X_2+B_3X_3.................+.B_pX_p$$

where the X's are the values of the independent variables and the B's are the coefficients estimated from data. If a linear discriminant function is to distinguish among three groups, the groups must differ in their discriminant score. Using the discriminant score, the probability that a case with a discriminant score of D_1 and D_2 belongs to the group 1, 2 or 3 is calculated and used in classification. Table 8.9 contains group means of Func. 1 and Func. 2. Group 3 has negative means for both Functions. Group 1 has positive means for Func 1 and slightly negative means for Funct 2. Group 2 has positive means for Func 2 and negative means for Func 1.

Table 8.9 Canonical discriminant functions evaluated at group means (group centroids)

Group	Label	Function 1	Function 2
1	Non adopters	0.59163	-0.07605
2	Early adopters	-0.30476	1.05825
3	Late adopters	-0.68324	-0.23763

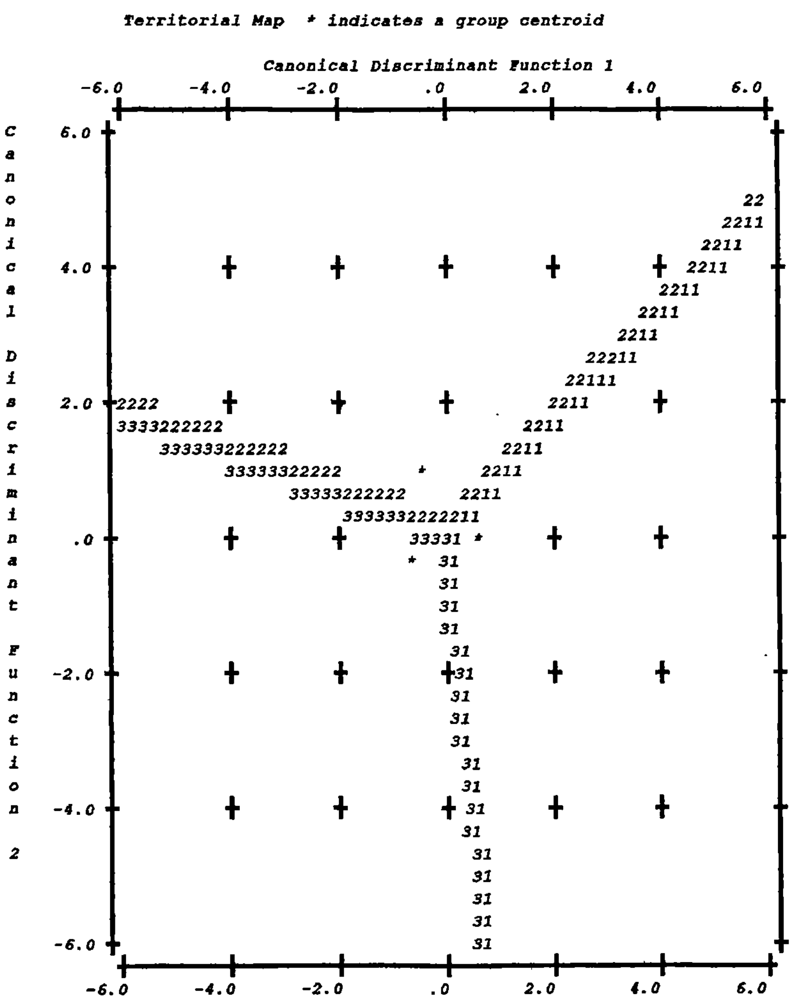

Fig. 8.2 Territorial map showing classification of non-adopters (1), early adopters (2) and late adopters (3)

Fig 8.2 shows the territorial map for the three groups on the two functions. The average score for a group is shown as a 'group centroid'. It is clear from territorial map and Table 8.9 that the group 2 is spread over the entire range. The analysis shows that:

(a) variables used in discriminant analysis fail to classify cases into three distinct groups, and

(b) group 1 (i.e. non-adopters) and group 3 (i.e. late adopters) are quite distinct.

On the basis of the above analysis, we conclude:

(a) Tree growing adoption is different from other farm technological adoption. According to technological adoption theory (Shultz, 1975; Rogers, 1983; Feder et al, 1985), early adopters must form a separate group as any new innovations are at first adopted by educated, rich, large farmers etc. But in the present study the spread of early adopters over the entire range clearly shows that the conventional theories cannot explain tree adoption processes.

(b) To study adoption behaviour a two-value model (adopter/non adopter) will be appropriate. Therefore, we reject m-logit model (multinomial logit model) in favour of logit model which is presented in the section that follows.

8.4.4.2 Logit model

8.4.4.2.1 Basic model structure

The adoption variable has two values: adopters or non-adopters. It assumes the value 1 if a farmer adopts and 0 if a farmer does not adopt. A logit or probit model is suitable for estimations in the case of a dichotomous dependent variable as a dichotomous dependent variable (Y=1, 0) presents problems in regression by violating many OLS assumptions. The logit model uses logistic cumulative distribution function (CDF) while the probit or normit model uses normal CDF. Both the models are comparable in respect to solution algorithm and are expected to yield similar results. We choose the logit model for convenience in interpretation of results and because the model requires far fewer assumptions. In logistic regression, we directly estimate the probability of adoption or non-adoption.

For a binary dependent variable, the numerical value of the variable is arbitrary. We are interested in classification of cases into one or the other categories of the dependent variable by the independent variables. The probability of being classified into the lower-valued category can be given as:

$P(Y=0)$

The higher-valued category can be calculated as:

$1-P(Y=1)$

The basic model can be written as:

Y=1 as $P(Y=1) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\beta_p X_p$

The predicted value of the above equation, theoretically, may not necessarily lie between 0 and 1. We can replace the probability that Y=1 with the *odds* that Y=1 (*odds (Y=1)*). The *odds (Y=1)* is the ratio of the probability that Y=1 to the probability that Y≠1. This can be expressed as:

odds $(Y=1) = [P(Y=1)] / [1-P(Y=1)]$

The odds has no fixed maximum value, but it has a minimum value of zero. The natural logarithm of the *odds* i.e., ln {[P(Y=1)] / [1-P(Y=1)]} is called 'logit (Y)' (Menard, 1995).

If we use the natural logarithm of the odds that Y=1, the predicted probability will be within 0 and 1. The equation can be written as:

$\text{logit}(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\beta_p X_p$

and *odds* $(Y=1) = e^{\ln[odds\,(Y=1)]} = odds(Y=1) = e^{\ln[odds(Y=1)]} = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 \dots\dots\dots\beta_{pX_p}}$

On converting the odds back to the probability that P(Y=1), using the equation, odds $(Y=1) = [P(Y=1)] / [1-P(Y=1)]$, we get

$$P(Y=1) = \frac{e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 \dots\dots\dots\beta_{pX_p}}}{1 + e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 \dots\dots\dots\beta_{pX_p}}}$$

If $Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\beta_p X_p$

On substituting the value of Z_i, we get,

$$P(Y=1) = \frac{e^{Z_i}}{1 + e^{Z_i}}, \quad or$$

$$= \frac{1}{1 + e^{-Z_i}}$$

The model can be written as:

$$P_i = \frac{1}{1 + e^{-Z_i}}$$

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots\ldots\ldots\ldots \beta_p X_p$$

where P_i is the probability of adopting tree-growing practice and Z_i is linearly related to the independent variables (X_p).

8.4.4.2.2 Model estimation and validation

The parameters of the model are estimated using the maximum-likelihood (ML) method. Since the model is nonlinear, parameters are estimated by an iterative process. We do not get R^2 in logistic regression model, but several analogues to R^2 (R^2_L, R^2_{LA}, pseudo-R^2, lambda-p (λ_p), tau-p(τ_p) and phi-p(ϕ_p)) can be used as a measure of multiple association between dependent and independent variables. General statistical packages (SPSS and SAS) do not print these statistics with the results. The details of estimation procedure are given in the Appendix 8.1. In most of the earlier studies (Royer, 1987; Hodges and Cubbage, 1990; Patel et al., 1995) only unstandardized logistic regression coefficients are presented and results are interpreted accordingly.

For the correct specification and validation of the model, it is necessary to consider nonlinearity in the model and interactions among variables. If the relationship is nonlinear in the logit, the change in logit (Y) for one-unit change in X is not constant but depends on the value of X. There are a number of techniques to detect nonlinearity in the model described by Hosmer and Lemeshow (1989). Similarly, it is also necessary to examine possible interactions among variables. The other problems in validation of the logit model include nonadditivity (the change in the dependent variable associated with a one-unit change in an independent variable depends on the value of one of the other independent variables) and collinearity (independent variables are correlated with one another) (Menard, 1995).

A number of independent variables are tested for significance. The expected influence of each of the independent variables is indicated by the positive, negative or question mark signs in the Table A8.1.2 (Annexure 8.1). A positive sign indicates that the variable would be expected to increase adoption; a negative sign indicates the converse. A question mark indicates the expected effect is unknown.

The stepwise logistic regression (criterion: probability of Wald statistics, entry, 0.05, out, 0.10) is used for primary selection of variables. However, the final inclusion of variables is on the basis of their contribution in the model, individual significance level, tests for nonlinearity and interactions. We test the interaction effect by comparing the model with and without all interaction items to determine whether the interaction is statistically and substantively significant. We do not include any interaction term in the model based on the above test. The model chi-square statistic (G_M) which is used to measure overall fit of the model, is highly significant (p=0.0000). In logistic regression, the slope of curve changes according to the value of independent variables. In our model LANDOWN is a dummy variable and IRRFTL is measured on 3-point scale. These variables cannot be compared directly to INCOME or PCTIMBER variable. A standardized coefficient measures variables in standard deviation (S.D.) units, i.e. one S.D. increase in the independent variable is associated with how many S.D. change in dependent variable. The estimation of standardized coefficients was not given by general statistical packages (SPSS and SAS). The estimation method is given in Appendix 8.1 and the results are presented in respective tables with unstandardized coefficients.

8.4.4.2.3 Results of the logit model

The estimates of the full model are given in Table 8.10. Standardized coefficients, partial derivative and elasticity are calculated for each independent variable taking the mean value of independent variables. All the variables in the model (full) are significant (p=0.01 to 0.0000). The significant variables indicate that the conceptual model formulated in the previous section may be an accurate hypothesis about the adoption decision.

Table 8.10 Estimated logit model (full) for the likelihood of adoption of tree growing

Explanatory variables	coefficient (β)	S.E. of β	Standardized coefficients	Derivative (prob. at mean)	Elasticity at mean
INTERCEPT	0.5241	0.5080	-	-	-
GOVFORTP	-0.0100*	0.0040	-0.1415	-0.0025	-0.2274
INCOME	-0.0005***	0.0001	-0.2662	-0.0001	-0.5910
PCPOLES	0.0845**	0.0299	0.1433	0.0211	0.1770
PCTIMBER	1.3995**	0.4790	0.1632	0.3499	0.2748
IRRFTL	0.6984**	0.2280	0.1909	0.1746	0.7349
LANDOWN	-2.0153****	0.2670	-0.3889	-0.5038	-0.6393

Notes: P=(Y=1) at mean =0.4965, N=288

Significance: *$p \leq 0.01$, **$p \leq 0.005$, ***$p \leq 0.0001$, ****P=0.0000

R^2_L=0.1811	-2 log likelihood (with intercept only)=698.69236
R^2_{LA}=0.16396	-2 log likelihood (with intercept and all variables) = 572.137
pseudo-R^2=0.2007	Model Chi-square (df=6) =126.555 (p=.0000)
λ_p=0.444	Improvement (df=1)=-9.654 (p=.0019)
τ_p=0.444	Classification: cases predicted correctly (overall)=72.22%
	The description of variable is presented in Table 8.1

The partial derivative of individual variables can be used to show the impact of individual variables on the adoption decision. For instance, one unit increase in per capita timber consumption (PCTIMBER) results in an increase in probability of adoption by 34.99%. Since the variables in the model are measured in different units, elasticity which is free from unit bias is a better measure. The model (Table 8.9) shows that a 1% increase in income results in 0.59% decrease in probability of adoption. Similarly, 1% increase in per capita pole and timber requirements will result in 0.18% and 0.27% increase in probability of adoption respectively. 1% increase in dependency on government forest (GOVFORTP) for forest produce results in 0.23% decrease in probability of adoption. The partial derivative of dummy variables tends to overestimate the marginal effect because values are either 0 or 1 (a partial derivative estimates instantaneous change in probability).

The significant findings are:

• The probability of adoption in small farmers (land ≤1.90 ha) is 0.77 as compared to 0.31 in the case of large farmers (land >1.90 ha). This is contradictory to findings by Saxena (1992) for Western U.P where market forces contribute significantly in the adoption decision and the majority of adopters are large farmers with experience in cash crops (sugar cane etc.).

•The effect of income on probability of adoption is more pronounced in the case of large farmers (Fig. 8.3). The role of trees as saving banks becomes less important at higher income. The probability of adoption at the same income is higher in the case of small farmers because (a) small farmers' sources of income are less diversified (b) large farmers have better access to other savings channels.

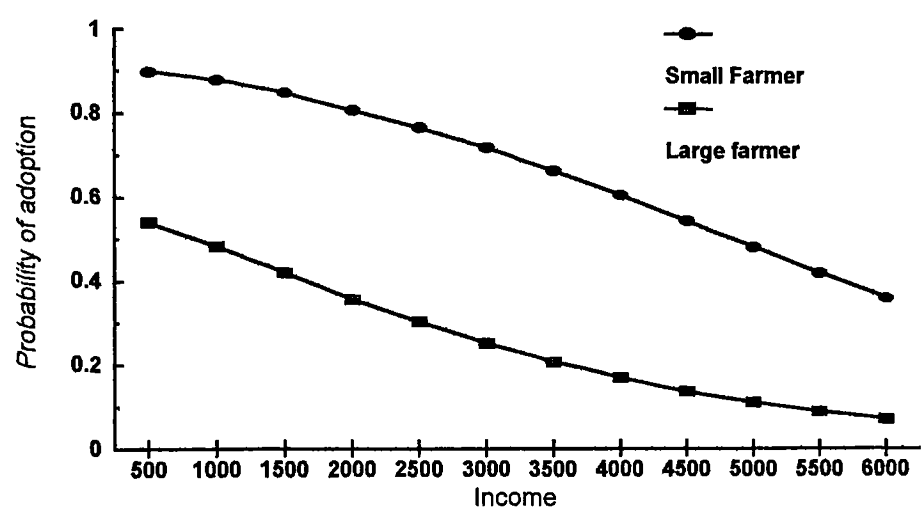

Fig. 8.3 Farmers' income and probability of adoption

• Better irrigation facilities result in greater probability of adoption in both large and small farmers (Table 8.11). Irrigated crops require intensive (in terms of supervision, labour, capital, fertilizer etc.) management. Tree-growing needs less capital and less supervision. As the income of farmers grows, farmers go for intensive management in larger areas and probability of adoption decreases. The opportunity cost of land becomes more important rather than securing small return. Small farmers' response to increase in income (in relation to tree-growing adoption) is less, probably because of their higher risk aversion level. Small farmers in this region grow vegetables (perishable, price fluctuations very high) in irrigated land which is risky as compared to cereals and cash crops grown by large farmers.

Table 8.11 Tree-growing adoption (probability of adoption) in response to irrigation facilities and farmers' income

Income	Small farmer			Large farmer		
(Rs per month)	Irrigation facilities			Irrigation facilities		
	Inadeq.	Good	Very Good	Inadeq.	Good	Very Good
500	0.81	0.89	0.94	0.36	0.53	0.69
1000	0.76	0.87	0.93	0.30	0.46	0.63
1500	0.71	0.83	0.91	0.25	0.40	0.57
2000	0.66	0.80	0.89	0.21	0.34	0.51
2500	0.60	0.75	0.86	0.17	0.29	0.45
3000	0.54	0.70	0.83	0.14	0.24	0.39
3500	0.48	0.65	0.79	0.11	0.20	0.33
4000	0.42	0.59	0.74	0.09	0.16	0.28
4500	0.39	0.53	0.69	0.07	0.13	0.23

Note: Inadeq.=inadequate or no irrigation

The model (full) shows that farm size is a very significant variable in farmers' adoption decision. So we develop two separate (small and large farmers) models to examine the contribution of different factors in farmers' decision making in individual categories.

A. Small Farmers

The estimates of the model with the model validation statistic are given in Table 8.12. The model chi-square is highly significant (P=0.0000). It predicts 100.0% and 95.6% cases correctly in the case of non-adopters and adopters respectively.

Table 8.12 Estimated logit model (small farmers) for the likelihood of adoption of tree growing

Explanatory variables	coefficient (β)	S.E. of β	Standardized coefficients	Derivative (prob. at mean)	Elasticity at mean
INTERCEPT	19.7238	0.0039	-	-	-
AGGRI	-0.0165****	4.2082	-1.4740	-0.00003	-0.0285
AGUPTINC	15.6052***	2.0026	0.7243	0.0256	0.0164
CASTE	-8.0156****	1.0265	-0.4356	-0.0132	-
COWEEP	4.2799****	0.0372	0.9060	0.0070	0.0192
GOVFORTP	-0.1646****	0.3620	-0.6816	-0.0003	-0.0155
HHPOP	-0.7624*	1.6349	-0.1070	-0.0013	-0.0082
LITERACY	-6.3786****	0.0432	-0.3322	-0.0105	-
PURWOODP	-0.1202**	1.2826	-0.3490	-0.0002	-0.0037
REGION	2.8999*	0.9961	0.1641	0.0048	-
IRRFTL	2.7406**	5.8921	0.1861	0.0045	0.0075

Notes: P=(Y=1) at mean =0.9984, N=142
Significance: *$p \leq 0.05$, **$p \leq 0.005$, ***$p \leq 0.0005$, **** $p \leq 0.0001$

R^2_L=0.69897	-2 log likelihood (with intercept only)=213.27378
R^2_{LA}=0.6052	-2 log likelihood (with intercept and all variables) = 64.202
pseudo-	Model Chi-square (df=10) =149.072 (p=.0000)
R^2=0.4476	Improvement (df=1)=-0.168 (p=.6819)
λ_p=0.8776	Classification: cases predicted correctly (overall)=96.74%
τ_p=0.9166	The description of variable is presented in Table 8.1

The main conclusions are:

- At mean level (mean value of all independent variables except the one referred to), literacy (literate or illiterate), caste (S.C+S.T or others), region (SGH or GRS) have very little impact on probability of adoption (Table 8.13). But their contribution is very significant for some values of independent variables.

Table 8.13 Caste, literacy, region and adoption decision

Adoption	Caste		Literacy		Region	
	S.C+S.T	Others	Illiterate	Literate	SGH	GRS
Probability	0.9713	1.0000	0.9998	0.8815	0.9996	0.9924

- Small farmers' adoption decisions are influenced by their source of income. Non-farm income (mainly urban) is perceived as secure income as compared to agriculture income which fluctuates sharply (monsoon and market). In Fig.8.4, a ratio of agriculture income to total income (total income=agricultural income+urban income) is plotted against probability of adoption for three irrigation facilities level (no or inadequate, good, very good). Zone B represents an area where agriculture income>urban income, the probability of adoption is very high and the influence of farm irrigation availability is negligible as urban income approaches to zero. Zone A represents the area where urban income>agriculture income and the probability of adoption increases with a decrease in a urban income. Better irrigation facilities lead to higher probabilities due to less secure income from vegetable crops (irrigated).

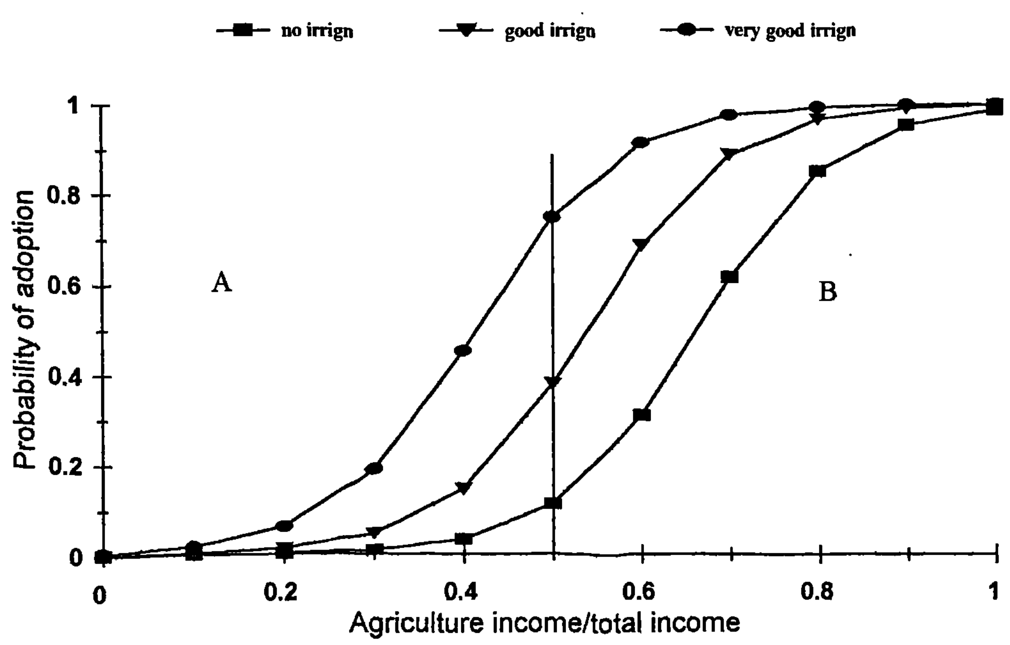

Fig. 8.4 The effect of the ratio of agricultural income to total income and irrigation facilities on probability of adoption

• Food security is of primary importance to small farmers. At low income levels, small farmers seek secure income in tree-growing innovations. With the increase in income, the feeling of insecurity diminishes. So the probability of adoption decreases. But at the same income level, farmers having better irrigation facilities opt for different crop patterns (high capital and labour requirement) (Fig. 8.5). In this situation, the probability of adoption increases in response to capital, labour and the supervisory constraint.

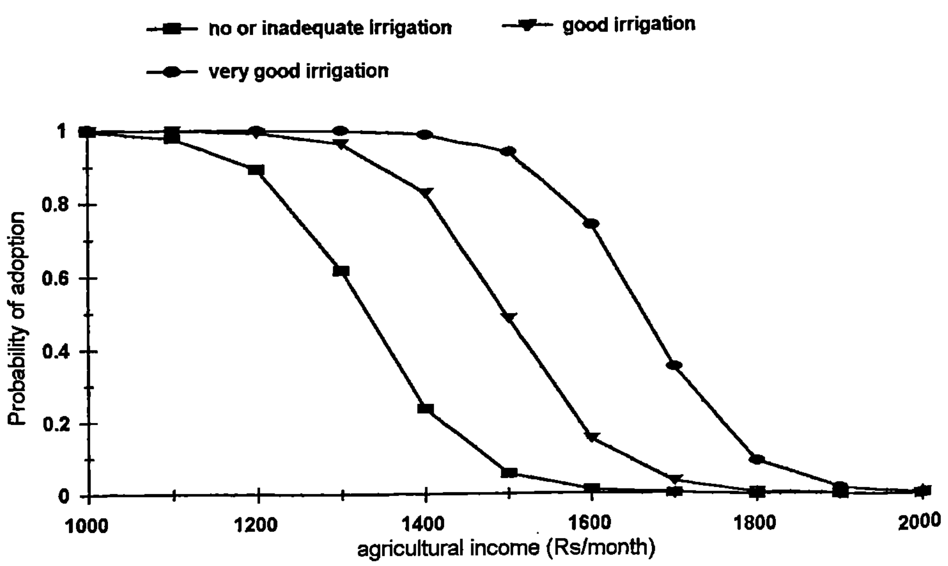

Fig. 8.5 Probability of adoption at different agricultural income and farm irrigation level

• Literate farmers have better access to banks and other financial institutions to invest their savings and seek credit as compared to illiterate farmers. At the same agriculture income level, the probability of adoption is significantly higher for illiterate farmers as compared to literate farmers.

B. Large farmers

The estimates of the model with the model validation statistic are given in Table 8.14. The model chi-square is highly significant (P=0.0000). It predicts 89.7% and 70.9% cases correctly in case of non adopters and adopters respectively. The adoption behaviour of large farmers is complex because it is also influenced by their personal characteristics, forest produce requirements, resource endowment etc. together with factors like the source of income and farm irrigation status.

Table 8.14 Estimated logit model (large farmers) for the likelihood of adoption of tree growing

Explanatory variables	coefficient (β)	S.E. of β	Standardized coefficients	Derivative (prob. at mean)	Elasticity at mean
INTERCEPT	-23.1759	4.1236	-	-	-
AGE	0.1274****	0.0304	0.1980	0.0029	0.1318
AGUPTINC	12.7367****	2.5580	0.8812	0.2918	0.2360
CASTE	-1.7110***	0.5171	-0.1850	-0.0392	-
COWEEP	-0.5929****	0.1092	-0.3296	-0.0136	-0.0656
FORPROD	2.8671****	0.5339	0.2913	0.0657	-
FWWOODKM	0.4159****	0.903	0.3327	0.0095	0.0765
LITERACY	1.7787***	0.4971	0.1769	0.0407	-
OCCUP1(1)	-2.4425**	0.8839	-0.5175	-0.0560	-
OCCUP1(2)	13.4416****	2.7074	2.8479	0.3079	-
OCCUP1(3)	-2.3689#	13.9180	-0.5019	-0.0543	-
PCTIMBER	7.6908****	1.2351	0.4489	0.1762	0.0740
URBAN	.0014*	0.0008	0.3163	0.00003	0.0179
AGASSET1	-2.6634****	0.5583	-0.2764	-0.0610	-
IRRFTL	1.5787***	0.4015	0.2014	0.0362	0.0867

Notes: P=(Y=1) at mean =0.9765, N=146

Significance: *p≤0.05, **p≤0.005, ***p≤0.001, ****P=0.0000, # not significant

R^2_L=0.42613 -2 log likelihood (with intercept only)=420.21511

R^2_{LA}=0.3595 -2 log likelihood (with intercept and all variables) = 241.148

pseudo-R^2=0.3588 Model Chi-square (df=14) =179.067 (p=.0000)

Improvement (df=1)=-11.451 (p=.0007)

λ_p=0.5299 Classification: cases predicted correctly (overall)=82.81%

τ_p=0.6295 OCCUP1 (cat.) value parameter coding

value	(1)	(2)	(3)
0	1	0	0
1	0	1	0
2	0	0	1
3	0	0	0

The description of variable is presented in Table 8.1

The main conclusions are:

- The probability of adoption increases with the increase in distance travelled for fetching fuelwood (distance: 1 km, prob.: 0.0085; distance: 15 km, prob.: 0.79) in the case of farmers whose main occupation is not agriculture. But for the farmers whose main occupation is agriculture, the distance does not affect the adoption decision. We may conclude that the second category of farmers (main occupation agriculture) does not grow trees to supplement their fuelwood needs. Their domestic fuel needs are mainly fulfilled by agriculture residue.

- The per capita timber requirement (PCTIMBER) influences the adoption decision for those farmers only whose main occupation is not agriculture (timber requirements: 0, prob.: 0.0062; timber requirements: 0.9, prob.: 0.8643). The farmers having non-farm income as their primary source of income require timber due to urbanized influence. For other farmers, requirements of poles may be a critical factor. The OCCUP1(2) variable, in fact distinguishes if agriculture income>non-farm income (OCCUP1(2)=1) or not, i.e. agriculture income< non-farm income (OCCUP1(2)=0). The same farm income/non farm income variable influences the adoption decision significantly in the case of small farmers.

- If a farmer has very little or no farm machinery (AGASSET) his adoption probability is very high (0.98, S.D. 0.017), but for a farmer with some farm machinery, the adoption decision is influenced by the level of farm irrigation status (which in turn changes crop patterns that require higher input). The probability of adoption varies from 0.66 (no or inadequate irrigation) to 0.98 (adequate). At subsistence agriculture (farm machinery less) level large farmers prefer tree-growing probably as a better land use option. But with good farm machinery, the criteria for the adoption decision shift towards problems (capital shortage, supervision and labour) caused by opting for high input crops.

- For a farmer with very little or no farm machinery the adoption probability is very high (0.97, S.D. 0.028) and the decision is not influenced by age of the farmer. A young farmer (age 20) with some farm machinery shows lesser probability (0.43) of adoption as compared to his older (age, 60; probability, 0.99) counterpart. It may be because of young farmers' low risk-aversion level and older farmers' supervisory constraints.

- At the mean level, the impact of urban income on probability of adoption is not very substantial (urban income Rs 0, prob. 0.95; urban income Rs 4000, prob. 0.99). But if a farmer has very little or no agriculture machinery and his main occupation is not agriculture, the increase in urban income results in the increase in probability of adoption (urban income: 0, prob.: 0.28; urban income: Rs 4000/month: prob. 0.99). This is the typical case of absentee landlords opting for tree-crops. With the increase in urban income, these farmers are no longer dependent on the farm for income.

8.4.5 Adoption intensity

In both the logit model and discriminant analysis, we have defined adopters as farmers who have planted 50 or more trees in the reference period, i.e. 1980-92. Some farmers had adopted tree-growing on their entire land area. But the majority of farmers have used part of their land in tree-growing. We use a ratio of land under tree growing to total land (i.e. area of plantation/total area of the farm) as the dependent variable to examine the factors influencing adoption intensity using multiple regression analysis. Instead of using individual variables, we use factor scores of all five factors, calculated in section 8.3.2, as independent variables. We find that only Factor 1 (planting technologies) is significant at 10% level and the explanatory power of the equation is too small (R^2=0.27) to arrive at any definitive conclusion.

8.5 Determinants of survival in FF

The success or failure of FF is often judged in terms of the survival of plants. The physical returns from plantations depend upon the biomass of individual trees and number of trees which have survived at the time of harvesting. The biomass of an individual tree is largely determined by site quality (soil type, rainfall etc.) and survival mainly depends on management practices (protection, weeding etc.). Both biomass and survival are determined by the quality of planting stock (genetic make-up of the species). The survival of plants in FF varies from 0-100%. The very low survival ranging from 0-10% was observed in 14% of cases while very good survival (>80%) was observed in 35% of plantations. In farmers' plots, there are a number of factors associated with survival of plants. Farmers' socioeconomic conditions, their awareness, management practice etc. are known to contribute towards achieving the desired survival. Arnold et al., (1990) have listed a number of factors responsible for low survival. They are:

(a) neglected weeding and soil work

(b) questionable seedling quality

(c) insufficient protection

(d) non-optimal time of planting.

Eucalyptus 'hybrid' and *Acacia auriculformis* account for more than 78% of total trees planted. In most nurseries, the seeds were collected locally without considering the quality of the seed source (plus trees). Grazing was considered as the most important problem in protection of the plantation by 18% of the farmers. The other problems in protection include fire, drought etc. The time of planting, which depends on the monsoon, is very crucial in the success of the plantation. In general departmental plantations (including RDF), the time schedule is vigorously maintained because success of plantations is measured in terms of survival. But in FF where to achieve distribution targets is perceived as the ultimate objective, to ensure seedlings availability to farmers in time often receives lesser priority.

We use multiple regression analysis (MRA) to analyse the factors explaining survival of plantations in farmers' plots. The following regression model is estimated using stepwise MRA (stepping method criteria: probability of F, entry, 0.05, out, 0.10).

$$SURVIVAL=\alpha_0+\alpha_1X_1+\alpha_2X_2+\alpha_3X_3+\dots\dots\dots\dots+\alpha_{17}X_{17}$$

The dependent variable in this model is SURVIVAL (expressed as number of trees survived/total planted). The intermediate harvests were included in the total number of survived trees. The model is estimated for 252 farmers covering six districts. Table 8.15 gives estimates of the above model.

Table 8.15 Survival estimates of linear regression model

Explanatory variables (x)	Estimates (α)	t-value	Beta
ADOPTDGR	0.082326*	2.011	0.052883
ADVICE	0.033181****	5.982	0.192906
AGE	-0.003567****	-4.148	-0.089239
AGUPTINC	0.084839**	2.856	0.091961
APROLAND	0.281133****	9.742	0.386741
CASTE	0.064772***	3.557	0.100404
EXPERNS	-0.050934**	-2.945	-0.068261
EXTNSN	0.022260**	3.142	0.134998
FWWOODKM	0.009899***	3.593	0.118010
IRRFTL1	0.041363**	2.896	0.089094
PCPOLES	0.007317***	3.948	0.099482
PCTIMBER	-0.089323**	-2.905	-0.083811
PROTECT1	0.040401****	4.443	0.150474
PROTHLP	-0.080137***	-3.489	-0.082355
REGION	0.052450**	3.059	0.082054
URBAN	2.77190E-05*	2.188	0.065874
WEEDNO	0.027172*	2.281	0.095552
CONSTANT	0.130320	-	-

Notes: Significance: *p≤0.05, **p≤0.00, ***p≤0.000, ****p p≤0.0000

R-sq=0.90391, Adjus R-sq=0.89693, S.E. 0.10281, N=252

F=129.48165, Significance F=0.0000

The description of variable is presented in Table 8.1

The model is well specified and the error term is independent. Tolerance is well above 0.01 and VIF is <4.5 for all the variables in the model indicating no problem of multicollinearity. APROLAND (suitable land, mainly agricultural land=1, not suitable land, mainly grazing land=0) is the most important variable in explaining survival. Higher survival is observed in agricultural lands and plantation on farm bunds. Plantations on grazing land or fallow land shows poor survival. The advice on silvicultural aspects of tree growing and its frequency both influence survival. The method of protection of plantations also influences plantation survival. The highest survival was observed in plantations protected by barbed wire or by watchman or by both. The farmers having experience in tree growing achieve lower survival in their plantation as compared to those who have no previous experience. The experience farmers might have devoted their most suitable land in earlier plantations. Now, only the second best land is available and is used for subsequent plantations.

On the whole, it is possible to explain thoroughly survival in the plantation on the basis of above listed variables. A model is also developed excluding all those cases showing 0% survival. It is possible that these farmers have participated in FF just to collect the subsidy and have no intention of tree growing. However, the results are not different from those of the above model.

8.6 Conclusions

We have examined different factors that lead farmers to adopt tree-growing. We have also considered possible interrelationships among different factors that lead farmers to adopt this practice. The logit model developed in this chapter can predict probability of adoption under different scenarios of socioeconomic characteristics of farmers while the factor analysis explains the role of tree management practice, extension services etc. in farmers' tree growing strategies.

In financial and economic cost-benefit analyses, we find high variability in farm forestry returns. In this chapter, we find high variability in individual farmers' tree growing strategies too depending upon their livelihood strategies. The consideration of these elements is absolutely imperative in any project appraisal as these are the main factors which decide not only project profitability but also help in drawing up future projects more suitable to ground realities.

Chapter 9

Social appraisal of afforestation projects

9.1 The objective of social appraisal

Financial, economic and social evaluations are three main aspects of project appraisals. Financial and economic aspects have already been discussed in chapter 6 and chapter 7 respectively. In chapter 6 we sought to quantify gains or losses from the government or the project authority's point of view. In chapter 7, we examined gains and losses wider than is usual in economic analysis by incorporating illicit removals in benefit streams. Unlike a financial appraisal which is concerned with the financial profitability of the project, an economic appraisal seeks to quantify losses or gains to the economy as a whole and it reflects net efficiency benefits to the nation (Irvin, 1978). A social appraisal is a step further in this direction as it considers, both efficiency and equity issues in a project appraisal. Projects cannot be evaluated in terms of their social utility through an economic appraisal because the efficiency criterion assigns equal value to all individuals in the society, ignoring their different income level and their different time preferences. Social appraisal addresses distributional and efficiency aspects together and reflects the distribution of a project's benefit to the economy.

The present chapter deals with the social dimension of a project appraisal. In this chapter our concern will be distributional aspects of a project. A social appraisal seeks to study the distributional aspects of a project by explicitly defining weights to different groups of the society and thereby assessing social utility of the project to the economy. The chapter begins by introduction of some of the fundamental concepts like the social welfare function and income distribution. In later sections, we use these concepts in social cost-benefit analysis of the farm forestry (FF) and the rehabilitation of degraded forest (RDF) components through case studies from the state of Bihar.

9.2 Social welfare function in context

Social cost-benefit analysis essentially seeks to incorporate social preference in the cost-benefit analysis framework. Social preference is interpreted as the sum of individual preferences. Social preferences are generally identified with Pareto optimality. A Pareto-optimal state is the state from which no Pareto improvement is possible and a Pareto improvement is a social change from which at least one person gains and nobody loses (Layard and Walters, 1994). Since it is not possible to find a project that fulfils the requirements of Pareto improvement (not a single person is worse off), the notion of *potential compensated Pareto improvement* was suggested by Kaldor (1939). According to Kaldor's proposition, if the gainers, from a move from one state to another, gain more than losers from that move, then the gainers could potentially compensate the losers. The second state should be regarded as socially superior. Scitovsky has demonstrated that Kaldor's test gives contradictory results. The Scitovsky paradox occurs because the transition from one state to another can be shown to be 'better' (worse) when valued at the prices ruling in the initial state, but 'worse' (better) when valued at the prices ruling in the new state (Dasgupta and Pearce, 1972). The above problems arising from *potential* (not actual) *compensated Pareto improvement* requires inclusion of both 'efficiency' and 'distribution' objectives into the objective function.

Now, we come to the problem of aggregation of individual preferences to define 'social choice'. Bergson-Samuelson's social welfare function addresses itself to this problem. If society consists of n individuals and U_i is the utility of the i th individual (i=1,2....n), the social welfare function (SW) can be given as:

$$SW=SW(U_i.....U_n)$$

The above social welfare function is basically a function of individual utilities. If the preferences amongst individuals in society were identical, the social utility function would be the same as the individual's utility function except it would be scaled up. However, the problem of articulating a social welfare function takes on added significance if individual preferences are not identical, and dictatorship is rejected. Arrow's and Sen's theorems are concerned with obtaining rules for determining a social ordering of those various alternatives based on the knowledge of individual orderings. The element of value judgement is involved in determining this ordering and consequently relative weights to different groups.

9.2.1 Arrow's impossibility theorem

The social welfare function can be considered as a social decision process (Arrow, 1963). Specifically, it is a collective choice rule for deriving a social ordering from individual preferences (Dasgupta and Pearce, 1972). Arrow's theorem states that there can be no such rule for determining social ranking which is based on individual preferences and satisfies four eminently reasonable requirements. They are: (a) Pareto rule, (b) independence of irrelevant alternatives, (c) unrestricted domains and (d) non-dictatorship (Layard and Walters, 1994).

The following important points emerge from the above discussion:

- Social cost-benefit analysis is supposed to provide a social choice based on aggregation of individual preferences.
- The impossibility theorem shows that such aggregation is not possible
- Explicit ethical judgement is required to determine social choice.

It is now well known that individual preferences without cardinality (with the exception of the ranking order of Sen, 1970, 1973) and interpersonal comparability are insufficient to allow for incorporating distributional issues in the project. The approach most commonly used (discussed in subsequent sections of this chapter) imposes four additional conditions: additive separability, symmetry, strict concavity and constant elasticity of marginal utility. The welfare function is called symmetric when the function value remains the same on different permutations of the same individual values. If welfare of an individual is defined as a function of his income (or consumption) alone, then the assumption of symmetry becomes less defensible. Non-symmetry may be needed to allow for other factors, such as leisure differences. Concavity is needed for egalitarian distribution. Strict concavity ensures that the marginal contribution to social welfare diminishes as a person's utility increases. The additive separability and constant elasticity of marginal utility assumptions might be justifiable on the ground of the simplicity of function (Ray, 1984). The important feature of constant elasticity form is that the weights tend to become very large as consumption disparities increase. This approach has two basic steps:

a. Individual utility is defined as a concave (to origin) transform on individual income or consumption levels, assuming an identical utility function, and,

b. Social welfare is defined as another concave ($W = \sum_{i=1}^{n} \frac{1}{\alpha}(U_i)^{\alpha}, \quad \alpha<1$) transform (required for maxima condition, second derivative negative) of individual utilities. It can be linear also as defined by Squire and van der Tak (1975). They assume an identical utility functions for all individuals, defined over consumption (C) in an iso-elastic manner

$(W = \sum_i U(i))$. This approach is not egalitarian in utility levels (α=1), the assumption that all individuals have identical utility functions makes it so in terms of consumption levels.
The second step is dependent on ethical judgement.

9.2.2 Three-objective social welfare function

So far we have considered efficiency and distribution for deriving the social welfare function. Brent (1990) has included the third dimension - the 'number effect' - into the function. The additional factor in the form of the number effect is required because the efficiency and distribution objectives fail to recognise the number of losers (or gainers) explicitly in a project. A project makes society better off if there are sufficient gains that losers may be compensated, and there is still some positive amount left over. This is the standard criterion (compensation test). But for real world projects it is impossible to arrange for compensation for all. It seems logical to include the number of uncompensated losers as a separate factor in the cost-benefit criterion (Brent, 1990). The methodology for incorporating the number effect into the social welfare function is still not well developed. Therefore, this aspect of project appraisal is not considered in the present study.

9.3 Income distribution

In recent years, there has been growing concern about the way the national income is distributed among households in the less developed countries (LDC) including India. There are a number of economic and social forces operating in the economy which influence the distribution of income. Income distribution shape is characterized by three main features - real income levels, income inequality and income clumping which are referred to in statistical terms as location, spread and modality respectively (Jenkins, 1996). The aspect of income distribution with which we are most concerned in social cost-benefit analysis is the inequality of income. The indices of inequality measure the extent to which actual distribution of income deviates from the egalitarian distribution of income (for a comprehensive review, see Kakwani, 1980). These indices are broadly classified into two groups: statistical measures of inequality and welfare measures of inequality. The statistical measures include:

(a) the range and decile ratio, (b) relative mean deviation, (c) coefficient of variation, (d) Hirschman Index and (e) Gini Index.

The welfare measures of inequality are based on the social welfare consequences of income distribution. Major conceptual problems with this approach are:

- specification of a utility function
- it does not consider inequalities of individuals while concentrating on the utility of all members of the society.

The most common inequality measures derived from the welfare approach are: the Dalton index, Atkinson's measures, the generalized Lorenz curve and the Sen index. All these measures are based on two key assumptions:

1. Welfare of individuals depends only on their income
2. Social welfare (of the society) depends on the welfare of individual members of the society.

All *these indices of inequality discussed above are static in nature as they are* concerned with the distribution of income at a point in time. It is observed that the pattern of income distribution as a whole changes very slowly over time but the factors usually assumed to influence it, for example per capita income, change more rapidly. The dynamic change usually involves:

(a) a general rise in incomes of all groups as a result of economic growth

(b) the movement of individuals among different income groups depending upon social mobility.

Adelman and Robinson (1978) have proposed a dynamic measure of inequality derived from the discounted values of the future income of individuals. The streams of future income projections are based on age, inter-class mobility etc.

The pattern of private consumption expenditure shows very little change over the ten-year period 1977-78 to 1987-88 in rural areas of India (Table 9.1). Therefore, the distribution of consumption expenditure at a point in time can be used for deriving weights for different groups.

Table 9.1 Distribution of total private consumption expenditure in rural areas

Income groups percentage	Private consumption expenditure (%)	
	1977-78	1987-88
0-30	15.0	15.6
30-70	33.1	33.3
70-100	51.9	51.1

Source: GOI, 1980; GOI, 1992a

It is often argued that the income distribution dimension in SCBA is of much relevance only to LDC's because of concerns for high inequality of income. But the recent data indicate that the inequality in developed countries measured as the ratio of income share of the highest 20% of the households ($H_{20\%}$) to that of the lowest 20% of the households ($L_{20\%}$), is relatively high as compared to some of the LDC's like India and Sri Lanka[1]. Jenkins (1996) has observed a marked increase in income inequality in the UK during the 1980s.

9.4 Dimensions of distributional weight

The issue of distributional weight is complex when the distribution of income is not equal. Even in a perfect competitive market, goods will be allocated to those with the greatest ability to pay, rather than those with the most willingness to pay (Brent, 1990). The distributional weighting procedure has two dimensions:

(a) intra-generational or intra-temporal distribution

(b) inter-generational or inter-temporal distribution

The intra-temporal dimension of distribution compares the income of rich and poor at a point in time. Conversely, inter-generational or inter-temporal distribution compares the income of the present generation to that of future generations.

1

Country (year)	% share of income or consumption		$H_{20\%}/L_{20\%}$
	$L_{20\%}$	$H_{20\%}$	
UK (1988)	4.6	44.3	9.63
Switzerland (1982)	5.2	44.6	8.58
India (1989-90)	8.8	41.3	4.69
Sri Lanka (1990)	8.9	39.3	4.42

Data Source (column 1, 2 and 3): World Development Report 1994 (World Bank, 1994)

The methods of deriving weights include:

(a) subjective weights decided by the government (Marglin, 1967; McGuire and Garn, 1969)

(b) the derivation of weight according to marginal utility of income of a particular group (Weisbrod, 1972)

(c) weights according to the reciprocal of marginal income tax rates (Krutilla and Eckstein, 1958, cited in Irvin, 1978).

The use of marginal rate of taxation as weights is criticised on the following grounds. Marginal rates often do not vary over very substantial income ranges implying constant marginal social valuations. This further implies that society makes no use of other taxes for equity purposes (Dasgupta and Pearce, 1972).

In SCBA, the weighting procedure is generally based on consumption as consumption is the ultimate aim of all economic activity. Therefore, the worth of a project has to be evaluated in terms of increase in consumption in the society. All income generated by a project is not consumed. Part of it is saved and reinvested. The present saving generates future consumption. The weighting procedure in inter-temporal distribution decides the magnitude of relative weight attached to consumption at different points in time. The two basic questions involving inter-temporal distribution weight are:

a. Is future consumption as valuable as present consumption?

b. At what rate should the value of the future consumption be discounted?

Equity demands that future generations should not be discriminated aginst just because they are born in future. The consumption of future generations is as valuable as that of the present generation. It suggests that the inter-temporal weight should be equal to 1. But this is not the conventional view (see, Price, 1993, Chapter 12, for more on this issue and alternative views).

The intra-temporal or intra-generational distributional issue addresses the quantification of the weights attached to the consumption of different individuals or groups of individuals in the society having different consumption levels. The additional unit of consumption has different values to different groups or individuals according to their present consumption level.

9.4.1 Inter-temporal distribution

The inter-temporal distribution accounts for consumption of future generations arising due to savings of present generations. The weight for savings at time 't' compared with consumption at 't' can be calculated as below (Dasgupta and Pearce, 1972):

Let a unit investment (year 0) generate an annual throw off q in perpetuity, a part of which s is saved and reinvested and the rest (1-s) is consumed. Then, cumulative income will be the sum of all the previous throw-offs (i.e. Income in year 1, q; year 2, $q+sq^2$; year 3, $[q+sq^2+sq(q+sq^2)]$ or $q(1+sq)^2$ etc.). Consumption, reinvestment and throw-off for each year can be given as below:

Year	Consumption	Reinvestment	Throw-off in perpetuity
1	$(1-s)q$	sq	sq^2
2	$(1-s)(q+sq^2)$	$s(q+sq^2)$	$sq(q+sq^2)$ or $sq^2(1+s)$
3	$(1-s)[q(1+sq)^2]$	$sq[q(1+sq)^2]$	$sq^2[(q+sq)^2]$

If the consumption rate of interest (CRI) is r, the sum of discounted consumption streams (v) will be:

$$v=\frac{(1-s)q}{1+r}+\frac{(1-s)q(1+sq)}{(1+r)^2}+\frac{(1-s)q(1+sq)^2}{(1+r)^3}\ldots\ldots\ldots\frac{(1-s)q(1+sq)^{n-1}}{(1+r)^n},\quad n=\infty$$

....eq. (9.1)

Taking {(1-s)q}/(1+r) as common eq. (9.1) can be written as:

$$v=\left[\frac{(1-s)q}{1+r}\right]\left[\frac{(1-s)q(1+sq)}{(1+r)^2}+\frac{(1-s)q(1+sq)^2}{(1+r)^3}\ldots\ldots\frac{(1-s)q(1+sq)^{n-1}}{(1+r)^n}\right],\quad n=\infty$$

....eq. (9.2)

Let (1+sq)/(1+r)=x, the above equation can be written in the form of an infinite GP series: when (1+sq)<(1+r) or sq<r and 0<x<1

$$v=\left[\frac{(1-s)q}{1+r}\right]\left[1+x+x^2+x^3\ldots\ldots n-1\quad n=\infty\right] \text{ or}$$

$$v=\left[\frac{(1-s)q}{1+r}\right]\left[1+\frac{1}{1-x}\right] \quad \text{eq. (9.3)}$$

On substituting the value of x in eq. (9.3), we get,

$$v=\frac{(1-s)q}{(r-sq)} \quad \text{eq. (9.4)}$$

Equation 9.4 only gives plausible results when sq<r. If sq≥r, the value of v will be infinite or negative. In this situation (sq≥r), it could assumed that after some finite period (say n), an optimal stage (savings are as valuable as consumption) is reached. The investment remains sub-optimal until $(T+1)^{th}$ year. Equation 9.21 can be written in the form of a finite GP series as below (Bruce, 1976):

n=T+1

$$v=\left[\frac{(1-s)q}{1+r}\right]\left[1+x+x^2 \ldots\ldots x^{T+1-1}\right] \text{ or}$$

$$v=\left[\frac{(1-s)q}{1+r}\right]\left[\frac{1(1-x^T)}{1-x}\right] \quad \text{eq. (9.5)}$$

On substituting the value of x in eq. 9.5, we get,

$$v=\left[\frac{(1-s)q}{r-sq}\right]\left[1-\left(\frac{1+sq}{1+r}\right)^T\right] \quad \text{eq.(9.6)}$$

Lal (1980) has used n (i.e. T+1)=50 years for India.

The above equations (eq. 9.4 and 9.6) are based on the assumption that investment will generate throw-off in perpetuity. If we assume that investment yields throw-off only once but the consumption stream will be generated in perpetuity as below.

A unit invested in year 0 produces (1+q) at the end of year 1. The income, consumption (s is proportion saved), reinvestment streams for subsequent years are as follows:

Year	Income	Consumption	Reinvestment
1	1+q	(1-s)(1+q)	s(1+q)
2	s(1+q)	$(1-s)s(1+q)^2$	$s^2(1+q)^2$
3	$s^2(1+q)^3$	$(1-s)s^2(1+q)^3$	$s^3(1+q)^3$

The sum of consumption streams up to infinity, after discounting at the consumption rate of interest (CRI=r), can be given as (Trivedi, 1987):

$$v=\left[\frac{(1-s)(1+q)}{(1+r)-s(1+q)}\right] \qquad \text{eq. (9.7)}$$

Since the present savings are equivalent to future consumption, the parameter v is used to assign inter-temporal impact weight. Eq. 9.7 seems inappropriate because it is not based on plausible assumptions. Depending upon the value of *r*, *s* and *q*, an appropriate equation (equations 9.4; 9.6) will be used for the social appraisal of FF and RDF in the case study.

9.4.2 Intra-temporal distribution weight

In intra-temporal distribution, we assign relative weights for incremental consumption to individuals at different consumption levels. To derive distributional weights, we have to define a utility function of each individual. If C is consumption and U is utility for that consumption level, the marginal utility of consumption will be dU/dC. The assumption underlying the utility function is that the marginal utility of consumption decreases as the level of consumption increases. The change in consumption dC will result in change in marginal utility as d^2U/dC^2. We assume that the percentage change in marginal utility of consumption is proportional to the percentage change in consumption.

$(d^2U/dC^2)/(dU/dC) \propto (dC/C)$ or

$(d^2U/dC^2)/(dU/dC)=-n(dC/C)$ or

$(dU/dC)=aC^{-n}$

where *a* is constant and *-n* is the elasticity of marginal utility of consumption.

$(dU/dC)=U_C$, U_C is marginal utility of consumption at consumption level C.

$$U_C=aC^{-n} \qquad \text{eq. (9.8)}$$

A higher value of n suggests a higher rate of diminishing marginal utility and more egalitarian government's objectives (Squire and van der Tak, 1975). The marginal utility of consumption for two different levels of consumption C_1 and C_2 can be written as:

$$U_{C1}=aC_1^{-n} \quad \text{eq. (9.9)}$$

$$U_{C2}=aC_2^{-n} \quad \text{eq. (9.10)}$$

On dividing eq. (9.9)/eq. (9.10), we get:

$$(U_{C1}/U_{C2})=(C_1/C_2)^{-n}$$

Suppose the marginal utility of consumption at today's average level of consumption is U_{C1}. We take it as the reference level and assign a marginal utility weight 1. Then the weight (d_2)can be given as:

$$d_2=U_{C2}=(C_2/C_1)^{-n} \quad \text{eq. (9.11)}$$

Eq. 9.11 can be written in general form as:

$$d_C=U_C/U_{\hat{C}}=(C/\hat{C})^{-n} \quad \text{eq. (9.12a)}$$

d_C is consumption distribution weight for marginal changes, C is consumption level C and $\hat{C}$ is average consumption level (i.e., reference level).

For a non-marginal changes in consumption, d_C is redefined as below:

If C_2-C_1 is non-marginal, the change in utility is given by integrating eq. (9.8),

If n=1

$$U_{(C)}=\int aC^{-n}dC$$

$$=a \ln C$$

$$U_{C(2)}-U_{C(1)}=a(\ln C_2-\ln C_1)$$

$$=(\ln C_2-\ln C_1)/\hat{C}^{-n}$$

If $n \neq 1$

$$U_{(C)}=\int aC^{-n}dC$$

$$=aC^{1-n}/1-n$$

$$U_{C(2)}-U_{C(1)}=a[C_2^{(1-n)}-C_1^{(1-n)}]/(1-n)$$

$$=a[C_2^{(1-n)}-C_1^{(1-n)}]/[(1-n)\hat{C}^{-n}]$$

The weight or change in utility per unit change in incremental consumption is given as:

$$d_C=(U_2-U_1)/(C_2-C_1)$$

$C_2>C_1$

$n \neq 1$

$$d_C=[\{C_2^{(1-n)}-C_1^{(1-n)}\}\{\hat{C}\}]/[(1-n)(C_2-C_1)] \quad \text{eq. (9.12b)}$$

n=1

$$d_C=[(\ln C_2-\ln C_1)(\hat{C})]/(C_2-C_1)$$

The choice of an iso-elastic utility function imparts to weight ($d=(U_C/U_{\hat{C}})=[(\hat{C}/C)^{n}]$) the following properties:

- If n=0, the weight on a consumption increment at all consumption level is unity.
- If n>0, d depends only on $\hat{C}/C$ (Ahluwalia, 1974).

For SCBA, the consumption forgone (social costs) and the consumption generated (social benefits) on account of the project should be broken down to show their distribution into various consumption groups. These should be multiplied by the utility weights for the mean consumption level for each group and the resulting figures added together to arrive at utility-weighted consumption costs and benefits.

9.5 Marginal utility of consumption: the model

The estimation of elasticity of marginal utility of consumption is required to estimate distributional weights and the social discount rates discussed in section 9.4 and section 9.6. The model is developed by Fellner (1967) based on earlier works of Fisher (1927). This model is widely used to estimate marginal utility of consumption (Lal, 1972; Kula, 1984, 1985, 1988) and it has been found to give plausible results.

Let the utility function of a representative individual represent national average income and consumption level, and the utility function be additively separable in relation to two goods viz. food and non-food.

$$U=U(x_1, x_2)=U(x_1)+U(x_2)$$

where x_1 ($x_1=x_{11}, x_{12}, x_{13}, x_{14}......x_{1n}$) represents consumption expenditure on bundles of food and x_2 ($x_2=x_{21}, x_{22}\ x_{23}.........x_{2n}$) is the consumption expenditure on non-food.

The first order condition for the maxima for utility function $U(x_1, x_2)$, under a budget constraint, is given by the following equation based on the Lagrangian multiplier method (Sharma, 1991).

$$(1/P_f)\{\partial U(x_1, x_2)/\partial x_1\}=\mu=(1/P_{nf})\{\partial U(x_1, x_2)/\partial x_2 \quad \text{or}$$

$$\{\partial U(x_1, x_2)/\partial P_f\, x_1\}=\mu=\{\partial U(x_1, x_2)/\partial P_{nf}\, x_2$$

where P_n and P_{nf} are the price indices of food and non food commodities, the Lagarangian multiplier μ is the marginal utility of consumption and $\{\partial U(x_1, x_2)/\partial x_1\}$ and $\{\partial U(x_1, x_2)/\partial x_2\}$ are the marginal utilities of food and non-food commodities respectively.

At equilibrium, additional expenditure either on food or non-food provides the same increase in social utility of consumption. Suppose m% change in food prices neutralises 1% change in real income of the representative individual so that the representative food consumption remains constant. It means that the marginal utility of income has changed by -m% with 1% change in real income which is the marginal utility of income (-n). Fellner (1967) has shown:

$-n=-m=-1/n_f$, ...eq. (9.13)

n_f can be expressed as:

$-n_f=-\check{n}_p/n_y$..eq. (9.14)

where $-\check{n}_p$ is compensated or pure price elasticity of demand for food, n_y is income elasticity of demand for food and $-n_f$ is the ratio of the two.

This is based on the assumption that at a given income food price increase leads to a decrease in food consumption in proportion of n_p and an increase in income in the proportion of $-n_p/n_y$ is required to keep food consumption at constant level. From eq. (9.13) and eq. (9.14) we get:

$-n=n_y/\check{n}_p$..eq. (9.15)

The direct estimation of $\check{n}_p$ is not possible. Therefore, we estimate uncompensated price elasticity (n_p) which gives compensated or pure price elasticity ($\check{n}_p$) after deduction of the income effect. The possible effects of relative change in price are as below:

(a) decrease in 'food' demand with decrease in the price of 'non-food' (substitution effect)

(b) reduction in the price of 'non-food' makes additional income available to the consumer, which may increase demand for food (income effect) (Trivedi, 1987).

The income effect can be estimated using the following equation given by Stone (1954) and Fellner (1967):

$\check{n}_p=n_p-\phi n_y$..eq. (9.16)

where $\check{n}_p$ is compensated price elasticity of the food demand function, n_p is uncompensated price elasticity of the food demand function, n_y is income elasticity of demand for food and ϕ is the proportion of food in consumers' budget.

Equation (9.16) is also called the Slutsky equation for relation of compensated and uncompensated responses to price changes written in elasticity form. The elasticity of marginal utility of consumption is given as below:

$-n=n_y/\check{n}_p$..eq. (9.17)

9.5.1 Food demand function

For estimation of n_y and $\check{n}_p$, it is necessary to define the food demand function.

We specify the food demand model as follows to estimate the values of n_y and n_p:

$$D=f(Y, P_f/P_{nf}, T) \quad \text{eq. (9.18)}$$

The above equation can be written in the following form after including the error term:

$$D=AY^{n_y}\left(\frac{P_f}{P_{nf}}\right)^{n_p} e^{\psi T} e^{\varepsilon} \quad eq.\ (9.19)$$

Equation (9.19) can be written in log linear form as below:

$$\ln D=\ln A+ n_y \ln Y+ n_P \ln (P_f / P_{nf}) + \psi T + \varepsilon \quad \text{eq. (9.20)}$$

where D is the demand for food expressed in terms of per capita food consumption expenditure, A is a constant, Y is per capita income, (P_f / P_{nf}) is the ratio of price indices for 'food' and 'non-food' items, ψ is a coefficient to capture any other change (especially taste) with respect to time and ε is an error term.

n_p and n_y can be estimated by the following equations:

$$n_p=\frac{\partial lnD}{\partial\ln(P_f / P_{nf})}, \qquad n_y=\frac{\partial lnD}{\partial\ln Y}$$

Jones (1993) has suggested an alternative form of food demand model and advocated a quantity-dependent approach instead of a price-dependent approach.

9.6 The social discount rate

The discount rate used in SCBA is known as the social discount rate (SDR) or the social accounting rate of interest (SARI) or the social time preference rate (STPR). It is defined as the 'rate of decline in value of the numeraire over time' (Price, 1989). In ST methodology (Squire and van der Tak, 1975) 'public income' is the numeraire, so the accounting rate of interest (ARI) is the SDR while in UNIDO methodology 'consumption' is the numeraire. Therefore, the consumption rate of interest (CRI) is the SDR (Brent, 1990). Now, we examine the relation between the two interest rates. The SDR is a particular interest rate and is the rate of fall in the value of numeraire over time. The shadow price of capital v (S & T methodology) can be given as:

$$v = \frac{W_g}{W_{\dot{c}}} \quad eq.\ (9.21)$$

where W_g is the social value of a unit of government resource and W_c is the marginal social value of one unit of consumption by a person in the group at the average level of consumption.

Taking logs of both sides of eq. (9.21),

$\ln v = \ln W_g - \ln W_{\dot{c}}$

Taking the derivative of both sides with respect to time, we get,

$$\frac{dv / dt}{v} = \frac{dW_g / dt}{W_g} - \frac{dW_{\dot{c}} / dt}{W_{\dot{c}}} \text{..........} eq.(9.22)$$

By multiplying both sides of eq. (9.22) by -1, we get,

$$-\frac{dv / dt}{v} = -\frac{dW_g / dt}{W_g} - \left\{ -\frac{dW_{\dot{c}} / dt}{W_{\dot{c}}} \right\} \text{..........} eq.(9.23)$$

where $-\frac{dv / dt}{v}$ is rate of fall in the value of *v*, $-\frac{dW_g / dt}{W_g}$ is rate of fall in the value of public income i.e., ARI and $\left\{ -\frac{dW_{\dot{c}} / dt}{W_{\dot{c}}} \right\}$ is the rate of fall in the value of consumption i.e., CRI.

Eq. (9.23) can be wriiten as:

The rate of fall of v over time = ARI - CRI

The above equation is based on the assumption that investment will always be more valuable than consumption (Squire and van der Tak, 1975; Brent, 1990).

For estimating SDR, we assume that individuals' welfare in a society is determined by their level of consumption rather than their level of income. We use the concept of inter-temporal welfare function which can be represented in the form of the social indifference curve (C_{t1} against C_{t2}, where C_{t1} is consumption in year t_1 and C_{t2} is the consumption in year t_2). The 'levels' of utility at any two points in the curve will be the same (by definition of social indifference curve) (Pearce and Nash, 1981).

$$\Delta C_{t_1}\left(\frac{dU_{t_1}}{dC_{t_1}}\right)=\Delta C_{t_2}\left(\frac{dU_{t_2}}{dC_{t_2}}\right) \qquad eq.\ (9.24)$$

$$\frac{\Delta C_{t_2}}{\Delta C_{t_1}}=\frac{dU_{t_1}/dC_{t_1}}{dU_{t_2}/dC_{t_2}} \qquad eq.\ (9.25)$$

$\Delta C_{t2}/\Delta C_{t1}$ is the slope of indifference curve. STPR is derived from individuals' rate of time preference. We use the diminishing marginal utility of consumption model to derive STPR. This is based on the following two assumptions:

(1) future generations will be richer

(2) diminishing marginal utility of consumption exists both between generations and within generations.

Applying the law of diminishing marginal utility, we assume that

$$\frac{d(dU_{t_1}/dC_{t_1})}{dC_{t_1}} < 0$$

we can write eq. (9.25) as:

$$1+r=\frac{dU_{t_1}/dC_{t_1}}{dU_{t_2}/dC_{t_2}} \qquad eq.\ (9.26)$$

where *1+r* (or $\Delta C_{t2}/\Delta C_{t1}$) is the slope of indifference curve and *r* is a social time preference rate (STPR).

The marginal utility of consumption at two instants of time t_1 and t_2 can be given as:

$$aC_{t_1}^{-n}=\left(\frac{dU_{t_1}}{dC_{t_1}}\right), \quad aC_{t_2}^{-n}=\left(\frac{dU_{t_2}}{dC_{t_2}}\right) \qquad eq.\ (9.27)$$

where *a* is constant and *-n* is the elasticity of marginal utility of consumption

Substituting eq. (9.27) in eq. (9.26), we get:

$$1+r=\frac{aC_{t_1}^{-n}}{aC_{t_2}^{-n}}=\frac{C_{t_1}^{-n}}{C_{t_2}^{-n}}=\frac{C_{t_2}^{n}}{C_{t_1}^{n}} \quad \ldots\ldots\ldots\ldots eq.\ (9.28)$$

$$\left(\frac{C_{t_2}}{C_{t_1}}\right)>1 \text{ now, so that } \left(\frac{C_{t_2}}{C_{t_1}}\right)=1+g \quad \ldots\ldots\ldots\ldots \text{eq. (9.29)}$$

where g is annual proportional growth of per capita consumption between time t_1 and t_2. Hence from eq. (9.28) and eq. (9.29), we get:

$(1+r)=(1+g)^n$ or

$r=(1+g)^n-1$ ....eq. (9.30)

If $g<<1$, the eq. (9.30) can be written as

$r=ng$

The eq. (9.26) is based on the assumption that utility is a function of consumption alone. If we assume that utility depends on both pure time preference and consumption, the eq. (9.18) can be written as:

$r=(1+g)^n-1+\rho$ ....eq. (9.31)

ρ is a pure time preference rate.

The use of ρ in the above equation is questioned by many authors (e.g. Nash, 1973; Price, 1973; Dasgupta and Heal, 1979; Kula, 1981; Pearce and Nash, 1981) mainly from a societal point of view. Under normal circumstances, society can be assumed immortal. Inclusion of ρ in the equation may be interpreted as reflecting the probability of extinction of the society. Squire and van der Tak (1975) recommended a very low value (0-5%) on the ground that most governments consider their obligation to the present generation and future generations.

Kula (1986) has derived STPR for Trindad and Tobago on the basis of an individualistic, independent and multi-period consumption utility function. Kula's approach is based on the model suggested by Eckstein (1961) and Henderson (1965) who argued that a discount rate for a nation can be computed on the basis of individuals' survival probabilities and sex-age distribution of the population. The pure time preference rate (m) is included as below:

$r=(1+m)(1+g)^n-1$

where m is a mortality based pure time discount rate.

The discount rate based on SOC approach intends to perform the function of allocating the investment among the potential candidates for alternative use of investment funds. It is often argued that the public project should be evaluated using a discount rate based on SOC approach because the investment funds in developing countries are extremely limited and in many cases the best alternative use of the investment fund is in the private sector in which case the following problems may arise (Kula, 1988):

a. Private profits may be quite high not because of 'efficiency' but as a result of imperfections in the market.

b. The estimation of opportunity cost of capital (detailed methodology is in Chapter 7) is difficult under market imperfection.

c. SOC does not consider society's perception of profitability.

Therefore, some adjustment in the SOC approach is required before it can be used in evaluating public projects.

Marglin (1967) and Feldstein (1964) have advocated a combined approach to including both social opportunity cost of capital (SOC) and a social time preference rate (STPR) which is based on the argument that the opportunities for transferring present consumption into future consumption through saving should also be reflected in the SDR. This is done by including an additional term for rate of fall in the social value of public income. They differentiate both sources of finance for a project and types of benefit.

$SDR = CRI + (1/v)\, dv/dt$

Scott (1977) has given an alternative approach which avoids problems raised by the non-equivalence of STPR and SOC by taking public sector investments only and using the concept of 'base-level' income. Scott (1977) defines base-level income as that level such that the Government is indifferent between marginal gains accruing to persons with base-level income and marginal gains accruing to itself. The rate of growth of base-level income can be used to estimate the rate of fall in both its marginal social value and in that of the Government expenditure, provided n (the elasticity of social weight given to marginal additions to such income with respect to changes in the income) and ρ (pure rate of time preference) are known. SDR can be given as follows:

$SDR= n\,(\dot{g} / g) + \rho,$

where $(\dot{g} / g)$ is the proportionate rate of growth of real base level income.

Generally, in developing countries, funds for investment are drawn from diverting consumption expenditure. The CRI which is based on the STP approach is preferable because it allocates consumption inter-temporally by determining overall rate of forgone current consumption. Since CRI is dependent on both *n* (elasticity of marginal utility of consumption) and *g* (growth rate of consumption), for a given value of *n* CRI will be directly proportional to *g* which in turn is related to economic growth. Higher values suggest lower weight attached to the future marginal consumption. The eq. (9.19) is valid under following assumptions:

- *n* is assumed to be the same for all individuals for different consumption groups during a time period.
- *n* is also assumed to be the same for average consumption groups in different time periods.
- *g* is constant for all consumption groups
- If the value of *n* and *g* are not constant over time, different discount rates will have to be used for different periods.

The selection of a group to represent a growth rate of consumption for a society is difficult when different groups of consumers have different rates of consumption. Use of average rates (of individual income groups) of income growth can distort calculations of NPV of projects, particularly those of long duration. It is suggested that the problem can be solved by recalculating inter-personal weighting factors periodically on the basis of relative incomes but it will involve separating weighting and discounting procedures (Price and Nair, 1985).

9.7 Shadow wage rate of labour

The market wage rate may not reflect the social cost of labour because:

- Imperfections in the market may lead to a gap between market wage rate and the opportunity cost of labour.
- The minimum wage legislation leads to further distortions in an otherwise competitive market.
- The wage payment from investment funds of the government results in the increase in present consumption of the labourers because of the increase in their wages and it also results in reduction in future consumption due to reduction in investments.

The shadow price of labour records changes in welfare when an extra unit of labour is made available for the public project. Squire and van der Tak (1975) have given the following basic equation for integrating efficiency and distribution:

$$S=E-C(\beta-\omega) \qquad \text{eq. (9.32)}$$

where S is *social price*, E is *efficiency price and* $C(\beta-\omega)$ *is the net social cost of increased* private consumption. The complete equation derived from eq. (9.32) for accounting shadow wage rates of labour (SWR*) is as below (Squire and van der Tak, 1975):

$SWR^*=m.\alpha+(w-m)(\beta-d/v)+(w-m)F.e.d/v$

This equation has three components:

(1) $m.\alpha$ is labour's forgone marginal product at accounting prices. m is rural wages. It can also be expressed in terms of consumption depending upon the numeraire.

(2) $(w-m)(\beta-d/v)$ is the net social cost of increased consumption. w and m are urban (for urban projects) and rural wages respectively (to capture 'migration effect'). (w-m) is extra consumption generated by extra income of the public project. β (not relevant to our numeraire) is the conversion factor for correction of domestic market imperfections. (3) $(w-m)F.e.d/v$ is the social cost of reduced leisure. The term $(w-m)F.e$ is the social cost of loss of leisure from having to work harder (disutility of efforts). *F* is proportion of an individual's evaluation (of working harder) that will be valid from the social point of view (F=1, consumer sovereignty assumption and F=0, protestant work ethic assumption). *e* is the proportion of the wage rate differential that reflects the worker's evaluation of the extra effort involved in the new job. *e*= 1 shows that in the migrant's view, all the wage differential is needed to compensate for having to work harder. *e*=0 shows the case where no extra effort is anticipated by the migrant worker.

In the traditional efficiency approach SWR* is set to m (i.e., market wage rate) but it implies the following assumptions d=1; $v=1/\beta$; $\alpha=1$, it merely avoids making these assumptions explicit (Brent, 1990).

We assume the value of the term $(w-m)F.e.d/v$ as zero (for details, see Lal, 1973), and consider the remaining two terms while estimating social costs of the project by applying differential consumption impact weight to different categories of workers and to the society as a whole.

9.8 Estimation of basic parameters

We need to express all costs and benefits in terms of forgone consumption (the numeraire) equivalents. Both intra-generational and inter-generational distribution will also be considered. This requires estimation of certain basic parameters. They are:

(a) marginal product or opportunity cost of capital (q),

(b) marginal propensity to save (s),

(c) elasticity of marginal utility of consumption (n), and

(d) growth rate of consumption (g).

(a) and (b) have already been estimated at the stage of economic appraisal (section 7.2, 7.3), the remaining two parameters (c and d) will be estimated in the following two sections.

9.8.1 Estimation of the elasticity of marginal utility of consumption (n)

The elasticity of marginal utility of consumption can be estimated using the food demand equation (eq. 9.20).

$$\ln D = \ln A + n_y \ln Y + n_P \ln (P_f/P_{nf}) + \psi T + \varepsilon$$

A time series (at a constant price of 1970) for gross national income (GNP), private consumption expenditure on food (PCEF) and total private consumption expenditure (TPCE) was compiled from NAS (IMF, 1988,1995) (Table A9.1.1; Annexure 9.1) for the period 1965 to 1988. The per capita GNP and food consumption expenditure over the period were calculated by dividing total GNP and food consumption expenditure by midyear estimates of total population of respective years. Some authors (e.g., Kula, 1984; Kumar, 1988) have used adult equivalents of population (multiplication factor; 0.765). We have not used adult equivalent consumption because of unavailability of relevant data for India.

The wholesale price index (WPI) for 'non-food' is not available in the national statistics. Therefore, wholesale price indices for 'food' and for 'all commodities' (base year; 1970=100) were obtained and used in the present study after appropriate adjustment as below.

The WPI for 'all commodities' (P_A) is given by:

$$P_A = w_f P_f + w_{nf} P_{nf} \qquad \text{eq. (9.33)}$$

where w_f and w_{nf} are the weight for the price indices for 'food' and 'non-food' respectively. Since, $w_f + w_{nf} = 1$ (all commodities can be grouped into either 'food' or 'non-food', the eq. 9.33 can be written as:

$$P_A = w_f P_f + (1-w_f) P_{nf} \quad \text{or}$$

$$P_A/P_f = w_f + (1-w_f)(P_{nf}/P_f) \quad \text{or}$$

$$\frac{P_f}{P_{nf}}=\frac{(1-w_f)}{\left(\frac{P_A}{P_f}-w_f\right)}$$

Thus, (P_f / P_{nf}) (price index for food/price index for non-food) can be calculated using the weight for food items in WPI (w_f =0.298, GOI, 1993b). Multiple regression gives the following best fit for the model (eq. 9.20). t-values are given in parentheses.

$$\ln D=1.2761+0.70450 \ln Y-0.069402 \ln (P_f/P_{nf})-0.0076587T$$

(3.9419) (-2.6982) (-1.7033)

R^2=0.7895 Adjus.-R^2=0.75752 SE=0.034934 DW-statistic=1.7758 n=24

The value of ψ is approximately zero (-0.008). Therefore, income elasticity for demand for food (n_y) and uncompensated price elasticity of demand for food (η_p) are approximately 0.70450 and -0.069402 respectively. The positive and negative value of n_y and η_p are consistent with consumer behaviour theory: the demand for food is expected to decrease with the increase in food prices and the demand for food is expected to increase with increase in per capita income.

The average of the proportion of food consumption expenditure in the total private consumption expenditure for the period 1965-1988 is 0.5798 (ϕ=0.5798) (Table A9.1.1; Annexure 9.1). Hence, the compensated price elasticity of food demand can be obtained as:

$\check{n}_p=n_p-\phi n_y$ [-0.069402-(0.5798 × 0.70450)] = -0.47787

Therefore, the elasticity of marginal utility of consumption for India is:

$$n=\frac{n_y}{\check{n}_p}$$

n=0.70450/-0.47787 n=-1.47425

The negative sign for n indicates that the marginal utility of consumption decreases with the increase in consumption. It means that social utility of extra consumption would decline by 1.47% with each 1% increase in average consumption. Squire and van der Tak (1975) have suggested values (of n) ranging from -0.5 to -1.5. Little and Mirrlees (1974) have given a wider range (-1.0 to -3.0). Our estimate for n is consistent with other estimates available in literature for India (n=-2.3 Lal, 1972; n=-2.07 Trivedi, 1987; n=-1.4 Sharma, 1991).

9.8.2 Estimation of growth rate of consumption (g)

The growth rate of per capita real consumption (g) is obtained by the following model:

$\ln C=\beta_0+gT+\mu$..eq. (9.34)

where C is per capita consumption in real terms, β_0 is a constant, T is the time variable and μ is an error term.

The time series data (1965-1988) are used for estimation of coefficients of equation (9.34). DW-statistic shows the problem of serial correlation in the model. We assume the error term (μ) follows first order autoregression (AR(1)) (subsequently, we test it for AR(2), AR(3) etc.), i.e.,

$\mu_t=\rho\mu_{t-1}+\varepsilon_t \qquad \rho<1$

where ρ is coefficient of autocorrelation and ε_t has no autocorrelation.

The equation 9.34 is transformed according to Cochron-Orcutt procedure (methodological details are in section 7.4.4). The results of regression are as below with t-ratio in parentheses:

$\ln C^*=6.1298 + 0.019866T$ n=24

(99.9405) (5.0878)

SE=0.039552 R^2=0.91312 R^2-adjusted=0.90444 DW-statistic=2.2537 ρ=0.63070

Therefore, the annual growth rate of per capita real consumption (g) is 1.9867%.

9.9 Estimation of social discount rate (SDR)

The values of the elasticity of marginal utility (n) of consumption, and growth rate of per capita consumption (g) have already been estimated in the previous two sections. The social discount rate (consumption rate of interest) for India can be calculated by substituting the value of *n* (absolute numerical value) and *g* in the equation 9.18.

$r=(1+g)^n-1$

$r=[(1+0.01987)^{1.47}-1]$ =0.0293448 or approximately 2.93%

9.10 Social value of investment funds (v)

The social value of investment funds (v) defines the weight for savings at time 't' compared with consumption at 't'. The weight can be calculated using equation 9.4 or

9.6. The values of other parameters required have already been estimated. If there are no savings (s=0), the value of v can be given simply by q/r (eq. 9.4). If q=r, the value of v will be 1 indicating no premium on investments. The values of q (marginal product of capital), r (social discount rate) and s (marginal propensity to save) are estimated as 0.1024 (growth model approach), 0.0293 and 0.1933 respectively in the present study.

As r>sq [0.0293>0.01979, (0.1933x0.1024)], eq. (9.4) can be used for the estimation of v

$v=\frac{(1-s)q}{(r-sq)}$, [(1-0.1933)0.1024]/[0.0293-(0.1933x0.1024)] =8.689815

v=8.6898

In Chapter 7, we have also estimated values of q as 0.1577 (average of two forms of the model) and 0.1794 (average of two forms of the model) using IOCR model and production function model respectively.

Taking q=0.1577, r=0.0293 and s=0.1933, we get:

r<sq   [0.0293<0.0304834, (0.1577x0.1933)]

In this case, eq. (9.4) becomes inapplicable (negative value for v; if r=sq, v=∞) as it implies zero relative value for consumption. Equation 9.7 suggests reinvestment comes only from incremental national output and does not come from total capital stock invested. Therefore, eq. 9.7 is not suitable in the present case study. We assume that savings will be optimal after 50 years (i.e., T+1=50); the value can be calculated as below using eq. (9.6):

$$v=\left[\frac{(1-s)q}{r-sq}\right]\left[1-\left(\frac{1+sq}{1+r}\right)^{T}\right]$$

[{(1-0.1933)0.1577}/{0.293-(0.1933x0.1577}}[{1+(0.1933x0.1577)}/{(1+0.0293)}]^{49}]

v=6.2263

When savings are only sub-optimal for a finite period, SDR will be CRI+(1/v)(dv/dt), not CRI (Price, 1996).

Similarly, if we take the value of q as 0.1794 (production function approach), the value of v will be 7.8286.

The high value of v suggests the high social value of public income. It means the opportunity cost investment drawn from the Government funds to implement projects is high, mainly due to the sub-optimality of the Government investment. The main advantage of incorporating an inter-temporal criterion in terms of the parameter v is to prevent bias in favour of short-lived and non-durable investments which may be introduced by conventional criteria in situations where the Government's marginal time preference with respect to consumption is less than the marginal productivity of capital (Dasgupta and Pearce, 1972).

9.11 Weights for intra-temporal distribution of consumption

In order to determine weights for different groups in the society, we use the concept of 'poverty line' as the critical consumption level. There are a number of studies regarding the definition and extent of poverty in India (Ahluwalia, 1976; Jain, 1986; Sanyal, 1988; Minhas et al., 1991). Each study is unique in respect of defining 'poverty' and uses a different methodology to estimate the extent of poverty in India. Therefore, the Planning Commission constituted an 'Expert Group' under the chairmanship of Prof. D J Lakdawala to consider methodological and computational aspects of estimation of poverty in India. The poverty line recommended by the expert group is based on minimum needs and effective consumption demand viz. a monthly per capita total expenditure of Rs 49 (rural) and Rs 57 (urban) at 1973-74 price as the base line. This was anchored in the recommended (by the Indian Council of Medical Research) per capita daily intake of 2400 calories in rural areas and 2100 calories in urban areas. The poverty line estimates are Rs 131.80 per capita per month and Rs 165.88 per capita per month for rural and urban areas respectively at 1987-88 price (GOI, 1992a). We estimate the poverty line for the year 1988-89 as Rs 148.35 per capita per month (CPI for agricultural labourers; 1960=100; 1987-88=629; 1988-89=708; GOI, 1993) for rural areas. This estimate appears to be plausible for the state of Bihar as 53.4% people were below poverty line in the year 1988-89 (GOI, 1993). Therefore, we use Rs 148.35 per capita per month as the critical consumption level ($\hat{C}$) in the present study. At this level, the weight will be equal to 1. The precise estimate of poverty consumption is not required because here we are concerned with relative weights. The consumption weights for marginal increase in consumption for all ten groups of individuals are estimated using equation 9,12a (Table 9.2).

Table 9.2 Distributional impact weights for marginal increase in consumption

Population percentile	[a]Monthly consumption per capita in Rs (C)	Marginal utility weight $d_C=U_C/U_{\hat{C}}=(C/\hat{C})^{-n}$
10	71.58	2.9191
10	94.82	1.9309
10	108.97	1.5738
10	122.36	1.3273
10	136.93	1.1250
10	152.69	0.9585
10	177.57	0.7677
10	202.59	0.6325
10	249.66	0.4653
10	426.88	0.2115

Notes: 1.[a] at 1988-89 prices,
2. Ĉ=poverty consumption level, Rs 148.35 per capita per month; n=1.47
Source: consumption data compiled from Mukhopadhyay (1994).

Now we use consumption level of various groups to ascertain whether the increase or decrease in consumption of subsidiary workers and main workers on account of the project is marginal or non-marginal. The average monthly per capita expenditure is given in Table 9.2

According to latest census of Bihar (Government of India, 1993), the total population of workers in the year 1991 was 27.778 million while that of non-workers was 58.596 million. This gives a dependency ratio of non-workers to workers as 2.11 to 1 which means on an average 3.11 persons are dependent on the wages of an average worker.

The ratio of subsidiary worker days to main worker days is estimated as 2.17 (Chapter 7; section 7.5.2.3). We assume that both main workers and subsidiary workers are drawn for the project in proportion to their respective population i.e. for every labour day required in the afforestatation project 0.3155 (1/3.17) labour days will be drawn from the main workers and the remaining 0.6845 (2.17/3.17) labour days will be drawn from subsidiary workers.

Table 9.3 Consumption of the workers with and without project

w = wage rate

Average wages	Main workers	Subsidiary workers	All workers
		without project	
a. weekly wages per worker[a]	6.7264w	1.9440w	6.1262w
b. per capita weekly wages (a/3.11[b])	2.1628w	0.6251w	1.9698w
c. per capita annual wages (bx52)	112.4671w	32.5042w	102.4316w
		with project	
d. weekly wages per worker	6.8510w	5.1455w	6.6369w
e. per capita weekly wages (d/3.11)	2.2029w	1.6545w	2.1341w
f. per capita annual wages (ex52)	114.5505w	86.0341w	110.9707w
g. increase in weekly wages per worker (d-a)	0.1246w	3.2015w	0.5107w
h. per capita increase in weekly wages per worker (g/3.11)	0.0401w	1.0294w	0.1642w

Notes: [a] employment in the week × wage rate; [b] 3.11 is average size of household

Source: Employment figures in *a.* and *d.* are from Table A7.2.7 (Annexure 7.1)

Table 9.3 shows the average weekly wages per worker earned by main and subsidiary workers 'with' and 'without' a project situation. The implementation of the project increases weekly wages by 3.2015w for an average subsidiary worker and 0.1246w for a main worker (weekly wages =no. day worked × wage rate (w)).

The per capita increase in the consumption in the household (average size 3.11 persons/household) of a subsidiary worker is 1.0294w on the initial wages of 1.6545w. The increase in per capita consumption for subsidiary worker is

{No. of labour days drawn for the project from subsidiary worker × per capita increase in weekly wages per sub. worker} / per capita weekly wages per sub. worker

= {0.6845 × 1.0294} / 1.6545

=0.4259w

Similarly, the per capita increase in the consumption of the household (size 3.11) of a main worker is 0.00574w ({0.3155 × 0.0401} / 2.2029).

The above analysis shows that:

a. the increase in consumption for a subsidiary worker is non-marginal

b. in the case of a main worker, the increase in consumption is marginal

The annual poverty consumption level is estimated as Rs 1780.20 (148.35×12) based on the earlier defined poverty line. The annual per capita consumption of main worker 'with' and 'without project' are Rs 2044.73 (114.5505×17.85; Rs 17.85 was the wage rate in the year 1988-89) and Rs 2007.54 (112.4671×17.85) respectively. The per capita increase in annual consumption (Rs 2044.73-2007.54=37.19) is maginal and both in 'with' and 'without' project situation the annual per capita consumption levels are above the poverty consumption level.

The consumption weight (d) for a subsidiary worker is estimated using eq. (9.12b) because the increase in consumption is non-marginal.

$$d=\frac{(86.0341\times17.85)^{1-1.47}-(32.5042\times17.85)^{1-1.47}}{[(1-1.47)(1780.2)^{-1.47}][(86.0341\times17.85)-(32.5042\times17.85)]}$$

$$=2.4649$$

The weighted mean marginal utility weight for all the ten decile groups (i.e., the society) is 1.1911 which is the utility weight for consumption generated by the government investment. If the recipients of forest produce obtained from illicit felling are distributed proportionately to the whole population, this is the utility weight for them also. If they are among the bottom five (below poverty line) decile groups, the corresponding mean marginal utility is 1.7752.

9.12 Computation of social cost of the project

The costs of the project expressed in terms of utility-weighted forgone consumption are termed social costs. The distribution impact weight depends on the source of funds and alternative use of funds in absence of the project. We make the following two assumptions:

Assumption CA-I

The major source for funding of afforestation projects is the Forest Department, Government of Bihar. These investment funds can be used elsewhere in the economy in the absence of the project. The combined impact weight for society's consumption loss is obtained by multiplying the social value of a unit investment by the mean marginal utility weight for the entire society. The consumption gains are estimated separately for main and subsidiary workers (Table 9.4).

Assumption CA-II

If the source of the project fund is the Rural Development Department (RDD), the implementation of the project will affect consumption expenditure as the funds of RDD are mainly used for employment guarantee schemes (e.g Jawahar Rozgar Yojana, National Rural employment Programme etc.) and 'Food for Work' schemes. In this case, it can be assumed that the project will be funded by reducing consumption expenditure. Therefore, inter-temporal consumption weight (i.e., v) will be unity as there is no impact on savings. The combined distributional weight for consumption loss and those for consumption gains of main workers and subsidiary workers are estimated taking the value of v as 1 (Table 9.4).

Table 9.4 Combined distributional weight per unit of expenditure

Cost item	Consumption loss[a]			Consumption gain[b]			Difference
	v	d	v.d	v	d	v.d	(loss-gain)
				Assumption CA-I			
Material	8.6898	1.1911	10.3504	1.0000	0.0000	0.0000	10.3504
Main worker	8.6898	1.1911	10.3504	1.0000	0.6071	0.6071	9.7433
Subsidiary worker	8.6898	1.1911	10.3504	1.0000	2.4649	2.4649	7.8855
Staff	8.6898	1.1911	10.3504	1.0000	0.4364	0.4364	9.9140
Vehicle etc.	8.6898	1.1911	10.3504	1.0000	0.0000	0.0000	10.3504
				Assumption CA-II			
Material	1.0000	1.1911	1.1911	1.0000	0.0000	0.0000	1.1911
Main worker	1.0000	1.1911	1.1911	1.0000	0.6071	0.6071	0.5840
Subsidiary worker	1.0000	1.1911	1.1911	1.0000	2.4660	2.4649	-1.2738
Staff	1.0000	1.1911	1.1911	1.0000	0.4364	0.4364	0.7547
Vehicle etc.	1.0000	1.1911	1.1911	1.0000	0.0000	0.0000	1.1911

Notes: v=consumption value; d=utility weight; v.d=utility weighted value; [a] Consumption loss to the society; [b]Consumption gain to workers

The social cost in case of **CA-II** will be less than that in case of **CA-I**. Hence the profitability in case of **CA-II** will be higher.

The net consumption loss due to the financial cost of the project constitutes the main component in social costing. The additional cost is due to the increased consumption by workers because the marginal productivity of labour is less than the market wage rate. Since an increase in workers' consumption is a desirable effect of the project, social benefit due to increased consumption is deducted from the total social costs to arrive at the net social cost of the project.

9.13 Computation of social benefit

The social benefits will depend on the sharing of benefits between the people and the Forest Department.

9.13.1 Social benefit due to income to the Forest Department from the plantations (RDF component)

Social benefits on account of income to the Forest Department will depend on how the government income from the plantation is spent. Broadly, there can be three possibilities:

Assumption B-I

The total revenue from the plantation is reinvested. The consumption value of the government income will be equal to v (8.6898). The combined utility weight will be 10.3504(v.d; v=8.6898, d=1.1911).

Assumption B-II

Here, the income from the plantation is entirely consumed. The consumption value of unit government income becomes unity (v=1). On applying intra-temporal consumption weight, it becomes 1.1911(v.d; v=1, d=1.1911).

Assumption B-III

The income from the plantation is treated like any other revenue. A part (s) of it is saved and the rest (1-s) is consumed. The consumption value of unit government income will be:

$sv+(1-s)$ [s=0.1933, v=8.6898] =2.4864

The combined weight (v.d) becomes 2.9616 (d=1.1911).

Assumption B-IV

In some districts (e.g. Ranchi, Bihar), under joint forest management (JFM), 20%

of the total plantation income will go to the Forest Department as royalty and the remaining 80% will be distributed among participating households of the village.

The combined distribution weight for the 80% of the benefit will be 1.1911(v.d; v=1, d=1.1911; assuming no savings) and that for the remaining 20% will be 2.9616 (assuming part (0.1933) of the government income saved and the rest is reinvested)

9.13.2 Social benefits due to people's income obtained from illicit felling (RDF component)

Assumption B-IF

The income obtained from illicit felling of the plantation can be regarded entirely as increase in consumption of poor people. We assume that the recipients of illicit felling income are all below the poverty line i.e first five decile groups. The weighted average marginal utility weight of this group is 1.7752. The combined weight will be 1.7752 (vd; v=1; d=1.7752)

9.13.3 Social benefits due to income to the farmers (FF component)

Assumption: BF-I

The benefits in FF plantations accrue to individual participating farmers. We assume that:

(a) The increase in consumption due to benefits from farm forestry is marginal.

(b) The entire income from farm forestry is consumed (v=1).

To derive intra-temporal consumption weights, we estimate individual farmers per capita consumption expenditure. This figure is deflated using CPI for agricultural labourers to estimate monthly per capita consumption expenditure at 1988-89 price (CPI for agricultural labourers; 1960=100; 1988-89=708; 1993-94 (P), 1087, GOI, 1993). The utility weight is calculated for each decile group. The average marginal utility weight for all farmers is 1.6535 (Table 9.5).

Table 9.5 Distributional impact weights for marginal increase in consumption (FF)

Population percentage	[a]Monthly consumption per capita in Rs (C)	Marginal utility weight $d_C=U_C/U_{\hat{C}}=(C/\hat{C})^{-n}$
10	45.85	5.6190
10	66.04	3.2863
10	89.85	2.0900
10	114.55	1.4624
10	133.46	1.1682
10	155.76	0.9309
10	173.96	0.7913
10	210.59	0.5975
10	283.79	0.3854
10	436.67	0.2045

Notes: 1.[a] at 1988-89 prices,
2. $\hat{C}$=poverty line, Rs 148.35 per capita per month; n=1.47
Source: socioeconomic survey of 252 farmers

9.14 Social appraisal of RDF and FF: case studies

9.14.1 Computation of social profitability

The social costs for different operations of the plantation are worked out separately by earlier estimated distributional weights to each category of workers (main and subsidiary workers) (Table 9.4). The social cost of the material is calculated by multiplying the distributional weight for the society by the economic cost of the material. As the main and subsidiary workers are drawn in the proportion of 0.3155:0.6845 (calculated in section 9.12), the total wage component has also been divided into the same proportion. The economic costs are calculated separately for main workers and subsidiary workers using scarce labour and surplus labour concepts of shadow wage rate estimation (Table A7.2.2; Annexure 7.2). The social costs of the loss in society's consumption due to the economic costs is obtained by multiplying the economic costs by the combined utility weight. The additional social costs of the loss in society' s consumption is due to the increased consumption of main and subsidiary workers. The total social costs are obtained by adding these two costs. The social gains to the main and subsidiary workers are due to increased consumption. The net social costs to the society are obtained by subtracting total gains from total loss (Table A9.1.2; Annexure 9.1). Similarly, net social costs to society are calculated for the Farm Forestry component (Table A9.1.3; Annexure 9.2).

In the case of harvesting costs, the consumption losses are derived treating then as the government revenue (part saved and part consumed). This gives the weight equal to sv+(1-s). The calculations are illustrated through derivation of discounted cash flow of FF plot 1A1(Table A9.1.3 and Table A9.1.4, Annexure 9.1).

9.14.2 Results of social appraisal (RDF)

Table 9.6 shows the profitability of RDF component under the earlier defined assumptions viz. CA-I, B-I and B-IF. Out of six districts only two show positive net present values. SGH region shows social NPV below zero.

50% of the total plots in RDF component are not socially profitable (Table 9.7). This is because of the higher weight attached to the source of the fund (i.e. the government) which was diverted from investment expenditure in other sectors of the economy.

Table 9.6 Results of social cost benefit analysis (RDF)

Assumptions: CA-I; B-III

	Profitability criteria	
	NPV/ha (Rsw/ha)	BCR
Districts		
Gumla (GRS1)	141166	1.47
Ranchi (GRS2)	156572	1.51
Sahebganj (GRS3)	-29083	0.87
E.Singhbhum (SGH1)	-67224	0.68
Garhwa (SGH2)	-85261	0.59
Hazaribagh (SGH3)	-11258	0.95
Regions		
GRS	93162	1.33
SGH	-46616	0.79
All plots (N=18)	16572	1.07

Note: Assumptions (CA-I; B-III) are explained in section 9.14

Table 9.7 Range of NPV and BCR (RDF)

Assumptions: CA-I; B-III

Region (number of plots)	**Number of plots**					
	NPV Rsw/ha			**BCR**		
	< 0	**≤15000**	**>15000**	**< 1.00**	**≤ 1.50**	**>1.50**
GRS (9)	2	5	2	2	5	2
SGH (9)	7	1	1	7	2	0
All plots (18)	9	6	3	9	7	2

Note: Assumptions (CA-I; B-III) are explained in section 9.14

9.14.3 Results of social appraisal (FF)

The region-wise and the district-wise results of social cost-benefit analysis of farm forestry component are summarised in Table 9.8. The weighted (according to size of plots) average NPV is positive in 4 out of 6 sampled districts. SGH region shows significantly higher profitability as compared to GRS region.

Out of 72 sampled plots, 30 plots show an NPV of less than zero (Table 9.9). This is because of the high weight attached to the government investment funds and because the benefit of the project is used for consumption purposes

Table 9.8 Results of social cost benefit analysis (FF)

Assumptions: CA-I; BF-I

	N	**Profitability criteria**	
		NPV/ha (Rsw/ha)	**BCR**
Districts			
Gumla (GRS1)	12	-4276	0.93
Ranchi (GRS2)	12	68607	1.91
Sahebganj (GRS3)	12	-44487	0.19
E.Singhbhum (SGH1)	12	30154	1.41
Garhwa (SGH2)	12	66744	1.90
Hazaribagh (SGH3)	12	37395	1.53
Regions			
GRS	36	-1832	0.97
SGH	36	44564	1.62
All plots	72	18484	1.28

Note: Assumptions (CA-I; BF-I) are explained in section 9.14

Table 9.9 Range of NPV and BCR (FF)

Assumptions: CA-I; BF-I

District/Region (number of plots)	Number of plots					
	NPV Rsw/ha			BCR		
	< 0	≤60000	>60000	< 1.00	≤ 2.00	>2.00
Districts						
GRS1 (12)	7	3	2	7	5	0
GRS2 (12)	2	3	7	2	5	5
GRS3 (12)	11	1	0	11	1	0
SGH1 (12)	6	2	4	6	2	4
SGH2 (12)	1	3	8	1	6	5
SGH3 (12)	3	3	6	3	4	5
Regions						
GRS (36)	20	7	9	20	11	5
SGH (36)	10	8	18	10	12	14
All plots (72)	30	15	27	30	23	19

Note: Assumptions (CA-I; BF-I) are explained in section 9.14

9.14.4 Sensitivity analysis (RDF)

In section 9.13, we have made two assumptions regarding the source of funds for afforestation projects. Table 9.10 presents the results of social cost-benefit analysis assuming the funds for afforestation projects were drawn from investment funds from the government and in the absence of the project these funds would have been utilised elsewhere in the economy. Table 9.10 indicates that RDF component is profitable in all the districts from the 'social' point of view only when the total benefits generated by the project are reinvested in the economy. In other assumptions viz. B-II and B-IV, RDF component is not profitable in any of the districts.

Table 9.10 Profitability of RDF woodlots under different assumptions of consumption and reinvestment

	Profitability criteria					
	NPV/ha (Rs/ha)			BCR		
	CA-I; B-I	CA-I; B-II	CA-I; B-IV	CA-I; B-I	CA-I; B-II	CA-I; B-IV
Districts						
Gumla (GRS1)	1123042	-94094	-47039	4.76	0.68	0.84
Ranchi (GRS2)	1204236	-94450	-44243	4.94	0.69	0.86
Sahebganj (GRS3)	363309	-123101	-104296	2.58	0.46	0.55
E.Singhbhum (SGH1)	160812	-121862	-110933	1.77	0.42	0.47
Garhwa (SGH2)	94781	-128400	-119772	1.45	0.39	0.43
Hazaribagh (SGH3)	405368	-111083	-91117	2.75	0.52	0.61
Regions						
GRS	912734	-103210	-63934	4.27	0.63	0.77
SGH	254902	-118861	-104411	2.16	0.46	0.53
All plots (N=18)	552283	-111786	-86113	3.24	0.55	0.65

Note: Assumptions (CA-I; B-I; B-II; B-IV) are explained in section 9.14

If the funds for financing the projects were drawn from consumption funds i.e. investments in the project results in reduction in consumption expenditure elsewhere in the economy, the RDF component in all the districts become profitable (Table 9.11 and Table 9.12). This is because of the lower weight attached to consumption expenditure.

Table 9.11 Profitability of RDF woodlot under different assumptions of consumption and reinvestment

	Profitability criteria			
	NPV/ha (Rs/ha)		BCR	
	CA-II; B-I	CA-II; B-II	CA-II; B-I	CA-II; B-II
Districts				
Gumla (GRS1)	1302167	85031	11.90	1.71
Ranchi (GRS2)	1383361	84675	11.90	1.67
Sahebganj (GRS3)	542434	56025	11.83	2.12
E.Singhbhum (SGH1)	339937	57264	12.37	2.91
Garhwa (SGH2)	278547	55366	11.42	3.07
Hazaribagh (SGH3)	583258	66807	11.90	2.25
Regions				
GRS	1091859	75915	11.89	1.76
SGH	434913	61150	11.87	2.53
All plots (N=18)	731894	67825	11.88	2.01

Note: Assumptions (CA-II; B-I; B-II) are explained in section 9.14

Table 9.12 Profitability of RDF woodlot under different assumptions of consumption and reinvestment

	Profitability criteria			
	NPV/ha (Rs/ha)		BCR	
	CA-II; B-III	CA-II; B-IV	CA-II; B-III	CA-II; B-IV
Districts				
Gumla (GRS1)	320291	132086	3.68	2.11
Ranchi (GRS2)	335698	134882	3.65	2.06
Sahebganj (GRS3)	150043	74830	4.00	2.49
E.Singhbhum (SGH1)	111902	68192	4.74	3.28
Garhwa (SGH2)	98504	63994	4.69	3.39
Hazaribagh (SGH3)	166632	86774	4.11	2.62
Regions				
GRS	272287	115192	3.72	2.15
SGH	133395	75600	4.34	2.89
All plots (N=18)	196183	93498	3.92	2.39

Note: Assumptions (CA-II; B-III; B-IV) are explained in section 9.14

9.14.5 Sensitivity analysis (FF)

A sensitivity analysis is carried out to examine the effect of change in source of the funds for the project. Here, we make an assumption that funds are drawn from diverting consumption expenditure. The profitability increases dramatically in all the districts (Table 9.13). Out of six districts five are now become profitable. Out of total 72 plots only 13 show negative NPV (Table 9.14). Out of these 13, 69% of plots are from Sahebganj district. This is because of low survival of seedlings in this district.

Table 9.13 Results of social cost benefit analysis (FF)

Assumptions: CA-II; BF-I

	N	Profitability criteria	
		NPV/ha (Rsw/ha)	BCR
Districts			
Gumla (GRS1)	12	41207	3.38
Ranchi (GRS2)	12	114982	4.91
Sahebganj (GRS3)	12	-1364	0.88
E.Singhbhum (SGH1)	12	76279	3.87
Garhwa (SGH2)	12	112521	5.01
Hazaribagh (SGH3)	12	82906	4.35
Regions			
GRS	36	42867	3.36
SGH	36	90374	4.42
All plots	72	63670	3.92

Note: Assumptions (CA-Ii; BF-I) are explained in section 9.14

Table 9.14 Range of NPV and BCR (FF)

Assumptions: CA-II; BF-I

District/Region (number of plots)	Number of plots					
	NPV Rsw/ha			BCR		
	< 0	≤60000	>60000	< 1.00	≤ 2.00	>2.00
Districts						
GRS1 (12)	2	5	5	2	3	7
GRS2 (12)	0	2	10	0	0	12
GRS3 (12)	9	3	0	9	2	1
SGH1 (12)	0	6	6	0	1	11
SGH2 (12)	0	2	10	0	1	11
SGH3 (12)	2	2	8	2	1	9
Regions						
GRS (36)	11	10	15	11	5	20
SGH (36)	2	10	24	2	3	31
All plots (72)	13	20	39	13	8	5

Note: Assumptions (CA-II; BF-I) are explained in section 9.14

9.15 Discussion and conclusions

The above analysis indicates that social desirability of plantations depends on:

a. source of investment funds,

b. treatment of project revenue, and

c. relative consumption level of beneficiary groups.

The social opportunity cost of investment funds of the government (v=8.6898) is much higher than that of consumption expenditure (v=1). Therefore, social profitability of individual plantations is higher if the funds were drawn from consumption funds. If the total revenue obtained from the plantation is reinvested (assumption B-I) instead of part saved and part reinvested, the NPV would be much higher. Forest Development corporation is an example where the revenue obtained from plantations are reinvested for growing other plantations.

The second aspect which affects the social profitability of the afforestation project is the treatment of benefits. Joint Forest Management (JFM) option (Assumption, B-IV) has not shown high social profitability (Table 9.12, 9.14) contradictory to common belief, because 80% of the benefits go in consumption expenditure and only the remaining 20% are available for reinvestment in the economy.

We have also assumed that benefits of illicit removal of forest produce are distributed among people below the poverty line i.e. the first five decile groups. In the case of illicit felling by timber smugglers, a lower utility weight is to be assigned as they (timber smugglers) may fall in the upper 2-3 decile groups.

For estimation of the consumption value of unit investment (v), the precise estimate of social opportunity cost of capital (q), the marginal propensity to save (s), the elasticity of marginal utility of consumption (n) and the growth rate of per capita real consumption (g) are required. We have used different methods to arrive at the objective estimate for opportunity cost of capital (q) because the estimate of 'q' can influence the results of economic as well as social CBA. The elasticity of marginal utility of consumption (n) and the growth rate of per capita real consumption (g) are used to estimate the consumption rate of interest. Our estimations are based on data for the whole economy. The value of 's' and 'q' would be different for the public and private sectors of the economy. In our case studies, funds for the project were drawn from the government funds (with the exception of small expenditure on weeding by a few farmers). Hence, it is appropriate to use the public sector data for estimation of 's' and 'q'. Some of the benefits e.g. illicit removals in RDF and all forest produce in farm forestry etc. accrue to the individual farmers. In this case, it would be more appropriate to use the private sector estimates of 's' and 'q' for estimating social value of investment funds (v). But it is practically very difficult in the absence of relevant data for small groups in the private sector. The use of pooled data for all sections of the private sector may not reflect the social value of investment funds precisely and may lead to further distortions in the estimates.

Chapter 10

Risk analysis of afforestation projects

It has been argued that careful project appraisal is worth little when uncertainty about the outcome and about the environment within which it will operate is great (Little and Mirrlees, 1991). Risk and uncertainty emanates from the uncertainty encompassing the projected variables. Therefore, the evaluation of projects depends on:

a. ability to identify and understand the nature of uncertainty surrounding the key project variables, and,

b. methodology to incorporate their risk implications on the project outcomes (Savvides, 1994).

The important variables in Farm Forestry (FF) and Rehabilitation of Degraded Forests (RDF) and their possible impact on expected returns have already been discussed in previous chapters. In this chapter, we attempt to process the elements of variability in project appraisal. The plan of the chapter is as follows. The chapter is divided into two sections. Section I discusses the theory of decision making under risk in the context of project appraisal. Then, risk analysis and simulation modelling is presented. Finally, the methodology is further explained in detail using case studies of the FF and the RDF components of the project. Section II deals with decision analysis of the project. The methods and results of the derivation of project managers' utility function are presented.

Section I

10.1.1 Project appraisal under risk

It has been debated widely in the project appraisal literature how (if at all) uncertainty should be allowed for. The argument ranges from discounting at the market rate of interest to more modest riskless discounting on the grounds that the government can effectively 'pool risk into unimportance' (Mishan, 1972a; Anderson, 1992) through its large and diversified portfolio. In the light of the contribution of Arrow and Lind (1970), it has been argued that the total cost of risk bearing is insignificant when the risks are shared by the large numbers of members of the society (for details see, section 3.4.5).

10.1.1.1 Treatment of risk in conventional project appraisal

The conventional approach requires the use of 'best estimate' of benefits based on information regarding a specific or similar event in the past, and uses it as an input variable in the evaluation model. This is a single figure. It does not allow for the existence of alternative outcomes. It is also not known whether this figure represents the mean, median, mode, a conservative estimate or an optimistic estimate. Even if we use the mode of every project variable, we may not get the most likely outcome of the project. For example, if there are eight mutually independent variables which can influence the project and each of eight variables has 80% chance of yielding a positive expected net present value (NPV), there is only 17% chance (0.80×0.80×0.80×0.80×0.80×0.80×0.80×0.80) that all eight variables will yield a positive expected NPV. So, the expected positive NPV of the project is dependent on a rather unlikely coincidence.

In conventional appraisal, the outcome of the project is presented as a certainty with no possible variance or error term, and sensitivity analysis is presented to account for possible variations. Sensitivity analysis allows change in the value of a variable, to test its impact on overall results. It is helpful in identifying the most important and most sensitive variable(s) of the project. Scenario analysis generally presents an optimistic and a pessimistic scenario for the project. Here, it is possible to study the impact of simultaneous change of values for a number of variables on the project outcome. But change in values of project variables are rather arbitrary and it does not consider possible interrelationship among variables. It may lead to an unrealistic scenario of the project outcomes.

The addition of risk premium in discount rate is often considered as a method for allowing for risk. But it is certainly not a good way to do it (Price, 1993). The main reasons are discussed section 6.3.1 (Chapter 6).

10.1.1.2 Approaches to risk adjustment in public project

The two main methods of project appraisal (UNIDO, 1972; Little and Mirrlees, 1974) defend the conventional practice of the use of expected net present value

(E(NPV)) in evaluating projects using a riskless discount rate. However, the two exceptions put forward are :

(a) of an unusually large project, where benefits are a substantial fraction of national income, and

(b) where national income is uncertain and the project benefit is not independent of national income (Anderson, 1992).

Liitle and Mirrlees (1974, 1991) have identified 'more difficult cases' when E(NPV) is inadequate as a criterion and suggest 'some practical method'. Assuming that no weight (positive or negative) is attached to uncertainties about national income, the social value by the expectation of social utility can be represented as:

EU(X), U is a concave utility function as $U'>0$ and $U''<0$.

This utility function is used by Little and Mirrlees (1974) to develop useful approximations in computing risk-adjusted values (approximately certainty equivalent) for project benefits for (a) 'unusually large projects and (b) 'mutually dependent projects'.

In the above formulation, the focus of the study is from the perspective of the whole economy. In this sense, adjustment of risk in afforestation projects may not be of much importance primarily because of two reasons:

(a) the size of afforestation projects is small as compared to the national income, and,

(b) project benefits are independent of national income.

But for comparison of different projects or for comparison of different components of a single project, we need to have some methodology for risk adjustment. We attempt to incorporate elements of risk in the project appraisal using risk analysis and decision analysis techniques in the subsequent sections of this chapter.

10.1.2 Decision making under risk

10.1.2.1 Risk concept and measures

The conventional appraisal of projects is based on simplifying assumptions of certainty about the environment and an objective of profit maximisation. It is observed that:

a. individuals show risk aversion tendency, and

b. risk aversion in turn is an explanation of many observed phenomena in the economic world (Arrow, 1984).

Introduction of risk extends these concepts to include the decision makers' perception and attitude to risk more directly.

In the literature, one finds such fundamentally different risk concepts as 'probability of loss', 'variance of profit', and 'the size of the maximum possible loss' (Young, 1984). Furthermore, risk can be based on subjective expectations of the decision makers or objective measure of some data.

Three main classes of decision rules can be clearly identified. They are:

(a) Game theory decision rule or decision rules requiring no probability information

The main examples are: minimax loss or maximin gain, minimax regret, Hurwicz α index and Laplace principle of insufficient reason (Halter and Dean, 1971).

(b) Safety-first or Lexicographic utility models

The safety-first rule is commonly used in risk analysis as a form of lexicographic utility. A lexicographic utility function is expressed as:

$U = f(X_1, X_2, \ldots\ldots X_n)$, where X_1, X_2, X_n, represent the sequential goals. Three types of safety-first rules have been suggested (Robison et al., 1984):

(i) Maximize $\bar{E}$, subject to

$P(E \leq E\text{-min.}) \leq P_T$

where $\bar{E}$ is maximum expected return, *P* is probability, *E-min* is specified minimum amount, P_T is a stipulated threshold.

(ii) Maximize L, subject to

$P(E < L) \leq P_T$

where *L* is lower confidence limit.

(iii) Minimize

$P(E < E\text{-min})$

These models use some measure of variability or spread of outcomes to provide a measure of risk.

(c) Expected utility theory

The expected utility theory (also known as Bernoulli's principle) is based on a theorem derived from a set of axioms about individual behaviour (for theoretical details, see von Neumann and Morgenstern (1947); Luce and Raiffa (1957)). This theory is the basis for much of decision theory under risk. It shows that decision makers who obey certain axioms should choose actions that maximize their expected utility. The axioms are considered conditions or assumptions of people's behaviour. They are based on a general assumption that people are rational decision makers and consistent in choosing among alternatives. If the axioms - ordering of choices, transitivity among choices, certainty equivalent among choices - hold, the theorem follows that an optimal risky choice is based on the maximization of expected utility (Robison, 1984). The expected utility model distinguishes between a decision maker's perception of the amount of uncertainty and his or her attitude towards additional income.

If the components of a decision problem include a set of action choices - a_1, a_2,...a_n, a set of monetary outcome - θ_i, a_j, associated with the j th action choice in the i th state of nature and probability density function P (θ_i) indicating the likelihood of outcomes in the respective states, for an action choice, the utility value for each possible outcome of an action choice is weighted by its probability and summed. The resulting expected utility is an index for the action choices which are ranked according to their level of expected utility with the highest value being most preferred (Robison, 1984). The expected utility (EU) for risky action, a_j can be evaluated[1] as (Young, 1984):

$$(EU)_j = \sum_{i=1}^{n} [U\pi(\theta_i, a_j)]P(\theta_i)$$

where $\pi(\theta_i, a_j)$ represents the income level of i th state of nature (θ_i) and j th action a_j; $U[\pi(\theta_i, a_j)]$ is the utility equivalent of the income level; and P (θ_i) denotes the probability of occurrence of the i th state of nature.

10.1.2.2 Risk attitudes of decision makers

The expected utility model can also be used to describe decision makers' risk attitude. If a decision maker obeys the axioms (listed in section 10.1.2.1), a utility function can be formulated that reflects the decision maker's preferences (Hazell, 1982). The decision maker's risk attitude can be inferred from the shape of his or her utility function. A linear utility function implies risk neutrality, a function concave to the origin implies risk aversion, and a convex function implies a risk preferring attitude. Some times, a decision maker's utility function has both concave and convex segments which indicates that he

[1] By taking the expectation of Taylor series expansion of the utility function about mean (μ_j), the expected utility of action j is also represented as:

$(EU)_j = f(\mu_j, \sigma^2_j, M3_j, M4_j, \ldots\ldots\ldots)$

where μ_j, σ^2_j, $M3_j$, $M4_j$,......... are the mean, variance, skewness, kurtosis and higher moments of probability distribution (Anderson et al., 1977).

has different attitude towards risk for different outcomes.

For a risk neutral decision maker (linear utility function), the ordering of action choices depends only on the expected monetary value and not on the other characteristics of the probability function. A concave utility function has a non-negative first derivative [$U'(x) \geq 0$] and a negative second derivative [$U''(x) \leq 0$]. Here, utility always increases as wealth increases, but the marginal utility declines. Thus, a risk averse decision maker will prefer an action with a perfectly certain return to another action with an equal, but uncertain, expected return. In this case, the certainty equivalent of a risky investment is always less than its expected monetary value.

The sign of $U''(x)$ (i.e., second derivative) indicates risk aversion or risk preferring behaviour. However, the magnitude of $U''(x)$ cannot be used for interpersonal comparisons of risk aversion because an individual's utility function is only unique up to a positive linear transformation (Robison et al., 1984). To facilitate comparison of individuals' utilities, Arrow (1984) and Pratt (1964) independently suggested that an individual's absolute risk aversion can be calculated by dividing negative of the second derivative of the utility function by the first derivative. This can be mathematically expressed as:

$$\lambda_a(x) = -\frac{U''(x)}{U'(x)}$$

where $\lambda_a(x)$ is absolute risk aversion.

The relative risk aversion ($\lambda_r(x)$) can be expressed as:

$$\lambda_r(x) = -\frac{x\,U''(x)}{U'(x)}$$

These measures are unaffected by arbitrary transformation of the utility function. They are large for more risk averse individuals and their sign shows type of risk attitude (risk averse or risk preferring). $\lambda_a(x)=0$ signifies risk neutrality.

10.1.2.3 Measuring risk attitudes

There are four main approaches for studying risk attitude of decision makers. They are:

(a) Direct elicitation of utility function (DEU)

It involves direct interviews with decision makers to specify their risk attitudes. Most DEU applications involve the expected utility approach (Binswanger, 1980).

(b) Risk interval approach

This method is based on identifying a confidence interval for the Arrow-Pratt measure of absolute risk aversion (for detailed procedure, see King and Robison (1981)).

(c) Experimental method

This method was developed by Binswanger (1980) for utility elicitation of 330 farmers selected at random from six villages of the semi-arid tracts of Maharashtra and Andhra Pradesh, India. The approach is based on a gaming situation involving initially real payoffs.

(d) Observed economic behaviour

This approach is based on the relationship between actual behaviour of decision makers and the predicted behaviour from empirical models.

The literature shows much diversity in the approaches to studying risk attitude (for a comprehensive review, see, Young (1984); Hazell (1982)). Most of the studies relate to elicitation of farmers' risk attitude. Project managers' risk attitude measurement is the focus of a few studies (e.g. Spetzler, 1977). We use the DEU method for the case study of elicitation of utility functions of project managers.

10.1.2.4 Risk efficiency models

As we have discussed in section 10.1.2.1, the expected utility model (EUM) provides a choice criterion (expected utility maximization) that integrates information about decision makers' preference and expectations to identify preferred choices under uncertainty. Despite wide acceptance of EUM in decision theory under uncertainty, it is difficult to identify decision makers' choices accurately through estimation of their utility function. Some of the common problems in elicitation of utility functions are: shortcomings in interview procedures (Binswanger, 1980), problems of statistical validation of the results and individuals' lack of knowledge about their preferences. Such problems with single-valued utility functions are overcome by using an efficiency criterion to order choices (King and Robison, 1984). An efficiency criterion provides a partial ordering of choices on the probability distributions of feasible alternatives. An efficiency criterion divides the decision alternatives into mutually exclusive sets: an efficient set and an inefficient set (Levy and Markowitz, 1979). The efficient set contains the preferred choice of a decision maker. The inefficient alternatives are not considered.

The efficiency criteria can resolve some of the problems associated with single-valued utility functions, but have shortcomings of their own. They are:

(a) the possible trade-off between their discriminatory power and general applicability

(b) they place few restrictions on preferences.

Despite the above listed shortcomings, the efficiency criteria are useful in deriving widely applicable theoretical results and are a valuable tool in risk analysis.

The most common efficiency criteria[2] are:

a. First degree stochastic dominance (FSD)

b. Second degree stochastic dominance (SSD)

c. Mean-variance efficiency

d. Mean-absolute deviation efficiency

e. Stochastic dominance with respect to a function.

FSD and SSD are the most widely used efficiency criteria in risk analysis and will be considered in the present study.

10.1.2.4.1 First degree stochastic dominance

First degree stochastic dominance (FSD) is the most universally applicable efficiency criterion. The FSD criterion holds for all decision makers who always prefer more to less of 'x' ('x' is the unscaled measure of consequences such as profit). This is a monotonically increasing utility function wherein the first derivative is strictly positive i.e., ($U'(x)>0$). Under FSD, an outcome distribution defined by cumulative distribution function (CDF) $F_1(R)$ is preferred to another CDF $G_1(R)$ if,

$$F_1(R) \leq G_1(R)$$

for all possible values of R in the range of [a, b] with at least one inequality for some value of R. F_1 is related to its probability density function f(x) by,

$$F_1(R) = \int_a^R f(x)\, dx$$

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[2] Other efficiency criteria include: (i) Expected gain confidence limit (Baumol, 1963), (ii) Third degree stochastic dominance (Whitemore, 1970), (iii) Multi-attribute efficiency criteria (Kihlstrom and Mirman, 1974; Levy and Paroush, 1974), (iv) Convex stochastic criteria (Fishburn, 1974).

This efficiency criterion is transitive i.e. if F dominates G and G dominates H, F must dominate H. A discrete distribution can also be expressed in this form. Suppose that x takes only a finite number of values x_i, i=1, 2,...........n, all in the interval of [a, b]. A CDF is defined as (Anderson et al, 1977),

$$F_1(R)=P(x_i \leq R)=\sum_{all\ x_i \leq R} f(x_i)$$

FSD is defined as before except that now the inequality needs only to be examined at the discrete x_i values.

10.1.2.4.2 Second degree stochastic dominance

Second degree stochastic dominance (SSD) is more discriminating than FSD. SSD holds for all decision makers whose utility functions have positive non-increasing slopes at all outcome levels (i.e., U'(x)>0 and U"(X)<0)). SSD is assessed by defining a cumulative function that measures the area under a CDF over the range of the uncertain quantity. SSD for cumulative distribution F_1 is defined as (Anderson et al, 1977):

$$F_2(R)=\int_a^R F_1(x)\ dx$$

Then, the distribution F is said to dominate G in the sense of SSD if,

$$\int_a^R F_1(x)\ dx \leq \int_a^R G_1(x)\ dx$$

for all possible R with at least one strong inequality.

Thus, under SSD, distributions are compared based on the accumulated area under these cumulative distributions.

A discrete distribution can also be defined.

$\Delta x_i=x_i - x_{i-1}$ and x_n is the highest value of x

$$F_2(x_r)=\sum_{i=2}^{r} F_1(x_{i-1})\Delta x_i \text{..................} eq.\ (10.1)$$

$$r=2,.......,n \quad F_2(x_1)=0$$

Thus, for SSD, $F_2(x_r) \leq G_2(x_r)$ for all $r \leq n$, with at least one strict inequality. The risk aversion assumptions seem reasonable for many situations. However, the assumption of risk aversion does not always hold. This aspect will be covered in the next section.

10.1.2.5 Non-expected utility models

Expected utility theory has served as a *descriptive, predictive or positivistic, postdictive and prescriptive or normative* model of rational choice under uncertainty (Shoemaker, 1982). The expected utility model has long been the dominant framework for the analysis of decision making under risk. A number of pieces of experimental evidence suggest that decision makers often violate the key behavioural assumption of this model: for example, the independence axiom (or equivalently, of linearity in the probabilities) leading to 'the common consequence effect[3]' (the Allais Paradox is a special case of this general phenomenon). A second class of systematic violations is known as the 'common ratio effect[4]' which includes the 'certainty effect' (Kahneman and Tversky, 1979) and the 'Bergen Paradox'. A third type of systematic departure from the expected utility model relates to the elicitation of decision makers' utility. A systematic tendency was found for higher values of probability to lead to recovery of higher value of utility functions (Machina, 1987). The way of framing of the choices can also lead to different preferences (Tversky and Kahnema, 1986).

This has led to the development of non-expected utility models of decision-making. Several non-linear forms for the preference function [V(.)] are postulated such as 'prospect theory' (Kahneman and Tversky, 1979) and the 'utility without independence axiom' (Machina, 1989).

In the case of prospect theory, which substitutes the preference function V(.) and decision weights v (.), for the U(.) of EUM, to summarise a common pattern of choices, some serious theoretical and experimental problem exists. They are:

(i) universal applicability of the theory as all choices of different decision makers cannot be summarised by a single S-shaped value function and a set of v(.)'s.

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[3] As per widely accepted decreasing absolute risk aversion hypothesis, individuals display more risk aversion in the event of a loss and less risk aversion in the event of a gain. In the 'common consequence effect' individuals display more risk aversion in the event of an opportunity loss and less risk aversion in the event of an opportunity gain.

[4] It typically involves preference being switched as the value of p varies. According to the EUM, the preference ordering of choices should be independent of the value of p, 'common ratio effect' suggests that subjects reveal a tendency to switch preferences as p falls.

(ii) simultaneous measurement of V(.) and v(.) is problematic.

This theory, while being complex, is realistic but admits indirect violations of dominance and thus, intransitivity in pairwise choice (Quiggin, 1981).

10.1.3 Risk analysis: methodological overview

10.1.3.1 Risk analysis: the concept

Risk analysis was proposed originally by David Hertz as a logical extension of sensitive analysis (Rappaport, 1967, cited in Hertz et al., 1983). It is a methodology by which uncertainty encompassed in the variables is processed in order to estimate the impact of risk on the outcome. Risk analysis builds upon the basic framework of project appraisal by explicitly recognising the uncertainty which exists in all decision problems. A risk analysis can utilize all the information available to decision makers in the form both of subjective and objective probabilities. The output of risk analysis is not presented as a single certain value but a probability distribution of all possible returns.

Risk analysis seems to follow loosely interconnected procedures. However, several distinct stages can usually be identified and are best followed in a logical manner. In this section, these stages are quickly overviewed preparatory to subsequent and more complete elaboration of some of the key stages as they apply in individual case studies. The stages are:

Stage 1 Information about the project

Stage 2 Development of a robust forecasting model

Stage 3 Identification of key project variables (risk variables)

Stage 4 Estimation of probability distribution (subjective or objective) of key variables

Stage 5 Setting of relationships for correlated variables

Stage 6 Simulation runs

Stage 7 Statistical analysis of simulation results.

10.1.3.2 Information

The first stage of a risk analysis process is information gathering about the project, as in conventional project appraisal. The information gathering may involve primary and secondary data collection about the project. This information will be used in development of the model in the second stage.

10.1.3.3 Development of a forecasting model

A forecasting model must be capable of predicting correct results if correct data are input. The forecasting model defines mathematical relationships among variables. For afforestation project appraisal, the decision criterion can be written as:

$$NPV = \sum_{t=0}^{t=N} \frac{B_t - C_t}{(1+r)^t}$$

here, B_t is the benefit in year t (t = 1, 2,...N), C_t is the cost in year t (t = 1,2,...N), *r* is the discount rate expressed in decimals and *N* is the number of years over which costs and benefits occur.

Now, we need to estimate various variables (price, yield etc.) for calculation of benefits for each year. This can be used in defining the forecasting model. Simply, costs can be calculated by adding all discounted costs (material, wages, indirect expenditure etc) for individual years.

10.1.3.4 Identification of project risk variables

This stage involves identification of risk variables. A risk variable is defined as one which is critical to the viability of the project. A small deviation from the expected value of a risk variable both is probable and seriously affects the project outcome. Sensitivity analysis is used to identify the most important variables in the project. But as there is no rule in sensitivity analysis to determine the extent of change required in the value of a variable, we need to use a probable range for each risk variable from other informed sources in order for sensitivity analysis to yield meaningful results.

10.1.3.5 Probability distribution

In order to carry out a risk analysis, we have to specify probability distributions of risk variables. Almost all real systems including afforestation projects contain one or more source of randomness. It is necessary to represent each source of system randomness by a probability distribution in the simulation model. It is very important to define precisely the distribution of risk variables. Failure to choose the correct distribution can affect the accuracy of simulation results drastically. The methodology to define precisely the distribution depends on the complexity of the project and the availability of information about risk variables. For a new project or for *ex-ante* appraisal, we have to depend on expert opinion (in the form of subjective probability) or past experience in similar projects. Sometimes, it is almost impossible to predict the future value of a risk variable (e.g. price fluctuations). In this situation, the true value of the variable within the wide uncertainty margins can be used to define a probability distribution (e.g. triangular distribution). But in most cases it is possible to collect some data on risk variables. These data can be used to define the distribution using one of the following approaches:

Approach 1

The actual data values are used directly in the simulation model. This is referred to as a 'trace-driven simulation'.

Approach 2

The data values or their frequency are used to define an empirical distribution. This method is very useful when we cannot find a theoretical distribution. The empirical distribution can be generated as follows depending upon the nature of available data (actual values or frequency).

Approach 2a

If the original data ($X_1, X_2, \ldots \ldots X_n$ are observations) are available, we can define a continuous distribution function F by first sorting out the X_i's into increasing order. Let $X_{(i)}$ denotes the i th smallest of the $X_{(j)}$'s, so that $X_1 \leq X_{(2)} \leq \ldots \ldots \ldots \leq X_{(n)}$. Then, F(x) is given by:

$$F(x) = \begin{cases} 0, & \text{if } x < X_{(i)} \\ \dfrac{i-1}{n-1} + \dfrac{x - X_{(i)}}{(n-1)(X_{(i+1)} - X_{(i)})}, & \text{if } X_{(i)} \leq x < X_{(i+1)} \quad \text{for } i=1,2 \ldots n-1 \\ 1, & \text{if } X_{(n)} \leq x \end{cases}$$

The disadvantage of this method is that random values generated from it during a simulation run can never be less than $X_{(1)}$ or greater than $X_{(n)}$.

Approach 2b

If the original data are not available, only the frequency distribution is available, we generate continuous piecewise a linear empirical distribution from group data. Suppose that the n X_i 's are grouped into k adjacent intervals $[a_0, a_1]$, $[a_1, a_2]$, ...$[a_{k-1}, a_k]$, so that the jth interval contains $_j n$ observations, where $n_1+n_2+n_3$..............n_k=n. The distribution G(x) can be defined as:

$$G(x) = \begin{cases} 0, & \text{if } x < a_0 \\ G(a_{j-1}) + \dfrac{x-a_{j-1}}{a_j - a_{j-1}}[G(a_j)-G(a_{j-1})], & \text{if } a_{j-1)} \le x < a_j \quad \text{for } j=1,2....k \\ 1, & \text{if } a_k \le x \end{cases}$$

Approach 3

The standard theoretical distribution forms e.g. exponential, normal, Weibull etc. are used to fit empirical data and to perform hypothesis tests to determine the goodness of fit. This approach is preferable to approach 1 and approach 2 because:

a. Empirical distribution is not very reliable when data set is small.

b. If the data set is very large, the use of empirical distribution is cumbersome.

c. It is not possible to generate random numbers beyond the range of the empirical distribution. With a fitted theoretical distribution, random numbers beyond the range of observed values can be generated (Bratley et al., 1987)

Approach 4

Sometimes, no theoretical distribution provides a statistical fit for the empirical data. In this situation, a general four-parameter family of distributions (e.g. the Johnson translation system) can be used to model all sources of system randomness. The advantage gained with Johnson's translation system is that when inverted and applied to a normally distributed variable, it yields four families of density curves with a high degree of shape flexibility (Rodriguez, 1983)

We use approach 2b and 3 in our case studies.

10.1.3.6 Correlated variables

Risk variables are often correlated to each other. These variables tend to vary together in a systematic manner. For example, in plantation projects, if we get a higher number of poles, the quantum of fuelwood obtained will be less and vice versa. The nature of the relationship is often unknown. Ignoring the existence of correlation among variables can seriously distort the simulation outcome. The selection of values in a simulation run is purely random as assigned by a pre-defined distribution. Therefore, it is possible that some scenarios violate the relationship between two variables. This may lead to unrealistic results in risk analysis. It is necessary to find out any possible relationship among risk variables and reject simulation runs inconsistent with the correlation.

Savvides (1994) has suggested the use of correlation coefficient (r) as a proxy of relationship assuming linear relationship ($Y=a+bX+e$, where Y and X are the dependent risk variable and the independent risk variable respectively) among variables. The distribution is constrained so that a consistency is maintained with the counter value of independent variable. Although this method serves the purpose of containing the model from generating unrealistic scenarios, it is statistically not correct as by imposing constraints, we tend to modify the original distribution of the variables. The random number generated may violate the original distribution seriously. Secondly, the relationship between two variables may not be linear.

We use an alternative methodology for treatment of the correlation problem of the variables. First, the relationship between two variables is observed using a scatter plot. We do not constrain the distribution of the risk variable. The defined distribution is used to generate random numbers. This set of random numbers represents the complete distribution of variables. We arrange them in ascending or descending order depending upon the general trend of the relationship. Now, we again randomize the values in groups of two (one value from each variable) to maintain the correlation. A computer programme in Fortran 77 was written to perform this function (Programme 10.1.2, Appendix 10.1).

10.1.3.7 Simulation runs

During simulation runs, the values of variables are selected randomly according to the defined probability distribution. The net present value is calculated for each run and stored. Each run generates a random frame of the model depending on the correlation condition and probability distribution. The process of simulation is discussed in detail in section 10.1.4.

10.1.3.8 Analysis of results

The analysis of results is the final stage of risk analysis. In many simulation studies a single set of simulation runs of arbitrary length is chosen and the resulting simulation estimates are assumed as the representative model. Savvides (1994) has also suggested a sample size between 200 and 500 simulation runs should be sufficient. But we use random samples from probability distributions of risk variables to drive a simulation model. These estimates are just particular realizations of random variables that may have large variance, and consequently a particular simulation run of inappropriate length may differ greatly from the corresponding true characteristics of the model.

In order to analyse simulation results, simulation runs can be categorized into two types: terminating simulations and steady-state simulations. In terminating simulation, the duration of time period for runs (T_E) is specified depending on a terminating event (for example, in bank's customer service simulation, closing of the bank at a fixed time is a terminating event). In steady-state simulation the length of simulation theoretically goes to 'infinity'. In our case studies steady-state simulation is the most appropriate method. But it is quite possible to use the terminating simulation approach for systems more suited to steady-state simulation.

Suppose we make n independent simulation runs. Each of n simulations is started with the same initial conditions and is executed using a different sequence of random numbers, then each simulation run can be treated as an independent replication. Suppose, $X_1, X_2, X_3, \ldots X_n$ are IID[5] random variables with finite population mean μ and a finite population variance σ^2. Then, the sample mean (X'(n))

$$X'(n) = \frac{\sum_{i=1}^{n} X_i}{n}$$ is and unbiased estimator of μ i.e., $E[X'(n)]=\mu$

Similarly, sample variance can be given as:

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[5] IID - independent and identically distributed random variable. 'Identically distributed' means that the interarrival times (or any other activity) have the same probability distribution.

$$S^2(n) = \frac{\sum_{i=1}^{n} [X_i - X'(n)]^2}{n-1}$$

$S^2(n)$ is an unbiased estimator of σ^2 i.e., $E[S^2(n)]=\sigma^2$

If n is sufficiently large, an approximate 100(1-α)% confidence interval for μ is given by

$$X'(n) \pm t_{(n-1,\ 1-\alpha/2)} \sqrt{\frac{S^2(n)}{n}} \quad \textit{eq. } (10.2)$$

where $t_{(n-1,\ 1-\alpha/2)}$ is the upper 1-α/2 critical point for the t-distribution with n-1 df.

Instead of expected value, the whole distribution can also be compared to arrive at a steady state. The steady-state distribution F(Y) theoretically is only obtained in the limit as $i \to \infty$. In practice, however, there will often be a finite time index, say k+1. The steady state does not mean that the random variables Y_{k+1}, Y_{k+2},....will take the same value in a particular simulation run, rather, it means that they will have approximately the same distribution. The distribution can be compared using K-S tests.

10.1.4 Simulation

Risk analysis essentially draws its conceptual framework from simulation models. Simulation may be defined as an operations research technique that imitates the system[6] as it evolves over time or a point in time.

Simulation is a very powerful and widely used operations research technique for analysis of complex systems. It is not always possible to solve real-world problems analytically because of complexity and stochastic relations involved. The use of analytical models for complex systems requires a number of simplifying assumptions which result in inferior or inadequate solutions. Simulation models, which are the most flexible, can accommodate stochasticity easily and directly (Anderson et al., 1974). The main

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[6] A system is a 'collection of entities that act and interact towards the accomplishment of some logical end' (Pooch and Wall, 1993)

advantages of simulation are:

- In a simulation model, alternative project designs can be compared to examine which best meets the specific requirement.
- Simulation allows change in time frame without changing the key variables.
- A number of inventory policies can be tried on the model rather than taking the chance of experimenting on the real-world system.

Simulation is essentially not an optimizing technique. Optimization with simulation is possible but it is a slow and sometimes costly process. Law and McComas (1989, 1990) have summarized a number of pitfalls in simulation modelling. Sometimes, model parameters are difficult to initialize. These may require extensive time in collection, analysis and interpretation. Simulation supports the entire decision making process. To use simulation efficiently, a proper understanding of the simulation modelling process in decision making framework is required.

A simulation study normally consists of several distinct stages. They are (Shannon, 1975; Banks and Carson, 1984):

Stage 1 Objective of the study

1A Define a model and data collection procedure

1B Synthesis and stochastic specification

Stage 2 Checking the model

2A Verification

2B Validation

Stage 3 Construct a computer programme for:

3A Model analysis

3B Sensitivity analysis

3C Model experimentation

Stage 4 Perform simulation runs

Stage 5 Analyse output data

However, not all simulation studies consists of all these distinct stages: there may be considerable overlap between some stages or some stages may not be required at all.

10.1.4.1 Simulation models

A system can be studied either by experiment with the actual system or by experiment with a model of the system. If the model is simple (in terms of uncertainty of variables), it may be possible to find an exact analytical solution. In this case, it is usually desirable to study the model analytically rather than via simulation. However, in real world situations, many systems are highly complex and analytical solutions of these models are computationally inefficient and sometimes impossible. These complex models can only be solved by means of simulation.

Simulation models can be classified along three different dimensions (Watson, 1981).

(a) Continuous and discrete-event simulation models

Discrete-event simulation concerns the modelling of a system in which the system changes at only a countable number of points in time while in continuous simulation the system changes continuously over time. Continuous simulation models generally involve differential equations that give relationships for the rates of change of the state variables with time. Some systems are neither completely discrete nor completely continuous. In this case, we can use a combined discrete-continuous simulation (Pritsker, 1986).

(b) Deterministic and stochastic simulation models

A deterministic simulation model is one that does not contain any probabilistic or random components. A stochastic simulation model contains one or more random variables. Many systems have at least one random input variable. Stochastic simulation models produce output that is itself random. This is one of the main disadvantages of simulation.

(c) Static and dynamic simulation models

A static simulation is are presentation of a system at a point in time. It lacks a time dimension in the model. A Monte Carlo simulation is an example of static simulation.

A dynamic simulation represents a system as it evolves over time.

10.1.4.2 Random number generations

A simulation of any system requires a method of generating random variates. The random variates are generated from the uniform distribution (U (0, 1)). Random variates generated from the U (0, 1) distribution are called 'random numbers'. Random variates for all other theoretical distributions (e.g. Weibull, gamma etc.) can be obtained by transforming IID U (0, 1) in a way determined by the specific distribution (Banks and Carson, 1984).

Random numbers are generated using mathematical functions called 'random number generators'. The majority of random number generators in use are 'linear congruential generators (LCG's)'. Other generators are 'mixed generators', 'multiplicative generators', 'composite generators' and 'Tausworthe generator' (Sowey, 1986).

LCG's produce a sequence of integers x_1, x_2, x_3..............between 0 and m-1, according to the following recursive relation (Fishman, 1978):

$$x_{i+1}=(a\ x_i+c) \quad \text{modulo} \quad m, \qquad (i=0,1,2,.........)$$

where is x_0 called the seed, *a* is constant multiplier, *c* is the increment and m is the modulus.

The value of x_{i+1} equals the remainder from the division of (a x_i+c) by m. The random number between 0 and 1 is generated using the following equation[7]:

$$R_i=\frac{x_i}{m} \qquad (i=1,2,3,........)$$

The random numbers generated using LCG methods are called '**pseudo random numbers**'. They are not true random numbers because they are completely determined once the recursive relation is defined and all four parameters (x_0, a, c and m) are specified. However, the pseudo random numbers can be made to meet all the statistical properties[8] of true random number.

In simulation, we use pseudo random number generators because of their ability to reproduce a given stream of random numbers exactly. This property is very important mainly for two reasons. First, this makes debugging of computer programs easier. Secondly, we require use of identical random numbers in simulating different systems in order to obtain more precise comparison.

10.1.4.3 Monte Carlo simulation

The term Monte Carlo simulation is used by some authors to define any simulation involving the use of random numbers. It can be defined as 'a scheme employing random numbers i.e. U (0, 1) random variates, which is used for solving

[7] It is possible to generate a 0 (zero) but a random number cannot equal 1.

[8] Statistical tests include both empirical (Chi-square test, K-S test, serial tests, runs up test and correlation tests) and theoretical tests. Theoretical tests use the numerical parameters to assess a generator globally without actually generating U_i's (Morgan, 1984; Ripley, 1987).

certain stochastic or deterministic problems where the passage of time plays no substantive role' (Hammersley and Handscomb, 1964). However, Monte Carlo methods (e.g. Monte Carlo sampling) are used both in static and dynamic simulation for generating random numbers from a defined probability distribution (Morgan, 1984).

10.1.4.4 Simulation language

A simulation language or a general-purpose language such as FORTRAN, C, PASCAL or BASIC is used for programming simulation models. Most simulation languages use either the *event-scheduling*[9] or the *process*[10] approach for modelling. The common simulation languages (or complete software based on the language) are GPSS (General Purpose Simulation System), SIMAN (SIMulation Analysis), SIMSCRIPT II.5, SLAM II (Simulation Language for Alternative Modelling) (Banks and Carson, 1985).

There are a number of advantages of programming a simulation model in a simulation language rather than in general-purpose languages (Fortran, C, etc.). Simulation languages automatically provide most of the features needed for modelling and statistical analysis of the results. In the absence of access to simulation software, we use Fortran 77 (Unix) for programming in this study. However, statistical analyses for model validation and simulation outcomes are carried out using general-purpose statistical software because developing specialized statistical routines in Fortran is cumbersome and time consuming and it has no further utility once simulation software become available.

10.1.5 Risk analysis: a case study of RDF component of the project

Since the costs of raising plantations of the RDF component and harvesting of final produce were fixed according to the schedule of rates of the Government of Bihar, there was no element of variability in these factors. However, the benefits vary depending on biotic (e.g., illicit felling, grazing) and abiotic (site condition, rainfall etc.) factors. The prices of forest produce are also taken as constant with no uncertainty term as most

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[9] The times of future events are explicitly coded into the model.

[10] A 'process' is a time-ordered sequence of interrelated events separated by passages of time, which describes the entire experience as an 'entity'.

(over 90%) of these produce are sold to the public (the government mining companies, irrigation department) and private sectors (consumer depot) at a fixed price. Therefore, only three variables - number of poles, number of fencing posts and fuelwood quantity are identified as risk variables. This analysis is taken up from the forest department perspective using FCBA model (model WM-INA).

We use empirical distributions of these risk variables to generate random numbers because:

a. the data set is too small to fit a statistically significant theoretical distribution.

b. due to extreme skewness in variables, it is expected that extreme values within the defined range would be the most likely outcome.

The probability density functions of the variables are given in Table 10.1. We used these distribution to generate empirical distributions of random numbers. A computer programme in Fortran 77 is written to generate random numbers according to a given empirical distribution (Programe 10.1.1, Appendix 10.1).

Table 10.1 Probability distributions (PDFs) of risk variables

Fencing post		Poles		Fuelwood	
Range (nos.)	Probability	Range (nos.)	Probability	Range (m^3)	Probability
0-1000	0.33	0-400	0.33	0-20	0.11
1001-2000	0.06	401-800	0.00	21-40	0.28
2001-3000	0.00	801-1200	0.28	41-60	0.05
3001-4000	0.28	1201-1600	0.28	61-80	0.17
4001-5000	0.00	1601-2000	0.05	81-100	0.17
5001-6000	0.11	2001-2400	0.06	101-120	0.22
6001-7000	0.11				
7001-8000	0.06				
8001-9000	0.06				

10.1.5.1 Correlated variables

The two risk variables viz. 'number of poles' and 'number of fencing posts' show positive correlation (r=0.9758, P=0.000 (Pearson); P=0.000 (Kendall's τ-b); P=0.000 (Spearman); Fig. 10.1). The linear regression also shows the following relationship (t-value is given in parentheses):

Poles=116.0684+0.2461 Fencing post

(1.969) (17.849) R-sq.=0.95218 n=18

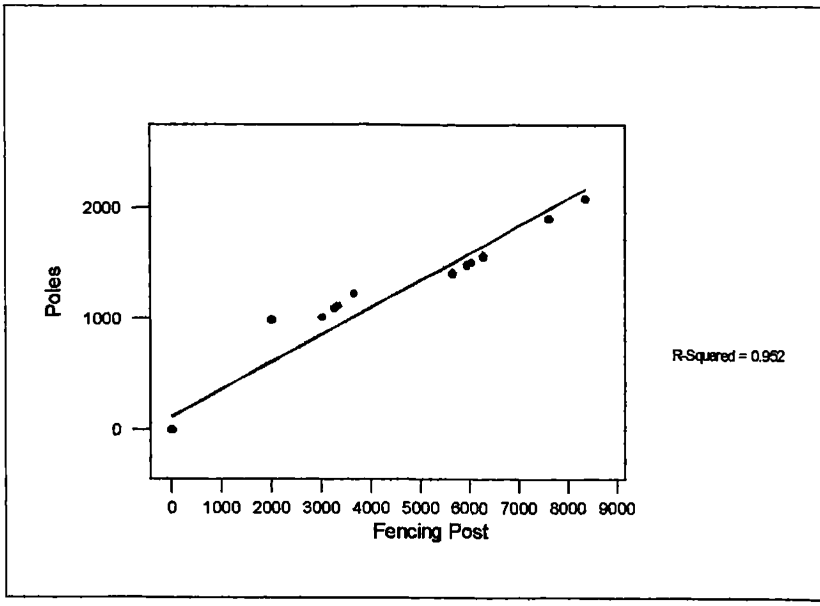

Fig. 10.1 Scatter plot showing correlation between two risk variables (Pearson correlation coefficient (r)=0.9758; P=0.000)

Now, it is required that this initial correlation between variables should remain the same after simulation runs. The methodology was already discussed in section 10.4.5 and the computer programme is presented in Appendix 10.1 (Programme 10.1.2). The relationship between the two variables is tested after 1200 simulation runs (Fig. 10.2). We do not find any significant difference between correlation coefficients before and after simulation runs.

Poles=84.2424+0.2324 Fencing post

(17.361) (206.036) R-sq.=0.97255 n=1200 (simulation runs)

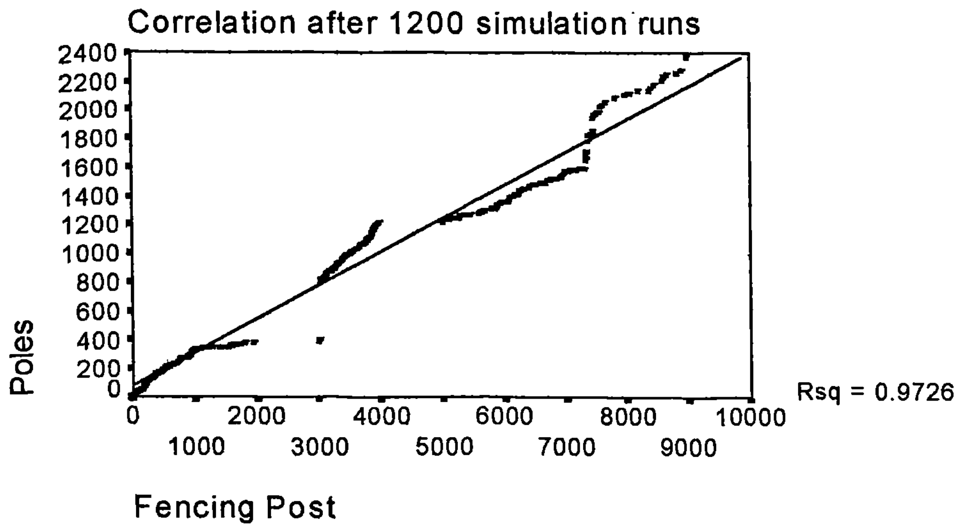

Fig. 10.2 Scatter plot showing correlation after 1200 simulation runs (Pearson correlation coefficient (r)=0.9862; P=0.000)

10.5.1.2 Simulation of risk variables of the RDF component

During a simulation, the values of the risk variables are selected randomly following the predefined distribution and correlation condition. The results (NPV, IRR and BCR) are computed for each set of values and stored following each run. The programme is given in Appendix 10.1 (Programme 10.1.3). This programme calculates net present value. For calculation of IRR and BCR, this programme is suitably modified. The outcome of simulation is presented in cumulative probability plots. Initially, we chose (purely arbitrarily) a sample size of 1200 runs. Now, we need to test whether our chosen sample size is 'adequate'. We run the model for 50, 100, 200......1200 simulations and store probability density function after each sequence of runs. The initial seed value for random number generation remained the same in all cases. Fig. 10.3 shows that after 400 simulation runs the distribution stabilized and increase in runs does not affect the probability distribution significantly. This is formally tested using Mann-Whitney and Sign tests. Since the value is large (P>0.05) the hypothesis that the distributions are the same is not rejected. We conclude that 1200 runs are adequate.

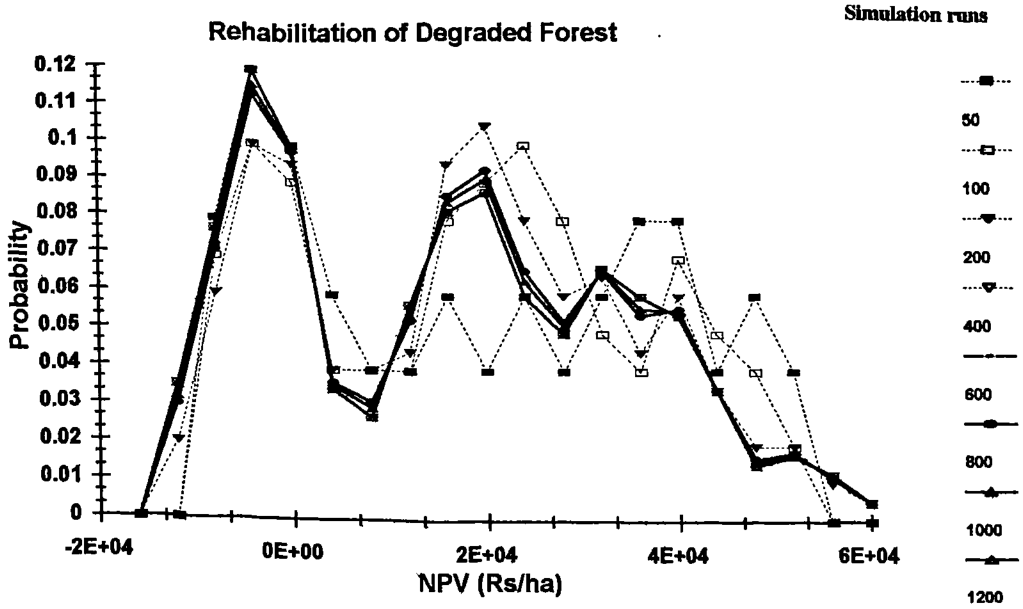

Fig. 10.3 Stabilization of probability density function after 400 simulation runs

To estimate confidence interval of the simulation results, we use the terminating simulation method. It can be assumed that after 1200 simulation runs, steady-state results. We make ten[11] independent[12] replications of simulation runs of fixed length (i.e., 1200 runs). The expected value (probability × NPV) for each replication is calculated as in eq. 10.2.

$$16101 \pm 1.833_{(9,\ 0.95)} \sqrt{\frac{(74.2668)^2}{10}} = 16101 \pm 43.0484,\ 95\%\mathit{CI\ for\ Mean}\ (16144,\ 16058)$$

The value obtained is the approximate 95% (not exact) confidence interval of mean because the correctness of the confidence interval given by the above equation (in terms of having coverage close to 1-α) depends on the assumption that the x_j's

[11] Ten is a minimum reasonable number for testing normality of the expected value data.

[12] The sequence of random number is changed in each replication. The methodology is given in Appendix 10.1.

(replications) are normal random variables. Subsequently, we test expected values (x_j's) for normality. The Kolmogorov-Smirnov test show that the data[13] is normal (P=0.8687).

10.5.1.3 Analysis of results

Every simulation run represents a probability of occurrence equal to:

$P=1/n$,

where P is the probability weight for a single run and n is sample size (n=1200)
The cumulative probability distribution of the simulation results is plotted by sorting the data in ascending order and adding probabilities of individual runs (Fig. 10.6; Fig. 10.7). A discount rate of 10% is used for NPV and BCR calculations. The probability of each outcome is the same (i.e., 1/1200). The continuous distribution can also be presented in a discrete fashion. The main problem is the absence of a definitive guideline for choosing the number of intervals, k. However, several rules-of-thumb have been suggested (Scott, 1979; Hoaglin et al., 1983). The best known of these guidelines is probably Sturges's rule:

$$k = [1 + \log_2 n] = [1 + 3.322 \log_{10} n]$$

where k is number of intervals and n is number of cases (n=1200).
There are many sophisticated ways to estimate a discrete density function from a continuous distribution (for a review, see, Wegman, 1982). However, Sturges's rule gives good approximation.

Fig 10.4 presents the probability of all possible outcomes of the RDF component. The probability of getting a negative NPV is only 33.25% at 10% discount rate. Similarly, IRR and BCR of simulations of RDF component are presented in Fig. 10.6 and 10.7. Both the plots show continuous CDF. The probability of getting IRR below 0 is 9.25%. The probability of getting BCR more than 2.0 is 13%.

The complete probability distribution can be summarized in terms of expected values. The expected value (EV) is a weighted (according to probability) average of the values of all possible outcomes. The expected value aggregates all the information depicted in a probability distribution into a single number and is only a gross indicator of a project's worth. It is very useful for quick comparison among different projects or

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[13] The expected values of ten sequence of simulation runs obtained are: 16080, 16170, 16110, 16080, 16220, 16115, 15990, 16115, 16150, 15980.

different component of a project.

The cumulative probability distribution of outcome also provides the data to quantify the value of information or the cost of uncertainty. The expected value of possible gains forgone (NPV: 17650 Rs/ha) and the expected value of possible loss (NPV: -1520 Rs/ha) can be used decide whether it is worthwhile to postpone a decision or reject the project and seek further information or whether to make decision immediately. It is worthwhile to postpone a project if the possible reduction in the cost of uncertainty is greater than the cost of securing more information in terms of probability distribution of risk variables (Savvides, 1994).

The expected loss ratio (ELR) of the project can be calculated using the following formula:

$$ELR = \frac{Expected\ loss}{Expected\ loss\ +\ Expected\ gain}$$

It can vary from 0 (no loss) to 1 (no gain). ELR measures the magnitude of expected loss relative to the sum of expected loss and expected gain (ELR=1520/16130=0.0942). ELR ratio of 0.0942 indicates very little loss as compared to net expected gain.

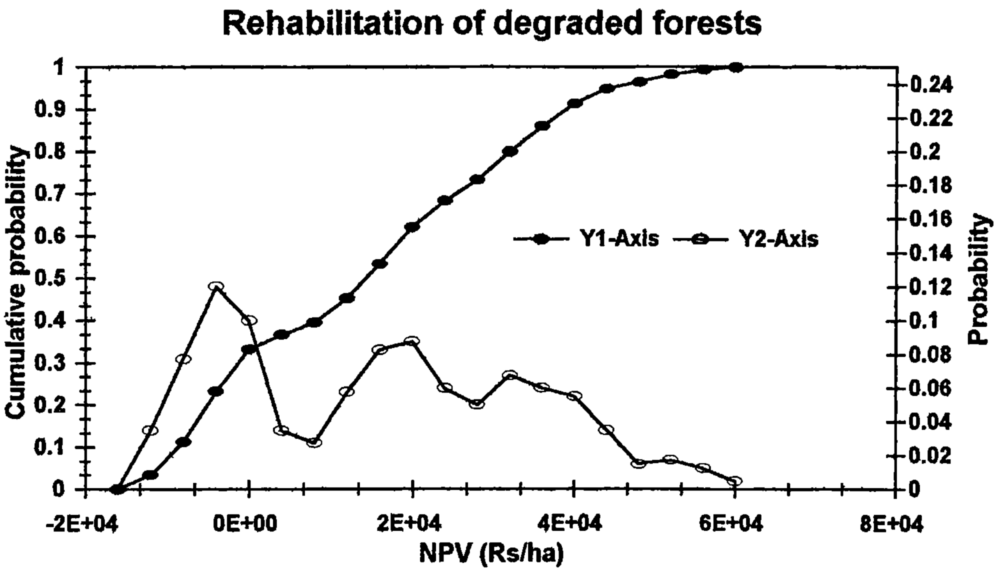

Fig. 10.4 Cumulative distribution function and probability density function of RDF component at 10% discount rate

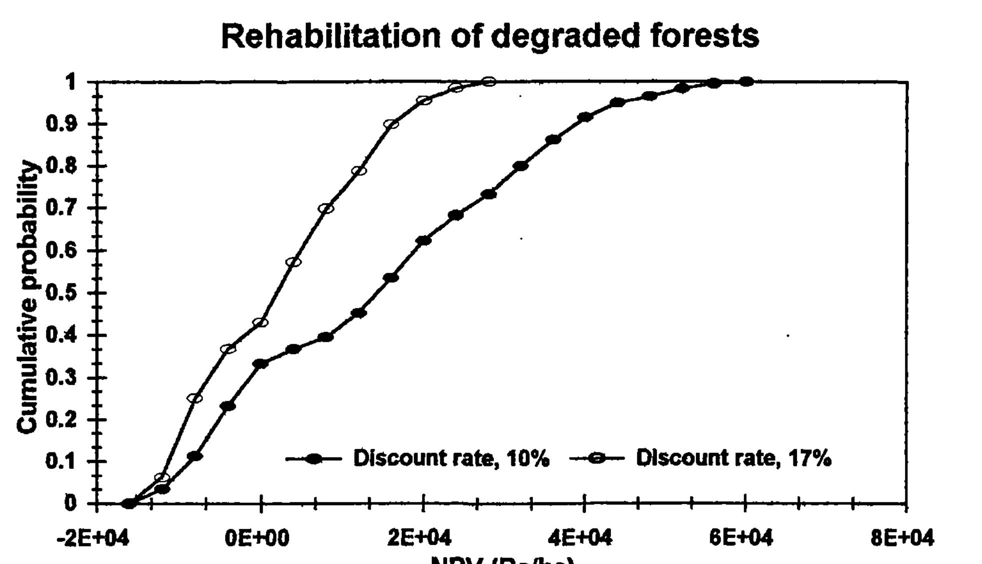

Fig. 10.5 Cumulative distribution function of RDF component at 10% and 17% discount rate

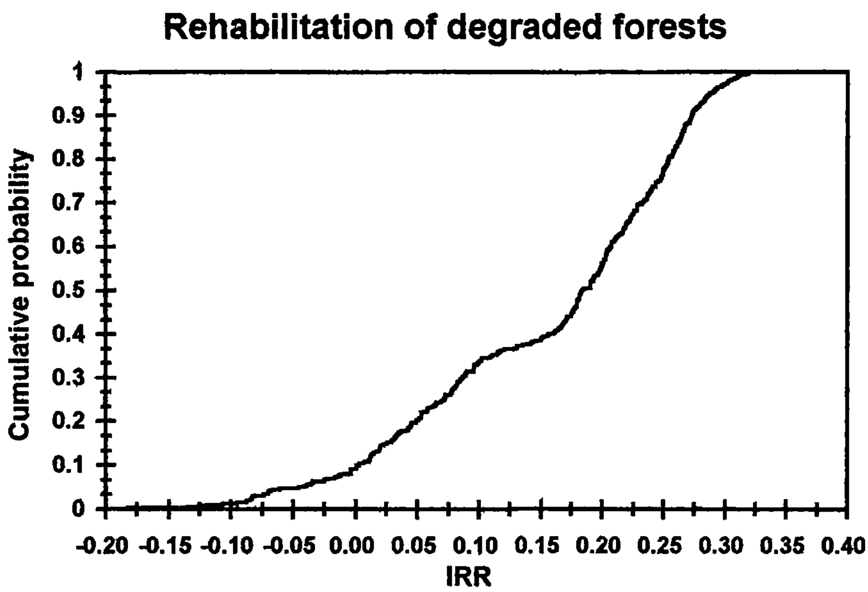

Fig. 10.6 Cumulative probability distribution of IRR

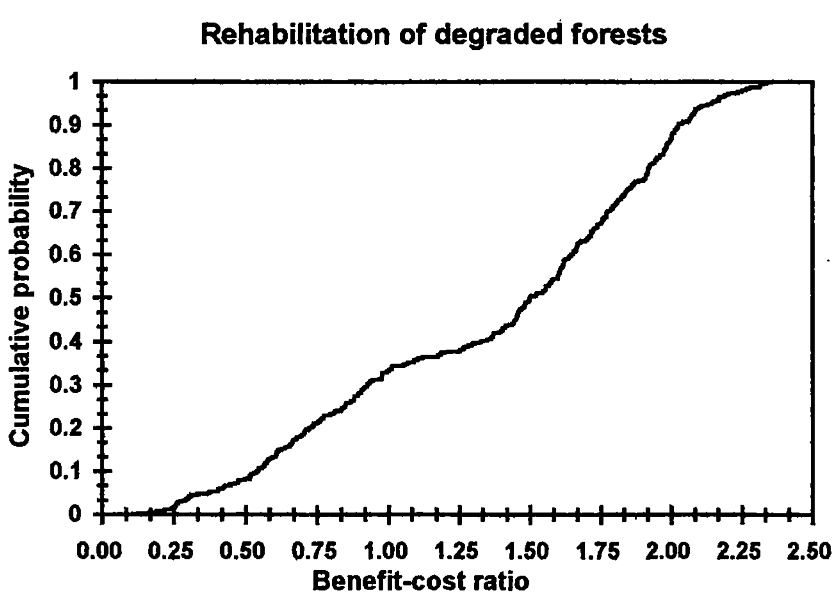

Fig. 10.7 Cumulative probability distribution of BCR

Fig. 10.5 shows probabilities of outcomes at two discount rates - 10% and 17%. These curves gives a probability of possible loss under two discount rates. It is also possible to compare the complete distribution of return (NPV) of two regions or two districts. If the cumulative probability distribution of return do not intersect at any point, it is preferable to choose the option whose probability distribution curve is further to the right. This is the case of first degree stochastic dominance (FSD). This method is more useful for comparison of different components.

10.1.6 Risk analysis: a case study of FF component of the project

After deciding the profitability criterion (NPV per ha in this case study), we identify risk variables in the FF component. The variables which are critical to the variability of the project are: number of poles, number of fencing posts, fuelwood quantity, distance from depot, prices of poles, fuelwood, fencing posts and grass. All these variables when tested (sensitivity analysis) within their possible margins of uncertainty were found to affect NPV of the project significantly.

10.1.6.1 Selection of input probability distribution of risk variables

It is necessary to represent each variable by a probability distribution (rather than just its mean) in the simulation model. The selection of a probability distribution for a risk variable involves setting up a range of values and allocating probability weights to each value. For some variables for example, 'number of poles', 'number of fencing posts', 'distance from depot', adequate information is available to arrive at respective probability distributions. But for a few variables for example, 'price of grass', we do not have complete information. In this case, we have to rely on subjective information to assign a probability distribution.

Fuelwood quantity shows normal distribution according to the Kolmogorov-Smirnov normality test (P-value: 0.135) and the Ryan-Joiner normality test (P-value approx. >0.10) but the Anderson-Darling normality test shows that the distribution is not normal (P-value: 0.029). Anderson-Darling test of normality is considered to be the most reliable test. Therefore, we truncate the distribution. Out of 72 values, 68 are used to define the initial distribution. All the tests show that the distribution is not significantly different from normal (Fig. 10.8; Fig. 10.9).

The remaining four values (all zeros) are used to truncate the normal distribution to the left to generate the final distribution of the variable. For generation of random numbers following a normal distribution, a computer programme in Fortran 77 is written (Programme 10.2.3, Appendix 10.2). The truncation of the normal distribution is done by restricting random numbers according to probability of getting zeros (4/72=0.055). Random numbers generated have some (<0.01%) negative values[14]. Negative value of fuelwood quantity is meaningless. Therefore, these values are eliminated from the sequence and are replaced by the values obtained by random sampling of the remaining values. The whole sequence is again tested for normality. It shows a normal distribution.

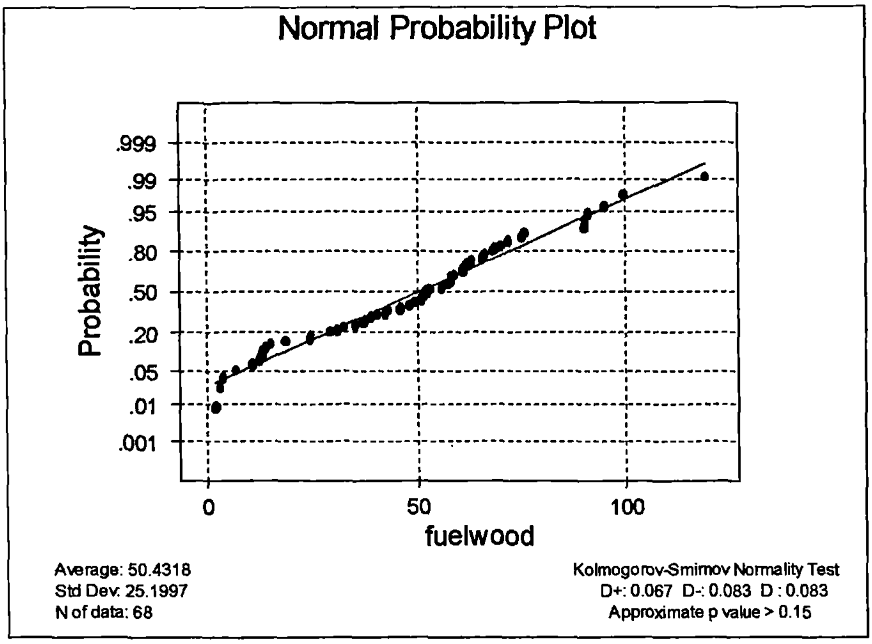

Fig. 10.8 Normal probability plot of variable 'fuelwood quantity'

To avoid getting negative values and also to tackle the problem of truncation, a log normal distribution (Range: 0, ∞) was also tried but it did not fit the data well. The normal distribution can also be used to represent a non negative quantity (e.g., fuelwood quantity, time) by truncating its density at x=0. But it involves a complex algorithm.

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[14] The range of normal distribution is $-\infty$ to $+\infty$. $\mu \in (-\infty, +\infty)$, $\sigma > 0$; σ=standard deviation, μ=mean

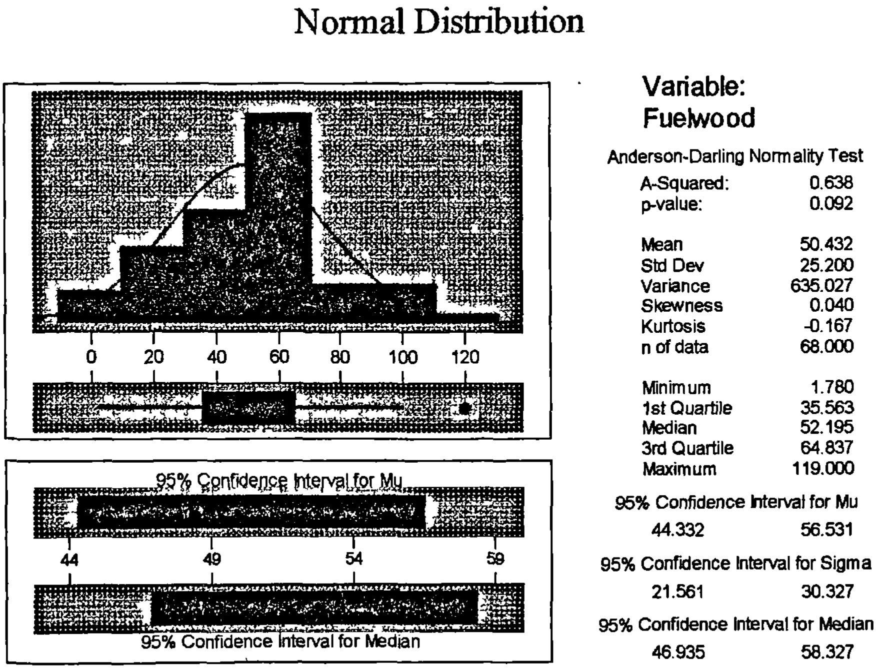

Fig. 10.9 Normal distribution of variable 'fuelwood quantity'

Table 10.2 Probability distribution (PDFs) of risk variables-FF component

Fencing post		Poles	
Range	Probability	Range	Probability
0-500	0.35	0-100	0.46
501-1000	0.03	101-200	0.00
1001-1500	0.03	201-300	0.00
1501-2000	0.04	301-400	0.06
2001-2500	0.03	401-500	0.06
2501-3000	0.03	501-600	0.06
3001-3500	0.07	601-700	0.01
3501-4000	0.06	701-800	0.22
4001-4500	0.07	801-900	0.07
4501-5000	0.13	901-1000	0.00
5001-5500	0.08	1001-1100	0.01
5501-6000	0.00	1101-1200	0.01
6001-6500	0.04	1201-1300	0.04
6501-7000	0.00		
7001-7500	0.00		
7501-8000	0.04		
8001-8500	0.01		

We do not find any suitable theoretical distribution for 'number of poles' and 'number of fencing post' variables. Therefore, empirical distributions of these two variables are used. For all produce of intermediate harvests, we use empirical distributions. The programme given in Appendix 10.1 (Programme 10.1.2) is modified according to desired input distribution. Table 10.2 presents probability distribution (PDF) of these variables. Unlike in RDF, these variables are not significantly correlated. A possible reason is that in RDF conversion of standing trees (into poles, fencing posts and fuelwood) is done according to definite guidelines of the Forest Department, but in FF intermediate harvests were taken depending on need of particular forest produce.

The 'Distance from the depot' variable follows a Weibull distribution. We estimate shape (1.46204) and scale (33.7973) parameters from the data using MLE (maximum likelihood estimate) (Fig. 10.10).

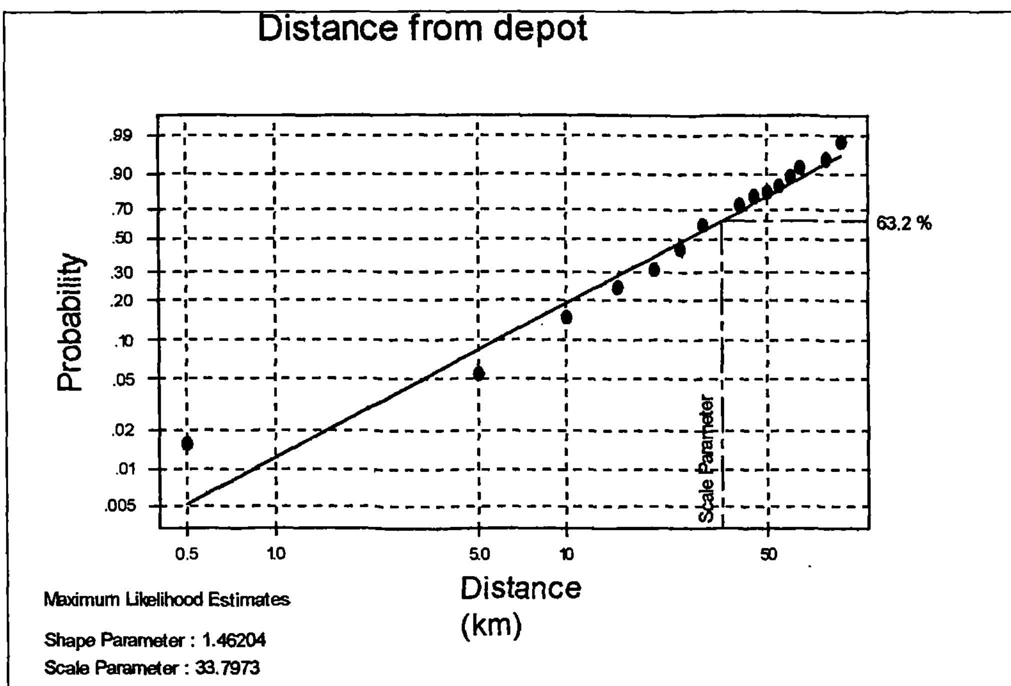

Fig 10.10 Estimation of shape and scale parameter of Weibull distribution

Now, we need to test whether the fitted Weibull distribution provides a good model for 'the distance from the depot' data. We use Kolmogorov-Smirnov (K-S) tests for goodness of fit. The K-S test statistic Dn is simply the largest (vertical) distance between Fn(x) (empirical distribution) and F'(x) (hypothesized distribution) for all values of x.

$Dn = \max. \{Dn^+, Dn^-\}$

We found that D_{72} = 0.062, so that the adjusted statistic[15] is

$$\sqrt{n}.\ D_n, \qquad \sqrt{72}.\ 0.062 \quad = 0.5261$$

Since 0.5261 is less than 0.803 (=$C''_{0.90}$), we do not reject H_0 at the α=0.10 level (90%). K-S tests give the same weight to the difference for any value of x, whereas many distributions differ primarily in their tails. The Anderson-Darling test is designed to test such discrepancies. We use the Anderson-Darling test also to see whether the fitted Weibull distribution provides a good model. We found that A^2_{72} = 0.983, so that the adjusted test statistic is:

$$\left(1+\frac{0.2}{\sqrt{n}}\right).\ A_n^2, \qquad \left(1+\frac{0.2}{\sqrt{72}}\right).0.983 \quad =1.006$$

Since 1.006 is less than the modified critical value ($C''_{0.99}$=1.038), we do not reject H_0 at 0.01 level (99%).

The programme for generating random numbers (following a Weibull distribution) of the variable 'distance from the depot' is given in Appendix 10.2 (Programme 10.2.3).

The variable 'grass price' seems to vary randomly between Rs 175 and Rs 215 per quintal depending on season and availability of crop residue etc. Therefore, we choose a uniform distribution for generating random numbers for the simulation model. A computer programme (Programme 10.2.4, Appendix 10.2) is written in Fortran 77 for generation of random numbers. Fig. 10.11 presents the output distribution.

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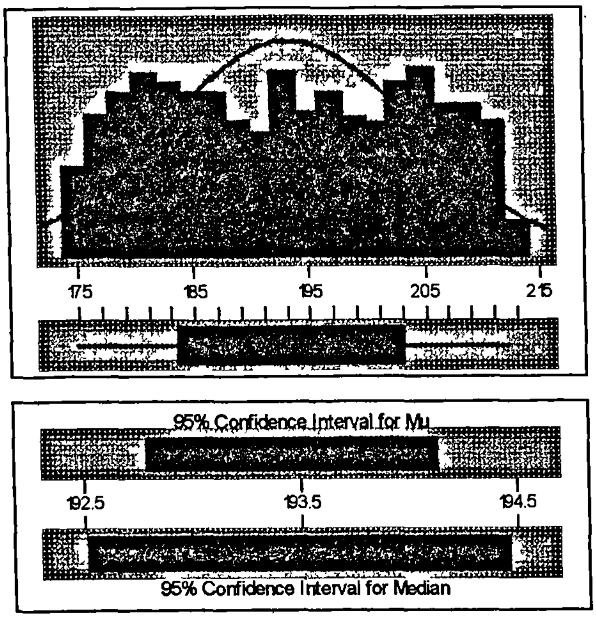
[15] H_0 is rejected if the adjusted K-S statistic $\sqrt{n}.\ D_n$ is greater than the modified critical value $C^*_{1-\alpha}$ (Chandra et al., 1981).

Uniform distribution



Variable:
grass price

Anderson-Darling Normality Test

A-Squared:	12.46
p-value:	0.00
Mean	193.46
Std Dev	10.83
Variance	117.18
Skewness	0.03
Kurtosis	-1.23
n of data	1000.00
Minimum	175.00
1st Quartile	183.72
Median	193.51
3rd Quartile	203.13
Maximum	212.45

95% Confidence Interval for Mu

192.79	194.13

95% Confidence Interval for Sigma

10.37	11.32

95% Confidence Interval for Median

192.52	194.47

Fig. 10.11 Uniform distribution of variable 'grass price'

The information regarding risk variable 'fuelwood price' is not sufficient to define an empirical or theoretical distribution significantly. In some simulation studies it may not be possible to collect data for the risk variable, or the data is not enough to define a theoretical or empirical distribution. In these cases, heuristic procedures can be used. Anderson and Dillon (1992) has suggested the use of the triangular distribution approach. The main problem with the triangular distribution is that it requires subjective estimates of the absolute minimum and maximum possible values.

A second approach is to assume that the random variable X has a beta distribution (a, b). A beta distribution offers more modelling flexibility as compared to a triangular distribution because of the variety of shapes it (beta density function) can assume. If we assume that the value of X varies between a (minimum) and b (maximum) randomly and $\alpha_1=\alpha_2=1$ (α_1, α_2 are shape parameters of beta distribution), the distribution will take uniform distribution form (U (a, b)). If $\alpha_2>\alpha_1>1$ (or $\mu<c$, μ=mean, c=mode), the distribution will be right skewed. Conversely, if $\alpha_1>\alpha_2>1$ (or $\mu>c$), the distribution will be skewed to left. The mean (μ) and mode (c) of a beta distribution (Range: 0, 1) can be given as:

$$\mu = \frac{\alpha_1}{\alpha_1 + \alpha_2} \quad or \quad \alpha_2 = \frac{(1-\mu)\,\alpha_1}{\mu} \quad \text{.......... } eq.\ (10.3)$$

$$c = \frac{\alpha_1 - 1}{\alpha_1 + \alpha_2 - 2} \quad \text{.......... } eq.\ (10.4)$$

Substituting the value of α2 in equation 10.4, we get,

$$\alpha_1 = \frac{\mu\,(2c-1)}{(c-\mu)} \quad \text{.......... } eq.\ (10.5)$$

where shape parameters $\alpha_1 > 0$ *and* $\alpha_2 > 0$

We use the beta distribution so as to best utilize the available data for variable 'fuelwood price'. The fuelwood price ranges from Rs 200/m^3 to Rs 270/m^3. The most likely price (i.e., mode) is assumed as Rs 250/m^3. The mean value (μ) is calculated as 241.18. First, we rescale the minimum and the maximum values between 0 and 1(rescaled value; μ=0.588, c=0.71). The shape parameters α_1 and α_2 are calculated using equations 10.3 and 10.5:

α_1 = {0.588(2 × 0.71)-1} / (0.71-0.588) =2.02 or approx. 2.0.

α_2 = {(1-0.588)2.0} / 0.588 =1.40 or approx. 1.4.

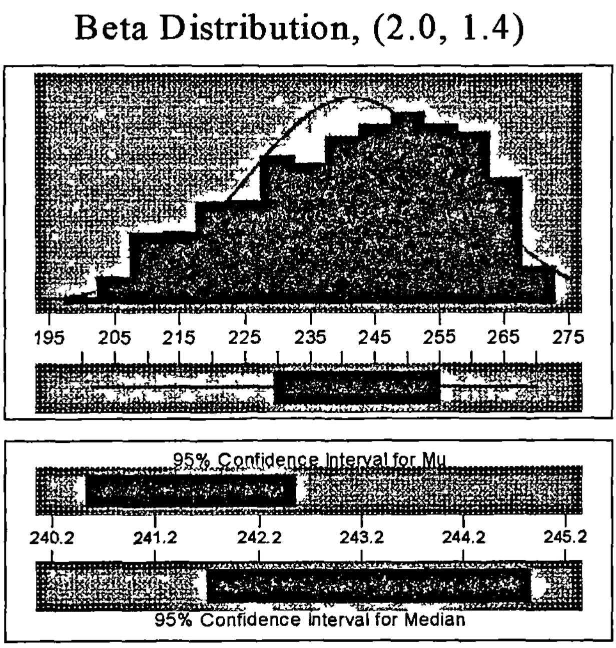
The parameters α_1 and α_2 calculated above are used to generate random numbers following a beta distribution between 0 and 1. The random numbers were again rescaled between min. (200) and max. (270) values. A computer programme was written for generation and rescaling of random numbers (Programme 10.2.5, Appendix 10.2). The output distribution derived from 1000 random numbers is presented in Fig. 10.12

The price of poles varies between Rs 20 per piece and Rs 40 per piece. The 'most likely value' (mode, c) is assumed as Rs 25. Rs 27.5 is the mean value (μ). The shape parameters α_1 and α_2 are calculated after rescaling all the values between 0 and 1(rescaled value: c=0.25; μ=0.375).

α_1 = {0.375(2 × 0.25) -1)} / 0.25-0.375 =1.5

α_2 = {(1-0.375)1.5} / 0.375 = 2.5

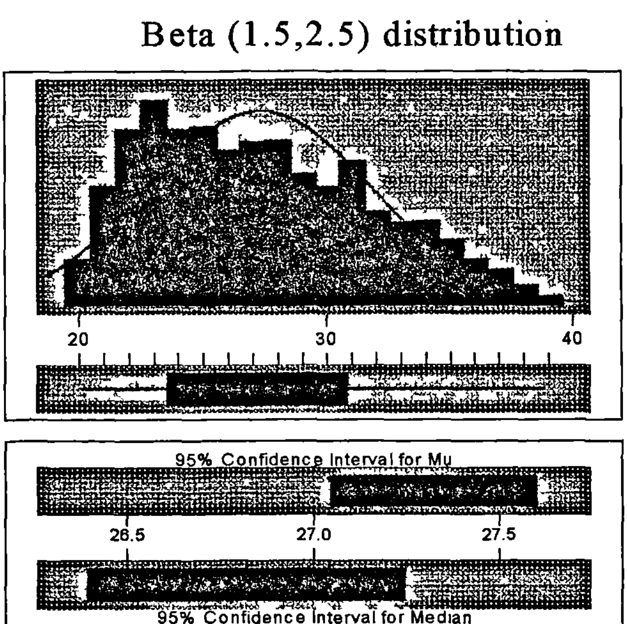
The shape parameters α_1 and α_2 are used to generate random numbers following beta distribution. The distribution is rescaled between 20 and 40. The programme (Programme 10.2.5, Appendix 10.2) is modified for new parameter values. The output distribution is presented in Fig. 10.13.



Variable: Fuelwood price

Anderson-Darling Normality Test	
A-Squared:	7.44
p-value:	0.00
Mean	241.54
Std Dev	16.35
Variance	267.40
Skewness	-0.34
Kurtosis	-0.80
n of data	1000.00
Minimum	201.42
1st Quartile	229.60
Median	243.19
3rd Quartile	254.70
Maximum	269.98
95% Confidence Interval for Mu	
240.52	242.55
95% Confidence Interval for Sigma	
15.67	17.10
95% Confidence Interval for Median	
241.70	244.84

Fig. 10.12 Beta distribution of variable 'fuelwood price'



Variable: Pole Price

Anderson-Darling Normality Test	
A-Squared:	9.92
p-value:	0.00
Mean	27.33
Std Dev	4.47
Variance	19.99
Skewness	0.43
Kurtosis	-0.73
n of data	1000.00
Minimum	20.10
1st Quartile	23.54
Median	26.77
3rd Quartile	30.73
Maximum	38.75
95% Confidence Interval for Mu	
27.05	27.60
95% Confidence Interval for Sigma	
4.28	4.68
95% Confidence Interval for Median	
26.39	27.24

Fig. 10.13 Beta distribution of variable 'pole price'

The values of the risk variable 'fencing post price' range between Rs 10 per piece and Rs 15 per piece. The most likely price is assumed as Rs 13. The mean value is calculated as Rs 12.857. α_1 and α_2 are calculated after rescaling mean and mode between 0 and 1 (rescaled value: μ=0.5714, c=0.60).

α_1 = {0.5714(2 × 0.6 -1)} / (0.6- 0.5714) =3.9958 or approx. 4.0.

α_1 = {(1-0.5714)4} / 0.5714 = 3.00035 or approx. 3.0.

Programme 10.2.5 (Appendix 10.2.5) is used for generation of random numbers following a beta (4, 3) distribution for this variable also after changing scale parameters and the range in the original programme. The output distribution is presented in Fig. 10.14.

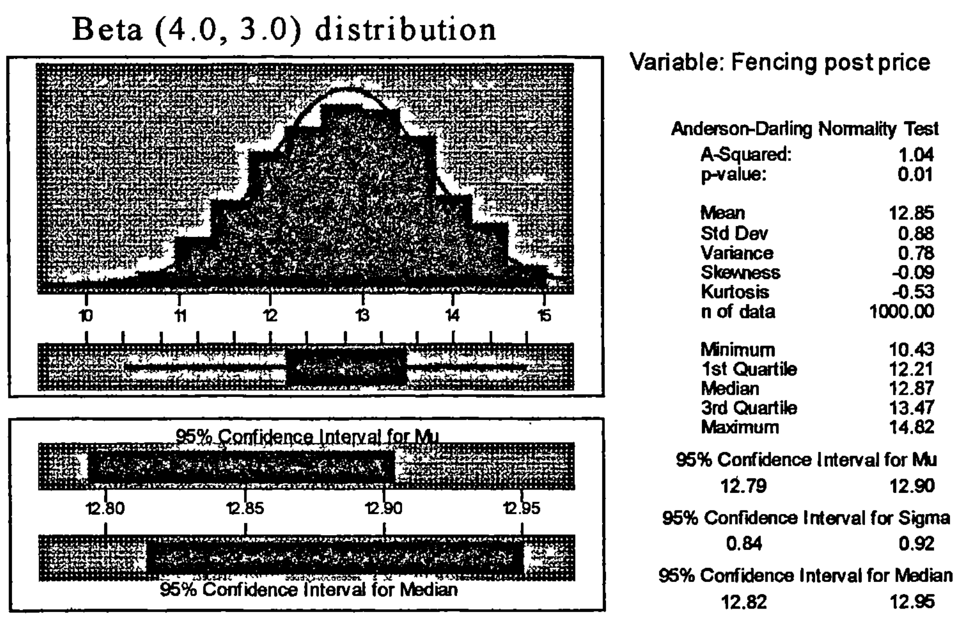


Fig. 10.14 Beta distribution of variable 'fencing post price'

10.1.6.2 Simulation of risk variables of the FF component

Random numbers following the specified distribution of risk variables were used in the computation of net present value. The outcome of simulation is presented in the cumulative probability plot (Fig.10.16). A discount rate of 10% is used. We choose a sample size of 1000 simulation runs. To validate selection of the sample size, we run the model for 100, 200,........1000 simulations. Fig.10.15 shows that after 600 simulations, the distribution stabilizes and an increase in runs does not affect outcome significantly.

This is formally tested using the Mann-Whitney test. Since the P-value is well above the 0.05 level, the hypothesis that the distributions are the same, is not rejected. We conclude that 1000 runs are adequate.

For estimation of confidence interval of simulation results, we make ten independent replications[16] of simulation runs of fixed length (i.e., 1000 runs). The expected value ($\sum$probability x NPV) for each sequence of run is calculated. We obtain (eq. 10.2) 95% CI for mean as 18610.75, 18711.49. We test the data for normality to validate the correctness of the 95% confidence interval. All the tests (K-S test, P=0.8077; A-D test, P= 0.310; Ryan-Joiner test, P>0.10) show that the data are normal.

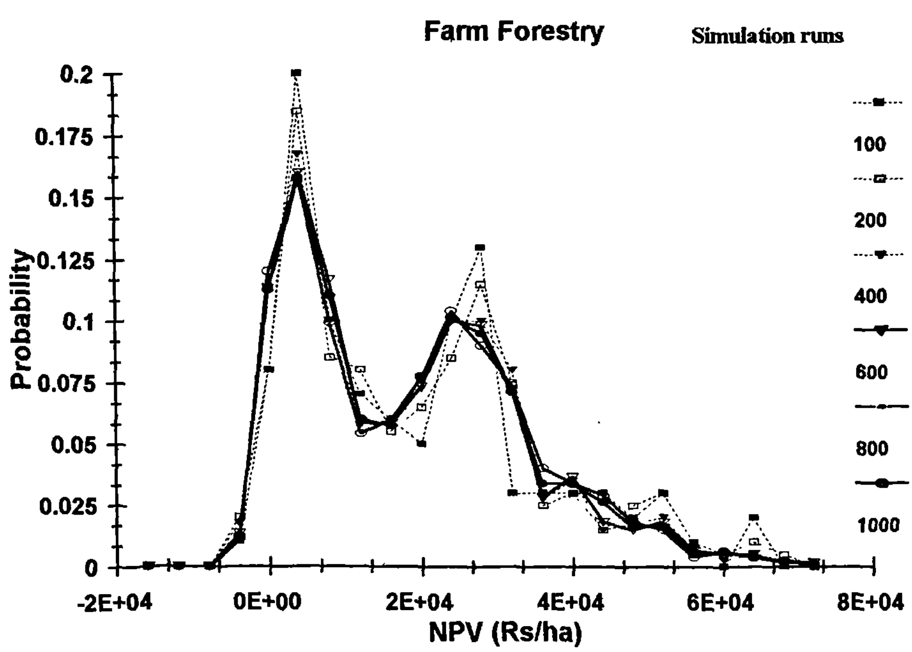


Fig. 10.15 Stabilization of probability density function after 600 simulation runs

10.1.6.3 Analysis of results

The cumulative probability distribution of simulation results is presented in Fig 10.16. Fig 10.17 presents both CDF and PDF of simulation outcome. The probability of

[16] The expected values of ten replications of simulation runs are: 18556, 18774, 18644, 18756, 18674, 18560, 18649, 18691, 18660, 18649.

getting a negative NPV is only 13.1% at 10% discount rate. The expected value ($\sum$NPV × probability) from the discrete distribution is Rs 18680. The range of outcome is very large. The expected loss ratio (ELR) of FF component is much less (ELR=44/18680, =0.002355) than that of RDF component.

10.1.7 Comparison of FF and RDF component

The concept of risk analysis is based on an assumption that the preference of individual decision maker could not be obtained, quantified and employed directly in the analysis. The aspects related to elicitation and quantification of decision makers' risk aversion will be discussed in section II of this chapter. RDF and FF component can be compared in terms of their respective expected values. The expected value of FF component (Rs 18680) is higher as compared with RDF component (Rs 16130). Using the concept of stochastic efficiency, the complete distribution of outcome can be compared. A distribution function dominates another if it lies more to the right in terms of differences in area between the CDF curves cumulated from the lower values of the uncertain quantity (Anderson et al, 1977). Fig. 10.18 presents CDF (discrete) of FF and RDF components. It is clear that the area marked 'A' exceeds the area marked 'B'. The area between the curve can be calculated using equation 10.1. The intersection points are highlighted in the inset of Fig. 10.18 and in Fig. 10.19.

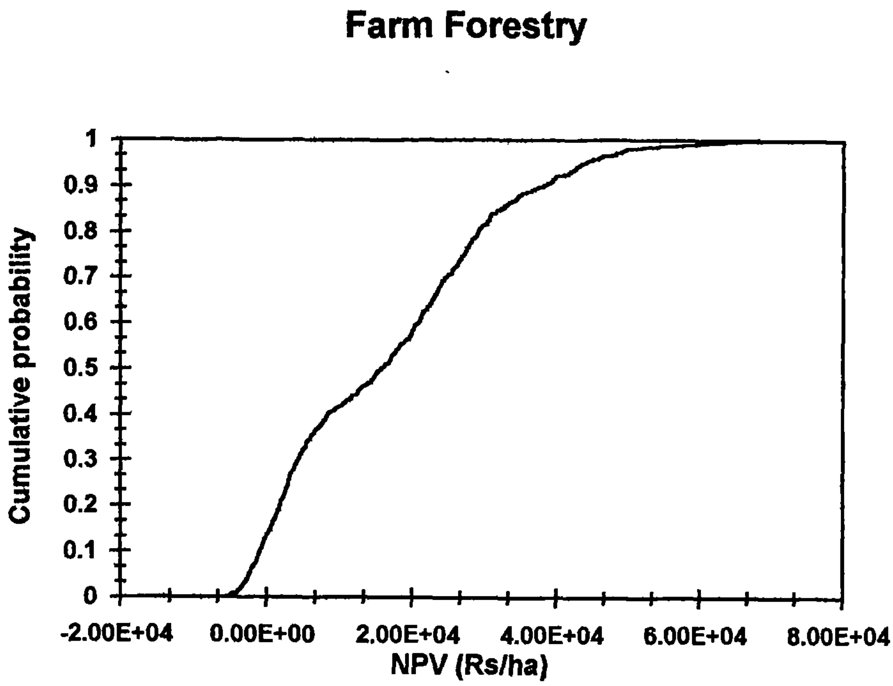


Fig. 10.16 Cumulative probability distribution (continuous) of simulation results

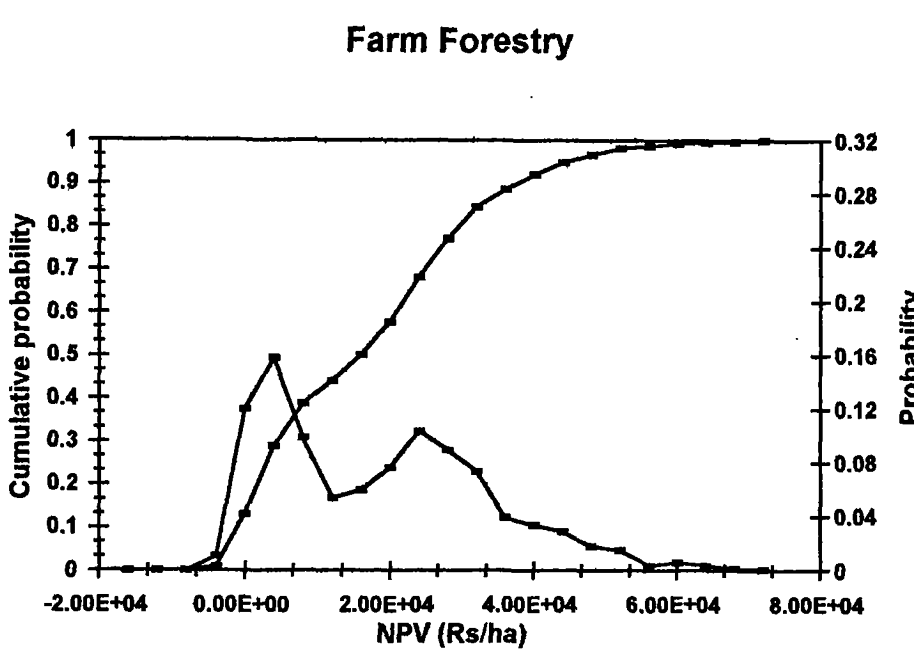


Fig. 10.17 Cumulative distribution function and probability density function (discrete) of simulation results

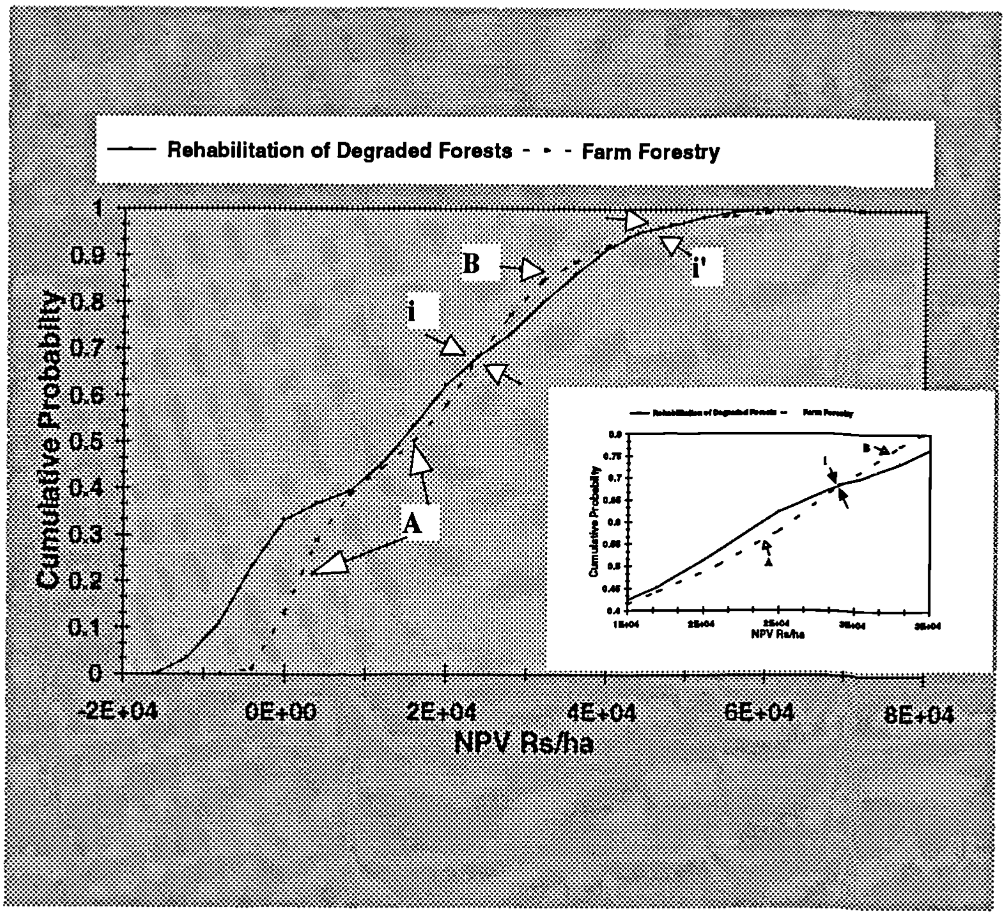


Fig. 10.18 FF and RDF components-Second Degree Stochastic Dominance

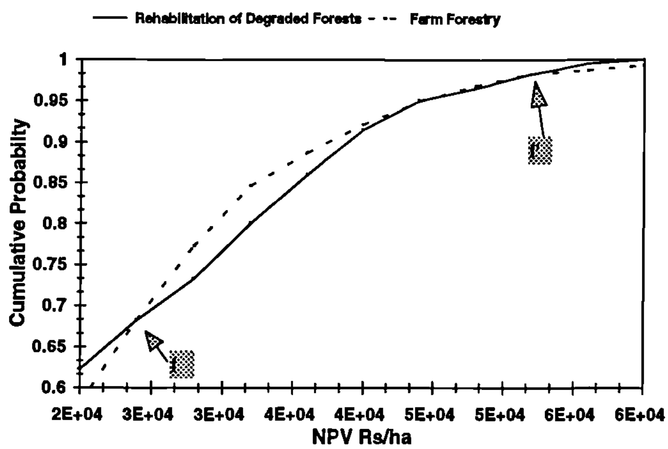


Fig. 10.19 Cumulative probability plot showing crossing of CDFs at point i and i"

Section II

10.2.1 Decision analysis of the project

As already discussed, in risk analysis the decision maker is confronted with probability distributions of the profitability criterion instead of a single value. The additional information that a probability distribution presents increases the difficulty of reaching a decision, (FSD and SSD do provide some solution to this problem) since the decision maker must judge the acceptability of the risk in each alternative. Risk analysis does not offer any solution to this problem. A decision maker has to use his or her intuitive risk judgement (Sepzler, 1977).

Decision analysis is a logical extension of risk analysis. The steps of the decision process are identical up to the development of a probability distribution of the decision criterion. However, the intuitive risk judgement, which is used in risk analysis, is quantified by means of decision makers' utility functions. If a decision maker's utility function over the range of outcomes can be found, the expected utility of each act can be calculated and the optimal choice is simply the choice which maximizes the decision maker's expected utility. In other words, the selection of risky projects should be based on maximizing the expected utility of net present value; i.e., maximize:

$$U = E\,[U(NPV)]$$

The above equation can be expressed in terms of a probabiliy distribution as (Anderson et al., 1977):

$$U = \sum U\,(NPV|x_1, x_2)\; P\,(NPV|\, x_1, x_2)$$

where x_1, x_2 are independent projects.

Given knowledge of the decision maker's utility function, the optimal choice in terms of U (NPV) can be determined.

The expected utility model despite its several theoretical and practical limitations (like common consequence effect, certainty effect, framing of the choices, preference reversal etc.) provides a systematic and rigorous analysis of risk in project appraisal. The utility function is a critical component in decision making under risk. The utility function of an individual reflects his risk attitudes. The knowledge of the shape of an individual's utility function is crucial in predicting rational behaviour under uncertainty. By constructing an individual's utility function, which is unique to each individual, the attitudes of decision makers to risk could be inferred and the function can be used in project appraisal under risk.

10.2.2 Elicitation of risk attitudes of project managers

Most forestry projects are formulated under the assumption of risk neutrality on the part of the project managers and under the assumption of full realisation of the project benefits, without any element of risk. Projects are formulated under the assumption of homogeneity of the entire project area. However, the success of the project in each site is dependent upon physical conditions obtaining in the area and the biotic factors operating in the area, which bring in a great degree of variability in project returns. In implementation of projects, project managers tend to consider the potential returns from a site and tend to select only sites with potentially assured positive financial returns. Government having a large diversified portfolio is generally assumed to be risk neutral but project managers (responsible for implementation) may not be risk neutral as their performance is evaluated on the basis of success of projects and a certain outcome may be preferred to an uncertain one of the same expected NPV. The bias (site selection) in project implementation could be attributed to the risk aversion on the part of the project managers. Therefore, a knowledge of the risk attitudes of the project managers is essential for project appraisals.

The theory of utility plays a key role in decision analysis. In situations involving the appraisal of risky alternatives, utility analysis provides the practical means whereby preferences of the decision makers are crystallised and consistent choice simplified (Anderson et al. , 1977). The procedure for handling choice under uncertainty involves two components: personal strength of belief about the occurrence of uncertain events - which is reflected in the subjective probabilities - and personal valuation of the consequences - which is measured by utility of the decision maker. In this sense utility analysis is conditional on expressed preferences and decision makers' choices.

10.2.2.1 Expression of utility

In the concept of utility function, utility is generally expressed as a function of wealth(W), i.e.,

$$U(W) = U(w+M)$$

where, W is final wealth, w is initial wealth and M is the certainty equivalent of the prospect.

However many economists who have tried to measure utility functions empirically have chosen to represent utility function in terms of gains and losses (Anderson et al., 1977; Lin et al., 1974). The psychological literature has always worked with utility function in terms of gains and losses (Eeckhoudt and Gollier, 1995). The advantage of using wealth is that in evaluating the effect of wealth changes on individual behaviour, one can use knowledge about the shape of the utility function as it was measured before the wealth change (Binswanger, 1981). Conversely, a utility function in terms of gains and losses may also change somewhat as wealth changes. Still, it cannot be used to derive such conclusions unless one also specifies how the utility function will change as wealth changes, necessitating measurement of an additional relationship.

The utility function is generally defined in terms of gains and losses rather than wealth (Binswanger, 1981). Machina (1989) has suggested that the utility function might be best defined in terms of changes from the 'reference point' of current wealth.

Utility can be either unidimensional or multidimensional. If consequences of a decision problem can be represented in terms of only a single attribute, e.g., net present value, the utility function has only one argument (Anderson et al., 1977). If a decision problem involves multiple attributes or multiple consequences, then approaches such as the benchmark method (Raiffa, 1968), or 'quasi-separable utility function approach (Keeney, 1974) are adopted. These methods are very cumbersome. This study seeks to measure utility in terms of a single attribute, i.e., percentage survival of plantations.

10.2.2.2 Derivation of utility functions

It is clear from the above discussion that the utility function is a critical component in decision analysis. Derivation of utility functions is not a trivial problem (Lin, 1973). Many empirical studies have sought to derive utility functions mainly through direct elicitation. These direct elicitation approaches have used mainly interview techniques, involving choices between either hypothetical payoffs (Lin et al. , 1974; Herath, 1980; Hamal and Anderson, 1982) or actual money payoffs (Griesly and Kellog, 1982; Binswanger, 1980). The DEU method has been criticized on the following grounds

(Binswanger, 1980; Robison, 1980):

a. hypothetical payoffs

b. subject bias from different interviewers

c. compounding of errors in the elicitation process

d. start point and end point bias

To overcome some of these criticisms, games involving real payoffs have been used by some researchers (Robison, 1982). But problems of a financial, moral and practical nature severely limit the use of this approach. For these reasons the present study uses an interview technique, with choices involving hypothetical, but realistic management options involving risky and sure outcomes.

There are three best known variations of the direct elicitation approach for elicitation of unidimensional utilities (Robison et al.,1984). They are:

a. von Neumann-Morgenstern method

b. Modified von Neumann-Morgenstern method, and,

c. Ramsey method.

All the three methods use the certainty equivalent axioms in repeated applications of hypothetical gambles. The Von Neumann-Morgenstern method requires decision makers to identify the probability for the favourable outcome that would yield indifference between the risky alternative and a sure thing whose value is the average of the favourable and unfavourable outcomes (Robison et al., 1984). The difficulties that people have in understanding probabilities renders this method difficult to use (Anderson et al., 1977).

The modified Von Neumann-Morgenstern method is also referred to as 'equally-likely certainty equivalent method (ELCE)' and is considered as the simplest method (Anderson and Dillon, 1992). This method is also known as the fractile method (Machina, 1989). In this method, certainty equivalent is elicited for a hypothetical 50/50 lottery with the best and the worst possible outcomes of the decision problem as the two risky consequences, after rescaling their utility values as 1 and 0 respectively. Further finding the certainty equivalent of the 50/50 chance of the first elicited certainty equivalent (CE) and the worst outcome, CE and the best outcomes give the values of CE1 and CE2, which solve U(CE1)=1/4 and U(CE2)= 3/4 respectively. By repeating the procedure the utility function can be completely assessed. A suitable algebraic form can be fitted to the elicited points which permits calculation of the derivatives of the function and inferring the risk attitudes of the decision makers. This approach has been commonly used in empirical work (Dillon and Scandizzo, 1978). This method was used in the present study.

The Ramsey method is used particularly with people with a strong aversion to gambling *per se* (Anderson et al., 1977). It is based on preference between acts with 'equally likely but risky outcomes' (ELRO). It elicits certainty equivalents for a series of risky alternatives in order to overcome possible biases associated with gambling or selected probability levels. It has been used in much empirical research (Officer and Halter, 1968; Lin et al., 1974). However, the method involves a complicated questioning procedure.

10.2.2.3 Limitations of use of the certainty equivalent method in elicitation of utility functions

The use of 'equally-likely certainty equivalent' method in eliciting preferences among choices is beset with many theoretical problems. While expected utility theory is based on the axioms of transitivity, continuity, independence and ordering, in many decision problems, choices are made violating the above axioms. In particular, the axiom of independence is often violated. Individuals often are observed to make different choices in gain and loss situations leading to asymmetry of preferences (Tversky and Kahnemann, 1986), resulting in risk seeking behaviour under loss situations and risk aversion under gain situations. These aspects are already discussed in section 10.3.5. The adoption of non-expected utility models needs large samples and there have not been practical applications of these models in elicitation of utility of project managers.

10.2.2.4 Elicitation of the preferences: the case study

In this study the respondents are project managers and members of the Indian Forest Service. All the respondents are well educated and have very good understanding of the decision problem. In view of this and the complexity associated with the use of non-expected utility models it is felt appropriate to use the certainty equivalence approach in eliciting the preferences of the project managers. The equally-likely certainty equivalent' method, which is simple and easy to administer, is used to elicit their preferences and to derive information on the shape of individual utility function and their risk attitudes. The basic aim of this exercise is to determine the general risk attitudes of the respondents and calculate the derivatives for use in decision analysis.

The financial returns from forestry projects are long term (relative to service period of managers) in nature. The number of the trees surviving is the most important determinant of the project returns. Most often, the survival percentage of the trees in the plantation is considered as the worth of the returns from the project and consequently as a measure of the performance of the project managers. Hence, the utility of the project is measured in terms of the survival percentage of trees from the perspective of the project managers. Project managers can be considered to be interested in maximising the plantation survival and a plantation with a high degree of survival is considered to be the most successful. Therefore, it is appropriate to elicit the risk attitudes of project managers towards choices involving the possible survival percentages of plantations in the project area, taking the best and the worst outcomes.

Choices between the best and the worst outcomes of an afforestation venture are used to elicit preferences. Theoretically, a survival of 100% is most desirable and therefore, is taken as the upper limit for elicitation of risk attitudes. Appraisal of the project indicates an average figure of 30 % survival in the lower half of the plantations classified on the basis of survival. Hence the range of elicitation of preferences is taken as 30% to 100%. Choice of reference values for the hypothetical game is very important and can affect the conclusions of an analysis based on the resulting preference curve (Schlaifer, 1969; Dillon and Scandizzo, 1978). The choices offered to the project managers, while being hypothetical, are realistic management alternatives. Using the certainty equivalent approach preferences are elicited to derive 1/4, 1/2, 3/4 fractiles of the utility or preference function. Then an appropriate functional form is fitted to ascertain the risk attitudes of the project managers and to calculate the risk aversion parameter. Suitable consistency checks are also carried out during the course of the interview to correct for any inconsistencies. The interview of twenty two project managers representing four states (viz. Bihar, Orissa, Karnataka and West Bengal) of India were taken. All the respondents were officers of the Indian Forest Service and were actually involved in administration of afforestation projects. The most important point in elicitation of preferences is to convince project managers that:

a. There is no right or wrong answer.

b. They should act as forest officers on duty (not as a game players) taking decisions after carefully considering alternatives.

c. This is not a quiz to see what the interviewee knows, but an attempt to quantify his personal attitude about his preferences under risk.

The out line of the choice game is presented in Fig 10.20. The game was completed in three stages. A, B, A', B', A", B" are risky consequences of a decision problem. *a* and *b* are the upper (100% survival) and lower (30%) limits of preferences respectively and *c* is the certainty equivalent (CE) for a hypothetical 50/50 lottery with the best and the worst possible outcomes of the decision problems as the two risky consequences (i.e., (a, b)≡c). The CE's were not directly requested. The respondent was asked to express his preference relative to the current 50/50, lottery. In this way, the questioning was 'zeroing in' upon the CE. The questionnaire is presented in appendix 10.1. To keep the expression of preferences consistent with inner preferences and one with another, the responses were cross checked (for example, (d, e)≡c ?; (i, g)≡c ?; (h, f)≡c ?). Where checks did not correspond closely, the game sequences were repeated until consistency was obtained. For the purpose of consistency checks and for plotting certainty equivalents, an arbitrary utility scale is used as $U(b)<U(a)$, where $b<a$ (U(a)=1.000; U(b)=0.000). The detailed procedure of elicitation of risk attitudes of project managers are described in the questionnaire (Appendix 10.3).

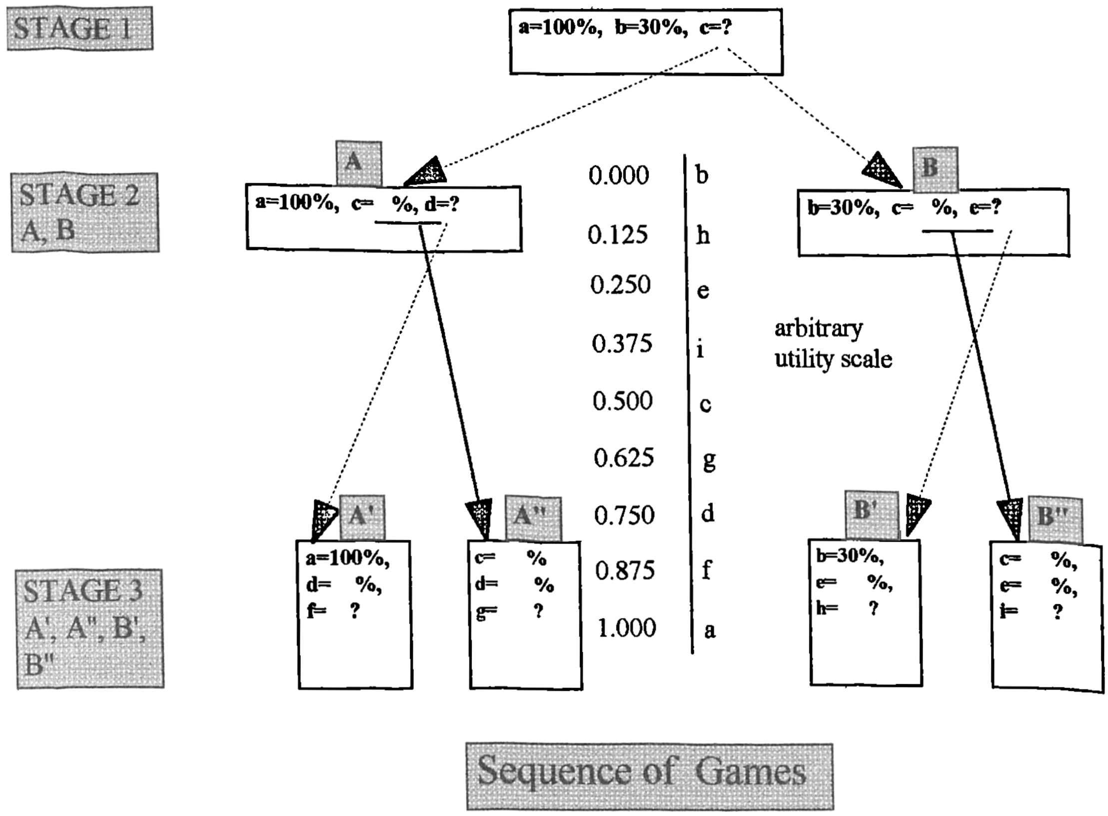


Fig. 10.20 Sequence of games for utility elicitation

10.2.2.5 Fitting a utility function to the data

One of the objectives of this exercise is to find a mathematical form for utility functions that would be able to represent adequately the attitude of project managers. All such functions must be monotonically increasing in utility since individuals prefer the larger of two present values. In the empirical risk literature, a wide variety of functional forms for a decision maker's utility has been used. All forms commonly in use can be traced to Pratt's (1964) suggestions of three utility functions exhibiting constant, decreasing and increasing absolute risk aversion (Saha, 1993). A common assumption has been a polynomial function (Markowitz, 1959; Farrar, 1962; Lin et al 1974). However, the polynomial utility function has been criticized (Lin and Chang, 1978) because it exhibits increasing absolute risk aversion (λa) or negative marginal utility. Generally, researchers agree that a utility function should imply a decreasing or constant risk aversion. It means that as a decision maker expects more of a net gain, he becomes willing to take more of a chance. Therefore, suitable utility functions for this study must have the following properties:

a. continuous and twice differentiable

b. lead to a function $\lambda a = -U''(x)/U'(x)$, which is ≥ 0 over the range of x.

c. λa should be constant or monotonically decreasing (Anderson, 1992).

The widely used quadratic utility function does not satisfy the last condition over any range (Pratt, 1964). The functions used in this study are summarised in Table 10.3.

Table 10.3 Utility functions and coefficient of risk aversion

Functional Form (FM)	First derivative, dU/dx	Second derivative, d^2U/dx^2	Coefficient of risk aversion, λa	Range	Type of risk aversion
1. U(x)=a+bx	b	0	0	-	risk neutral
2. $U(x)=ax-be^{-cx}$ (a, b, c >0)	$a+bce^{-cx}$	$-bc^2e^{-cx}$	$\frac{bc^2e^{-cx}}{a+bce^{-cx}}$	all x	decreasing
3. $U(x)=bx-e^{-ax}$ (a, b >0)	$b+ae^{-ax}$	a^2e^{-ax}	$\frac{a^2e^{-ax}}{ae^{-ax}+b}$	all x	decreasing
4. $U(x)=a+bx+cx^2$ (a, b>0; c<0)	b+2cx	2c	$\frac{-2c}{b+cx}$	$\frac{b}{2c} \geq x \geq 0$	increasing

Note: The restrictions of the equations are shown in parentheses below each equation.

The functional forms were first chosen based on theoretical considerations and fitted to the data. The final forms were selected on the basis of fit to the data through visual observations and R^2. All the above mentioned functions satisfy theoretically expected forms except the quadratic utility function. This function is used to fit the data of the subject K6. The subject K6 shows a marked departure from the expected rational behaviour. At low values of x the subject is risk preferring while at higher values the subject shows risk aversion. The fitted equations for all subjects are given in Table 10.4.

Table 10.4 Fitted utility functions of all subjects

Respondent	FM	Fitted equation	R-sq.	Risk aversion coefficient (λa)
B1	2	$U(x)=0.01031x-2.00096e^{-0.06036x}$	0.9957	0.01135
B2	3	$U(x)=0.01076x-e^{-0.03655x}$	0.9878	0.00877
B3	3	$U(x)=0.01072x-e^{-0.03404x}$	0.9839	0.00878
B4	2	$U(x)=0.01019x-1.73584e^{-0.05748x}$	0.9931	0.01088
B5	3	$U(x)=0.01073x-e^{-0.03706x}$	0.9878	0.00878
B6	2	$U(x)=0.01036x-1.74443e^{-0.05481x}$	0.9936	0.01137
B7	2	$U(x)=0.01028x-2.26947e^{-0.06425x}$	0.9924	0.01149
B8	3	$U(x)=0.01054x-e^{-0.03831x}$	0.9920	0.00887
K1	3	$U(x)=0.01185x-e^{-0.04885x}$	0.8945	0.00718
K2	3	$U(x)=0.01177x-e^{-0.04904x}$	0.8790	0.00720
K3	3	$U(x)=0.01138x-e^{-0.04189x}$	0.9549	0.00816
K4	3	$U(x)=0.01074x-e^{-0.03367x}$	0.9833	0.00875
K5	3	$U(x)=0.01107x-e^{-0.05051x}$	0.9495	0.00738
K6	4	$U(x)=-0.91800+0.3040x-0.00010x^2$	0.8920	0.01149
K7	2	$U(x)=0.01088x-2.16204e^{-0.06081x}$	0.9521	0.01145
K8	2	$U(x)=0.01056x-1.31032e^{-0.04507x}$	0.9866	0.01037
K9	2	$U(x)=0.01097x-1.62058e^{-0.04973x}$	0.9649	0.01118
K10	3	$U(x)=0.01053x-e^{-0.04046x}$	0.9930	0.00878
W1	2	$U(x)=0.01018x-2.06028e^{-0.06310x}$	0.9948	0.01101
O1	3	$U(x)=0.01044x-e^{-0.04273x}$	0.9939	0.00867
O2	3	$U(x)=0.01086x-e^{-0.03381x}$	0.9775	0.00869
O3	1	$U(x)=-0.37220+0.01380x$	0.9930	0.00000

Notes: 1. FM=functional forms. All the functional forms (i.e., 1, 2, 3, 4) are explained in Table 10.3.
2. All the estimates of parameters are derived using non linear regression.
3. λa is calculated for mean value of x ($\bar{x}$).

To get an idea of the fit of the functions to different subjects, utility plots of two subjects (representing two functional forms) are presented (Fig. 10.21 and Fig. 10.22). The reference line at the middle of the plot shows risk neutral attitude.

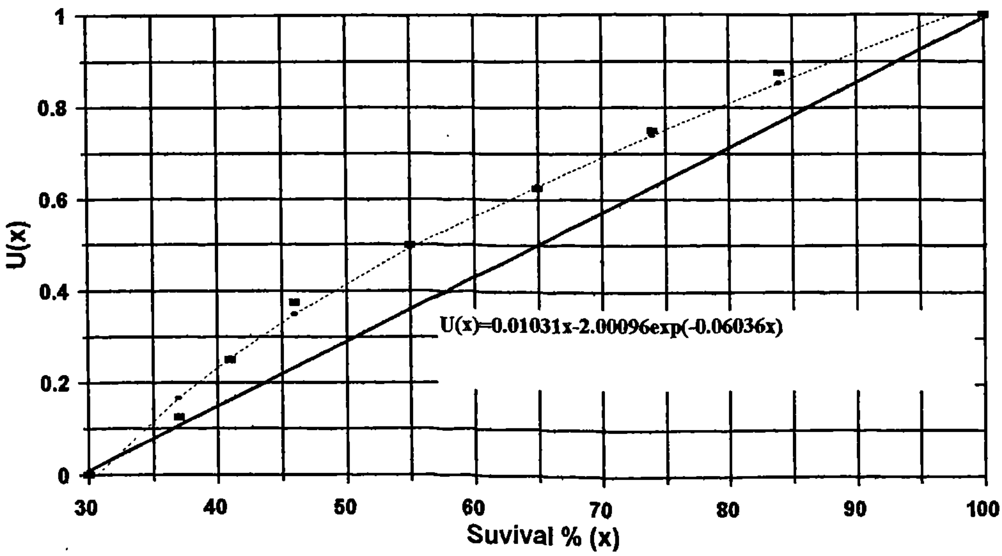


Fig. 10.20 Utility function of subject B1

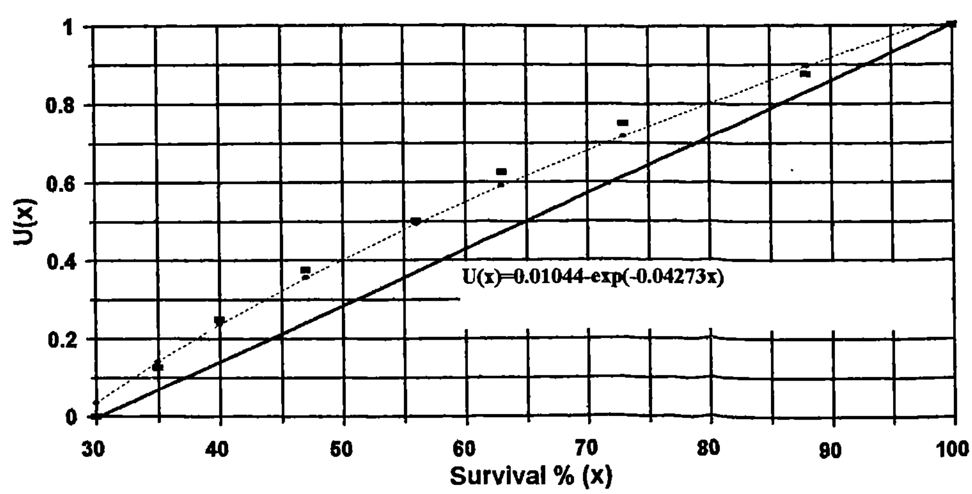


Fig. 10.21 Utility function of subject O1

10.2.2.6 Analysis of the results

The coefficient of absolute risk aversion (λa) is commonly used both in theoretical and empirical studies (Anderson, 1992). But this measure is not unit free and its magnitude depends on the units in which x (i.e., survival %) is measured (100%≡100 or 1.0). However, if a value of coefficient of relative risk aversion (λr=x.λa) can be calculated, then λa can be estimated as λr/x for a given estimate of x. By way of a concise summary of project managers' risk attitudes a cumulative probability distribution of absolute risk aversion (calculated at mean value of x) is presented as a distribution function in Figure 10.22. This representation indicates that risk aversion does not vary markedly between individuals.

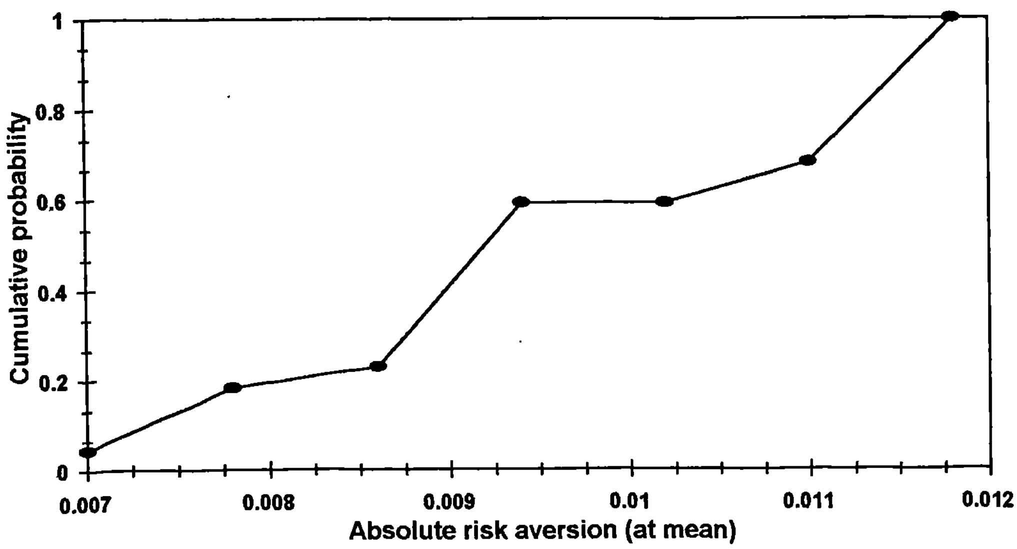


Fig. 10.22 CDF's of absolute risk aversion (λa) of project managers

The absolute risk aversion obtained in this study cannot be directly compared to data reported by other investigators[17] (for a brief review, see, Hull et al., 1977) because the coefficient of absolute risk aversion depends on the unit used to derive the λa. On

[17] These studies aimed at measuring the utility functions of executives. A survey of literature shows that the elicitation of utility functions of project managers of afforestation projects (or any public sector project) has not been attempted previously.

the other hand, relative risk aversion is not unit dependent and accordingly, the distribution of this measure is summarised in Figure 10.23.

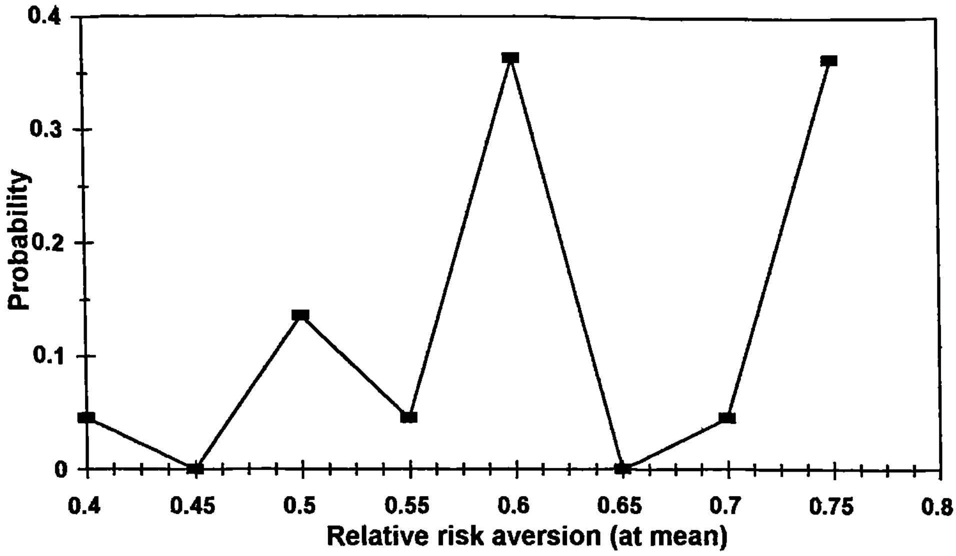


Figure 10.23 PDF's of relative risk aversion (λr) of project managers

Most values are very close to Arrow's (1965) speculative typical value of unity. All values lie within the intuitively likely range of zero to four speculated by Lttle and Mirrlees (1974, pp 330). It is concluded that risk aversion is the prevalent risk attitude among Indian project managers (forest officers). This study supports the frequently made assumption of individual decreasing absolute risk aversion (DARA). Out of 22 subjects 20 show DARA (curve B1 and K1). Risk neutral attitude (curve O3) and increasing absolute risk aversion (curve K6) are shown by one subject each (Fig. 10.24).

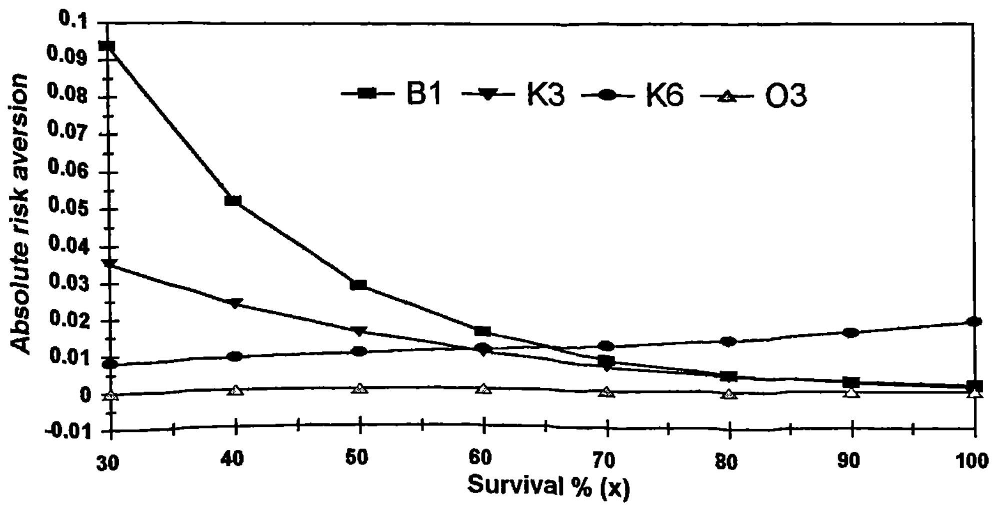


Figure 10.24 Absolute risk aversion-survival plot (λa-x plot) showing decreasing, increasing and risk neutral attitude of project managers

10.2.3 Conclusions

Risk analysis is a very powerful tool of project appraisal. It is not a substitute for conventional project appraisal methodologies but rather a methodology that enhances its results and consequently helps in decision making. The approach in decision analysis is based on the assumption that the utility curve of an individual decision maker could be obtained and employed directly in analysis. Sometimes, it is difficult to represent a decision maker's choice in a particular algebraic form. Stochastic efficiency rules (FSD, SSD) are very helpful when a decision maker's preferences cannot be obtained explicitly.

The individual utility functions of project managers can be used in developing a consistent risk policy of the organisation depending on economic and social priorities. The communication and acceptance of a risk policy throughout the department could help to avoid opportunity costs that are incurred by rejection of risky alternatives. In the absence of any risk policy, the project managers tend to play 'safe' and opt for certain alternatives which may not be consistent with the goal of maximization of expected utility.

Chapter 11

Discussion and conclusions

11.1 Introduction

Over the last few decades, there has been an increasing amount of evidence to suggest that project appraisal in practice may have been less successful than it was once expected to be (Noorbakhsh, 1994). The reasons range from weakness in the planning of projects, to lack of project preparation and inappropriate application of evaluation techniques. The response to such a situation has been three-fold:

1. Development of alternative methods of evaluation such as logical framework, rapid rural appraisal etc. which may or may not require CBA.
2. Emphasis on selection and evaluation of projects on social grounds (mostly unquantifiable).
3. Targeting projects to specific groups based on policy objectives (e.g., Kissan[1] nursery for scheduled caste and scheduled tribe farmers).

These selection and evaluation methods do provide some insight into performance of projects but largely depend on value judgements based on informed sources. They also lack the precision of CBA. Most project preparation and analysis necessarily involves uncertainty about values used in estimating input and output quantities and prices. CBA does provide a comprehensive framework for appraisal of such projects, but generally the results of CBA in conventional appraisal, are presented as a certainty which does not provide realistic picture about project performance. This has been a primary reason for development and application of less rigorous appraisal techniques.

Although recent developments in risk analysis and simulation techniques have opened the door to more sophisticated and accurate treatment of project appraisal under risk and uncertainty, very little empirical work has been published to date in the cases of public project appraisal in general and afforestation project appraisal in particular.

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[1] Small private nurseries (decentralised) supported through input and buyback arrangements with the forest departments.

We sought to focus our investigation primarily on the following aspects:

a. examining the components where variability in returns is high.

b. accounting for variability in project appraisal.

c. incorporating these elements in decision making process and investigating their role in designing an appropriate policy of intervention (if required).

In response to rapidly degrading forests, the thrust of afforestation projects is in two directions:

a. Rehabilitation of degraded forest areas, and,

b. Extension of tree growing in non-forest areas.

People's role is important for success of the afforestation projects through protection of plantations in RDF areas and adoption of tree growing in non-forest areas. The differential adoption pattern and variable quantum and patterns of illicit removals result in highly variable outcomes in the respective components.

11.2 Risk and uncertainty in public projects

We have mentioned earlier that in conventional analysis, the outcome of the project is presented as a certainty with no possible error term, and sensitivity analysis is presented to account for possible variations. Treatment of risk in public project appraisal is important basically for two reasons:

1. To facilitate comparison among different projects or different components of the same project.

2. To account for project managers' bias in execution of the project depending on their risk attitudes. The government having a large diversified portfolio, is generally assumed to be risk neutral but the decision-makers in the government (mainly politicians) may show risk averse/ risk seeking behaviour based on political or personal or social considerations.

Therefore, it is necessary to consider elements of risk in a project. We have used three different approaches to risk appraisals in the present study. They are:

1. The expected value of NPV through the illicit felling models.

2. The probability density function or cumulative distribution function comparisons through stochastic efficiency rules.

3. The utility function of the project managers.

11.2.1 Illicit felling models

11.2.1.1 Physical models of threat appraisals

Physical yields of plantations can be calculated with the help of yield tables and financial appraisals can be carried out after adding a risk premium to the risk-free discount rate. The study shows that the risk premium approach is not appropriate even if we use variable risk premiums. We have developed Weibull-based models for illicit felling threat appraisal. The illicit felling models for *Eucalyptus* plantations show that the expected volume of plantations depends on how losses occur. Model WM-INA is based on the assumption that illicit felling is concentrated in an area and the increment in tree volume will not be affected. In this case, the net volume will be proportionate to the number of trees left after illicit felling. The other two models - WM-IA1 and WM-IA2 assume that illicit felling is well scattered and a higher increment in individual trees is expected due to the thinning effect.

We have applied model WM-INA in all case studies (FCBA, ECBA and SCBA) assuming that individual tree increment will not be affected due to illicit felling. However, the actual loss will depend upon the pattern of illicit felling. There is a need to investigate the actual pattern of loss in volume and increment of individual trees. On account of illicit felling, the overall worth of plantations increases when removal of wood takes place in accordance with models WM-IA1 and WM-IA2.

11.2.1.2 Financial Models

The analysis of financial consequences of illicit felling is presented through financial models. The first model EM1 is based on planned rotation and assumes replanting only after the completion of the planned rotation. The second model EM2 calculates mean expected value of an infinite series of rotations under risk of illicit felling. This model assumes replanting immediately after crop damage. These models are useful in rotation decisions under risk of illicit felling.

The financial models require an appropriate physical model depending on the actual routine of illicit felling. In the present study, financial rotation is calculated employing our physical model WM-INA. Similarly financial rotation and expected NPV can be arrived at using other models (WM-IA1 and WM-IA2).

11.2.1.3 Management decision models

Management decision models (deterministic and probabilistic models) help project managers in taking rational planting or no-planting decision under the threat of illicit felling. We present threshold values depending on time, quantum and pattern of illicit felling. It also takes into account the financial parameters such as discount rate, and price-size relation. A no-replant decision is proper when illicit felling is below threshold level (in that year). Conversely, if the illicit felling exceeds threshold value, it is prudent to replant the whole area.

Thus the above described models help in threat appraisal and decision making through:

a. quantification of physical attrition,

b. appraisal of financial consequence of physical loss, and ,

c. formulation of management options under threat of illicit felling.

These models form the basis of preliminary appraisal of afforestation projects. It is absolutely necessary for project appraisers or analysts to incorporate realistic estimates of physical loss and modify the project design and management option in response to the phenomenon. These elements can be incorporated in future projects to maximise returns from the project and to minimize variability.

11.2.2 Probability density functions or cumulative distribution function comparisons through stochastic efficiency rules

Risk analysis which involves the attachment of probabilities to parameter estimates can overcome the problem in selection of projects or individual components of the project. This technique is very helpful in decision making in forestry projects where returns are marginal in nature, even at a moderate discount rate. A project with small NPV may be accepted following risk analysis, on the grounds that its chances for producing a satisfactory return are greater than its probability of making unacceptable loss. Conversely, a project with high NPV associated with high probability of yielding an inadmissible loss may be turned down.

The probability of return profiles of FF and RDF clearly indicate chances of variable outcomes. However, the accuracy of its predictions can only be as good as the predictive capacity of the model employed. Overlooking significant inter-relationships and mis-specification of probability distribution of the variables can distort the result of risk analysis. The specification of probability distribution of the variables requires a lot of information. Sometimes, it is difficult to gather such information especially in the case of ex-ante appraisal of a new project. This is a limitation of this approach.

In the present study, we find that FF is preferable based on NPV/ha criterion. This is based on financial analysis. Similarly both the projects can be compared, based on ECBA and SCBA.

If funding rather than land is limiting, a similar analysis for BCR can be carried out to compare FF and RDF.

11.2.3 Utility function of the project managers

The utility function of the managers can be used for one of three purposes. It can be used to describe their risk attitude; it can be used to predict their future behaviour in risk situations; or it can also be used a tool for improving future decisions involving risk. Thus the risk attitude may be represented as a descriptive, predictive, or normative model.

In the present study, we have elicited utility functions of the project managers. We have used survival percentage to elicit preferences as financial return (NPV) is not considered important by the project managers in decision making. We have already discussed the reasons in chapter 10. The significant findings of this analysis are:

1. Most project managers (91%) show risk aversion behaviour.
2. The analysis supports the decreasing absolute risk aversion hypothesis.

11.2.3.1 The utility plot as a normative tool

If a utility function of the project managers can be found that represents the preferences of the decision makers over the range of NPVs, the expected utility of each act can be calculated and the optimal act is simply the act which maximizes the decision makers' expected utility.

$$U(CE) = \sum P(x_i)U(x_i)$$

where *U(CE)* is the certainty equivalent, $P(x_i)$ is the probability of outcome x_i and $U(x_i)$ is the utility of outcome x_i.

In accordance with utility theory, a rational individual must be indifferent between a project and his *CE* for the project. The risk premium can be calculated as:

risk premium = *EV* - *CV*

where EV is expected value.

$EV = \sum P(x_i)x_i$, where x_i is the ith outcome.

The application of this certainty equivalent method in risk appraisal of the FF and the RDF component has two main problems.

a. The expected utility model is for individual rather than for group decisions (problem of aggregation of utility functions).

b. We have elicited the project managers' utility function with respect to survival in plantations. Now, we require an NPV-based utility function.

The present study shows that different risk attitudes exist among the project managers. This can be resolved either in open conflict or by compromise (Luce and Raiffa, 1957) or by a policy statement. This could not be done in the present study.

It does not seem plausible to assume that the utility function of the project managers will remain the same if we use NPV instead of survival in elicitation of preferences because NPV depends on several factors including survival. Moreover, in a loss situation, the project managers may behave differently (we can get negative NPV but not negative survival). It is very obvious from the study that risk decisions by the project managers are based on survival and not on NPVs. Therefore, we need to specify other factors like discount rate etc. to the project managers and specify a common frame of reference to all the managers.

Based on the above considerations, the certainty equivalent model is not used in the present study.

11.2.3.2 The utility plot as a descriptive or predictive model of risk behaviour

The utility plots of individual managers are useful for descriptive purposes. The pattern describes the level of overall risk aversion coefficient. Absolute risk aversion coefficients and relative risk aversion coefficients describe risk attitudes of individual project managers. But these coefficients are based on a single fitted line which can only describe the general pattern of a risk attitude. Therefore, it is necessary to plot individual utility plots before fitting the data in a equation.

In using a utility plot to predict behaviour, the assumption must be made that present behaviour will be representative of future behaviour for similar pay-offs.

11.2.3.2.1 The development of a risk policy

The need for a risk policy and the broad implications of a risk policy are:

1. The choice between a highly risk-averting policy and a risk-neutral policy is essentially a choice between a safer low return and a higher average return on investment with higher variability.
2. The risk attitudes vary (the range is not very wide in the present study) among the project managers. It is, therefore, reasonable to conclude that, in the absence of a standard risk policy, different standards are applied in different project areas.

Based on the utility functions of the project managers a risk policy can be decided. The forest department's utility function can be derived by mutual discussion and consideration of broad policy objectives.

The communication of the risk policy throughout the forest department could help to avoid opportunity costs that are incurred by premature rejection of risky projects. A clear risk policy statement may lead to a greater improvement in the decision process. Nevertheless, to be effective, the risk policy must be supported by control procedures:

a. The project managers must not be penalized for taking risks

b. A good decision must be distinguished from a good outcome of a decision.

11.3 Economic appraisal

The results of economic CBA indicate that the estimated economic discount rate is vital in assessing the profitability of the afforestation project. In the present study, we attempt to estimate economic discount rate (EDR) using production function, dynamic production function, incremental output capital ratio and growth model. The suitable application of these methods largely depends on the data base required for a particular model. Most project appraisers do not attempt to estimate this parameter because of practical problems in econometric analysis and sometimes relevant data for a country are not readily available. The present study demonstrates that selection of correct EDR is critical in economic appraisal. Despite several theoretical and practical problems in estimating EDR, we require a precise estimate of EDR. The EDR derived in the present study can serve the purpose. The methodology used in this study can be used for estimation of EDR for other countries.

11.4 Social appraisal

The study shows that 50% of the total plots in the RDF component are not socially profitable (assumptions: CA-I, B-I and B-IF) as compared to 42% of the total plots in the FF component (assumptions: CA-I, BF-I). The social desirability and profitability of FF and RDF depend on: source of investment funds (the Forest Department or the Rural Development Department), treatment of project revenue (investment or consumption), relative consumption level of beneficiary.

The social opportunity cost of unit investment now is greater than that of unit consumption now. Therefore, the NPV of the project would increase if costs are met not by diverting investible revenue, but by diverting consumption expenditure.

The NPV has been calculated in our case studies under the assumption that the project revenue will be treated like any other revenue (part saved and the rest consumed). It means if the whole of the project revenue is consumed, the NPV would be less as compared with the project whose whole revenue is reinvested.

The relative consumption levels of beneficiaries are based on our experience and judgement. A field study is required to determine which group receives increases in consumption due to illicit felling.

11.5 Farmer tree growing

11.5.1 Participation

Farmers plant trees when they perceive that is a better land use option than the alternatives. Since returns from poles and fencing posts are much higher than those from fuelwood or tree fodder, farmers would naturally aim for these markets. This has been viewed by some critics of FF as a failure of the project which should aim at production of subsistence fuelwood requirement and thereby reduce pressure on natural forests. It could be seen as a rational decision making process by farmers

In FF adoption, we attempt to develop an evolutionary theory of farmer tree growing. We have identified four distinct evolutionary stages of tree growing in the context of overall land use strategy. A region's natural factor endowment, together with the level and type of appropriate technology, relative prices of commodity and input, and market infrastructure, set the broad limits within which the potential land use of an area evolved. The impact of evolution of land use may be measured by

a. changes of land use over time, following macro level changes, and

b. differences in land use by farmers with varying farm level endowments at a point in time.

We attempt to explain the whole process through cross sectional data for two main reasons.

a. Time series data of farmer tree-growing practice is not available.

b. It seems that farmers are at different stages of evolution depending on their land endowment, family size, irrigation facilities, entrepreneurship etc.

Evolution of tree growing in farm land is influenced by both macro and micro level factors. A farmer's adoption decision is determined by macro factors such as agricultural commodity price policy, development of market infrastructure both for wood and food crops, food security (through the public distribution system), development of financial institutions and credit availability. Adoption is also influenced by micro factors many of which relate to characteristics of the farmers, their resource endowment, opportunities of alternative land use and the constraint sets being faced. The majority of farmers in this region are still at the stage of subsistence agriculture. Others have reached a specialized stage of growing tree crops or other cash crops depending on their 'livelihood strategies'.

The study shows that the decision-making process of farmers in allocation of resources among competing land uses may be explained in an overall framework of evolutionary theory proposed in this study. A farmer's decision to adopt tree growing can be explained by the simplest form of multi-attribute decision making rule, akin to the one rendered by Benjamin Franklin in a letter[2] (dated Sept. 19, 1772) written to Joseph Priestly. This is a reason why complex formulations of linear programming and other operations research techniques generally fail to match the real-world farm plans and do not help in providing an insight into farmer decision-making processes. The farmers' decision process may not be based on calculation of exact financial costs and benefits but on a number of contextual independent and few interlinked factors. For example, the NPV rule suggests that the optimum economic rotation for *Eucalyptus* for a particular farm (site quality) as six years. But a number of farmers in the study area have

---

[2]Benjamin Franklin recognized the presence of multiple attributes in everyday decision problems and suggested a workable solution which he called 'moral or prudential algebra'. He perceived that each attribute has different weights (weights are to be assigned by the decision-maker) and suggested appropriate trade-offs between conflicting attributes (refer Yoon and Hwang, 1995 for a full text of the letter).

postponed the decision of harvesting even up to ten years probably considering trees as a cash reserve for meeting future consumption needs for which credit from banks may not be available. The NPV max. rule is based on our notion of a discount rate. A farmer may have a different discount rate for this particular purpose or he may not want to discount at all. It appears that farmers discount at least at two different rates - the one for savings (to meet contingencies) and the other for investments. For savings, farmers may accept a very low discount rate. They can forgo a higher rate in preference to assured return for meeting contingencies, though farmers face high interest rates in the informal credit market. A further detailed study on farmers' time preference is required to explain the phenomenon fully.

An insight into farmer tree growing behaviour is absolutely imperative for developing a suitable project, targeting specific groups and deciding issues like subsidies etc. in project planning. The role of subsidies in FF promotion will be discussed in the section that follows.

11.5.2 Subsidies

The social, economic and biological environment appears to have been a more important determining factor for expansion of effective FF than incentives such as subsidized or free seedlings, fertilizer, cash for survival of trees and extension services provided by the government. Some farmers in the project appear to be planting simply to collect cash incentives rather than long term returns from investment in trees. Survival in such plantations is very low. FF is well established as a land use strategy and the case for continuing subsidized seedlings and other cash incentives is weak. Seedling subsidies have inhibited development of private nurseries in the region. Abolishing subsidies would also remove the onus on the government to provide seedlings to the farmers thereby releasing the time of forest officers from a job which could be done by private nurseries. The Forest Department can concentrate on providing good quality (from plus trees) seeds to private nurseries.

11.6 Conclusions

By analysing illicit felling patterns, the study helps to develop both economically efficient and socially justifiable strategies of protection. The knowledge of farmers' tree adoption behaviour and sustenance of this practice would help in identification and formulation of suitable policy interventions.

From a policy perspective, it is critical that efforts to introduce afforestation projects (both within the 'protected forests' and outside in farmers' land) are put into a context which accurately reflects local farmers' need, ability and knowledge. The introduction of project appraisal in policy decision framework endeavours to formalise the process of learning lessons and disseminating them to project managers.

Appendix 5.1

PRESS statistics for model assessment

PRESS statistics is very important tool for selection of the most suitable model where data is small and data splitting is not practical. PRESS is an acronym for **Pre**dicted **S**um of **S**quares. In this approach, the 'y' value for each subject is set aside and a prediction equation is derived on the remaining data. Thus, n prediction equations are derived and n true prediction errors are found, since the 'y' value for each subject was not simultaneously used for fit and model assessment (Stevens, 1992). The PRESS residual for each subject is given by:

$$\hat{e}_{(-i)} = y_i - y'_{(-i)} \quad \text{.......... eq. (1)}$$

where $\hat{e}_{(-i)}$ is PRESS residual, y_i is the value of subject and $y'_{(-i)}$ is the predicted value (from model) when subject 'i' is not used in developing the model. PRESS is the sum of squared residuals:

$$PRESS = \sum [\hat{e}_{(-i)}]^2 \quad \text{.......... eq. (2)}$$

A model is fitted with only m-1 set of observations. This procedure is repeated for each set of observations. The total square sum of these values gives the PRESS value.

$$PRESS = \sum [y_i - y'_{(-i)}]^2 \quad \text{.......... eq. (3)}$$

Appendix 6.1

Estimation of risk-adjusted discount rate

Approach: RADR1

Let X_t be the risk free volume of the crop at age t and r be the risk adjusted discount rate, the discounted volume (Y_t) can be given as:

$(Y_t) = X_t/(1+r_t)^t$

For calculation of discounted volume at year 1 and 2 , the equation can be written as

$$Y_1 = \frac{X_1}{[1 + \{(1+m)\times(1+n_1)\} - 1]}$$

where m is discount rate n_1 is the probability of illicit felling in year 1.

Let the risk premium for the year 2 be n_2 , the discounted volume for the year 2 can be calculated first discounting the risk free volume (X_2) to the year 1 using risk adjusted discount rate (risk premium being n_2) and again discounting it to year 0 using risk premium n_1 .

$$Y_2 = \frac{X_2}{[\{(1+m)\times(1+n_1)\}\times\{(1+m)\times(1+n_2)\}]}$$

Similarly discounted volume for the year t Y_t can be given as:

$$Y_t = \frac{X_t}{[(1+m)^t\times(1+n_1)\times(1+n_2)........(1+n_t)]}$$

$1/[(1+m)^t \times (1+n_1) \times (1+n_2)......................\times (1+n_t)]$ is the discount factor for the year t, the risk adjusted discount rate for the year t (r_t) can be given as:

$$r_t = \left[(1+m)^t \times (1+n_1) \times (1+n_2) \ldots\ldots (1+n_t)\right]^{\frac{1}{t}} - 1$$

$$r_t = \left[(1+m) \times \left[\prod_{i=1}^{t} (1+n_i)\right]^{\frac{1}{t}}\right] - 1$$

where m is discount rate, n_i is probability of illicit felling in *i* th year

The value of n is obtained through models for each year and the value of risk adjusted discount rate (r_t) is calculated using the above equation. The values for all the districts is given in Table AP6.1.1.

Table AP6.1.1 Risk adjusted discount rate (RADR1)

	DISTRICTS					
YEAR	SGH1	SGH2	SGH3	GRS1	GRS2	GRS3
1	0.100	0.100	0.100	0.100	0.100	0.100
2	0.100	0.100	0.100	0.100	0.100	0.100
3	0.107	0.105	0.106	0.111	0.110	0.106
4	0.113	0.112	0.113	0.118	0.116	0.111
5	0.122	0.121	0.122	0.125	0.123	0.116
6	0.133	0.133	0.133	0.133	0.131	0.123
7	0.145	0.148	0.148	0.142	0.139	0.131
8	0.160	0.166	0.165	0.151	0.147	0.140
9	0.177	0.187	0.185	0.161	0.157	0.149
10	0.195	0.211	0.207	0.171	0.166	0.160

Approach: RADR2

After making deduction for loss (n), the remainder should be discounted by pure time preference rate (m). This approach is termed as RADR2. The discounted volume (Y_t) for the year t can be given as:

$$Y_t = \frac{X_t \times [(1-n_1)\times(1-n_2)........(1-n_t)]}{(1+m)^t}$$

1/[(1-n_1)x (1-n_2).......................x (1+n_t)]/(1+m)^t is the discount factor for the year t, the risk adjusted discount rate for the year t ($\acute{r}_t$) can be given as:

$$\acute{r}_t = \left[\frac{(1+m)^t}{(1-n_1)\times(1-n_2)........(1-n_t)}\right]^{\frac{1}{t}} - 1$$

$$\acute{r}_t = \left[\frac{(1+m)}{\left[\prod_{i=1}^{t}(1-n_i)\right]^{\frac{1}{t}}}\right] - 1$$

The value of n is obtained through models for each year and the value of risk adjusted discount rate ($\acute{r}_t$) is calculated using the above equation. The values for all the districts is given in Table AP6.1.2.

Table AP6.1.2 Risk adjusted discount rate (RADR2)

	DISTRICTS					
YEAR	SGH1	SGH2	SGH3	GRS1	GRS2	GRS3
1	0.100	0.100	0.100	0.100	0.100	0.100
2	0.100	0.100	0.100	0.100	0.100	0.100
3	0.107	0.106	0.106	0.112	0.111	0.106
4	0.114	0.112	0.113	0.118	0.117	0.111
5	0.123	0.121	0.122	0.126	0.124	0.117
6	0.135	0.135	0.136	0.135	0.132	0.124
7	0.149	0.153	0.153	0.144	0.141	0.133
8	0.167	0.176	0.174	0.155	0.151	0.142
9	0.188	0.204	0.200	0.167	0.162	0.154
10	0.213	0.239	0.232	0.179	0.173	0.166

Appendix 7.1

Constant returns to scale

(a) Two models of the general form of Cobb-Douglas function can be written as:

Model 1 $\ln Y=\beta_0+\beta_1\ln K+\beta_2\ln L+u$ ....eq. (a1)

Model 2 $\ln(Y/L)=\beta_0+\beta_1\ln(K/L)+u$

Model 2 is the restricted version of model 1. Sums of the squares of the residuals (RSS) are calculated both for model 1 (RSS_U unrestricted) and for model 2 (RSS_R restricted). We test whether the improvement of fit from restricted to unrestricted version is significant using the F statistic.

$$F=\frac{RSS_R-RSS_U}{RSS_U/(n-k-1)} \quad \text{......................} eq.(a2)$$

where n is the number of observations and k is the number of explanatory variables in unrestricted model. The values of RSS_R, RSS_U, n and k are 0.028435, 0.028388, 24 and 2 respectively. The F statistic is 0.03476 which is calculated by substituting the respective values in the eq. (a2). Since the critical value ($F_{(1, 21)}=4.32$, $P<0.05$) is higher than the F statistic, we do not reject the model 2, i.e. it is correct to assume returns to scale.

(b) Model 2 (restricted) can be converted into unrestricted one by the addition of $(\beta_1+\beta_1-1)\ln L$ for the purpose of examining the constant returns to scale hypothesis.

$\ln(Y/L)=\beta_0+\beta_1\ln(K/L)+(\beta_1+\beta_2-1)\ln L+u$ ....eq. (a3)

On simplifying, the eq. (a3) can be written in unrestricted form as:

$\ln Y=\beta_0+\beta_1\ln K+\beta_2\ln L+u$ ....eq. (a4)

On regression of eq. (a3) using the above time series data, we get t-ratio of $(\beta_1+\beta_2-1)\ln L$ as -0.18688 (critical value $t_{(24)}=2.05$, $P<0.05$). Therefore, it can be concluded that $(\beta_1+\beta_2-1)$ is not significantly different from zero. Hence, $\beta_1+\beta_2=1$. So we do not reject the assumption of constant return to scale.

(c) The hypothesis of constant returns to scale can also be tested by imposing restrictions that must lead to loss of fit and acertaining its statistical significance. For a single restriction of the form $H_0: r'\beta=q$, the F statistic can be given as (Green and Seaks, 1991; Green 1993):

$$F\,[J,\ n-k]=\frac{\left(\sum_{j} r_j\, b_j-q\right)^2}{\sum_{j}\sum_{k} r_j\, k_j\, Cov[b_j,\ b_k]}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.\ (a5)$$

where J, n and k are number of restrictions, number of observations and number of regressors respectively. q=1 (single restriction). b_j and b_k are coefficients of two explanatory variables assuming a matrix of R having K columns (with β) and j rows for a total of J restrictions ($J \leq K$).

The coefficients of eq. (a1) are estimated for the time series data (1965 -1988). A variance covariance matrix of parameters is generated using Microfit 3.0 econometric package. On substituting the value in eq. (a5), the F statistic can be given as:

$$F[1,21]=[-0.10797+0.91238-1]^2 \times [3.4370+0.65255-2(1.4971)]^{-1}=0.34925$$

Since, $F=0.34925< F_{(1,\ 21)}=4.32$ ($P<0.05$), we would reject the hypothesis. We can conclude that the data are consistent with constant returns to scale.

Appendix 8.1
Logit model evaluation statistics

A. Model evaluation statistics

F statistic and R^2 are used in linear regression to test statistical significance. The logit model is estimated using the maximum-likelihood (ML) method and the log-likelihood is used as criterion for selecting parameters. The statistic is usually presented as -2 log likelihood (-2LL) because it (by multiplying by -2) shows approximately χ^2 distribution. R^2_L is a proportional reduction in χ^2 (Menard, 1995).

$R^2_L=G_M/D_0$ and $G_M=D_0-D_M$

where G_M is model chi-square, D_0 is initial log likelihood function (i.e. with an intercept term only), D_M is deviation chi-square.

R^2_{LA} is adjusted R^2_L can be calculated as $R^2_{LA}=(G_M-2k)/D_0$.

k is number of independent variables in the model. Aldrich and Nelson (1984) have proposed pseudo-R^2 (psedo-$R^2=G_M/(G_M$-N). N is number of cases). It is equal to zero when independent and dependent variables are unrelated but it can never reach the value of 1, even at perfect relation.

Lambda-p (λ_p) and tau-p (τ_p) are analogous to R^2 and can be estimated using following equations:

(a) $\lambda_p=(N_S-N_{PI})/N_S$, where N_S is the number of cases in the smaller observed category and N_{PI} is the number of cases incorrectly predicted by the model.

(b)$\tau_p=(E_R-E_A)/E_R$, where E_A is the actual number of cases predicted incorrectly and E_R is the expected number of error $(E_R=(2.N_{y=0}.N_{y=1})x(N_{y=0}+N_{y=1})^{-1}$, $N_{y=0}$ and $N_{y=1}$ are number of cases in each category (y=0, y=1) of the dichotomous variable.

The statistical significance of λ_p and τ_p are tested using a binomial d statistic which has approximately normal distribution (Menard, 1995).

$$d=\frac{(P_e-p_e)}{\sqrt{P_e(1-P_e)/N}}$$

where N is total number of cases, P_e is E_R/N for τ_p and N_S/N for λ_p; p_e is E_A/N for τ_p and N_{PI}/N for λ_p. The above statistics are calculated for all the three models and presented in respective tables (Table 8.9, 8.11, 8.13).

B. Estimation of standardized coefficients

Standardized coefficients of variables help in directly comparing the impact of independent variables (measured in different units) on dependent variables. This is very useful when one or more variables are dummy variables. According to Chebycheff's inequality theorem, at least 93% of all cases will lie within 8 S.D. of the mean and 96% will lie within 10 S.D. of the mean even in case of very 'non normal' distribution (Bohrnstedt and Knoke, 1988).

$$b^*_{yx}=(b_{yx})(S_x)(\eta)/S_{logit\,(\hat{y})}$$

where b^*_{yx} is standardized coefficient of variable x, b_{yx} is unstandardized coefficient of variable x, η is calculated using ANOVA routine (predicted value as dependent variable by level of ADOPTION), S_x is S.D of x variable and $S_{logit\,(\hat{y})}$ is S.D of logit ($\hat{y}$).

logit ($\hat{y}$)=ln[$\hat{y}$/(1-$\hat{y}$)] $\hat{y}$ is predicted probability of adoption for each case.

Appendix 10.1

Computer programme for risk analysis

Programme 10.1.1 Generation of empirical distribution

1. Purpose

This programme generates continuous piecewise-linear empirical distributions from discrete data (fuelwood quantity RDF).

2. Specifications

Subroutine: G05EXF (P, NP, IP, LP, R, NR, IFAIL)
INTEGER: NP, NR, NOUT, IP, IFAIL
Double Precision: P(NP), P(NR)
Logical: LP

3. Description

G05EXF sets up a reference vector for use in G05EYF according to CDF(P) of fuelwood quantity (RDF component).

4. Parameters

P(NP): CDF of the distribution
NP: The dimension of the array P as declared in the sub programme from which G05EXF is called (constraint: NP>0)
LP: indicates the type of information contained in P. If LP is .TRUE. P contains a cumulative distribution function (CDF).
NR: The dimension of the array R as declared in the sub programme from which G05EXF is called. The optimum value is NR=5+1.4NP. Constraint: NR>NP+2.

```
*************************************************************************
*        RDF 'FUELWOOD quantity'                                        *
*        Programme for generation of empirical distribution             *
*                                                                       *
*                                                                       *
*************************************************************************
*    .. Parameters ..
        INTEGER        NP, NR
        PARAMETER      (NP=120,NR=173)
        INTEGER        NOUT
        PARAMETER      (NOUT=21)
*    .. Local Scalars ..
        INTEGER        I, IFAIL
```

```
*    .. Local Arrays ..
        DOUBLE PRECISION P(NP), R(NR)
        DOUBLE PRECISION G05CBF, G05EXF, IX
*    .. External Functions ..
        INTEGER       G05EYF
c       EXTERNAL      G05EYF
*    .. External Subroutines ..
C       EXTERNAL      G05CBF, G05EXF
*    .. Data statements ..
        DATA          P/0.11D0, 0.11D0, 0.11D0, 0.11D0, 0.11D0,
     +                  0.11D0, 0.11D0, 0.11D0, 0.11D0, 0.11D0,
     +                  0.11D0, 0.11D0, 0.11D0, 0.11D0, 0.11D0,
     +                  0.11D0, 0.11D0, 0.11D0, 0.11D0, 0.11D0,
     +                  0.39D0, 0.39D0, 0.39D0, 0.39D0, 0.39D0,
     +                  0.39D0, 0.39D0, 0.39D0, 0.39D0, 0.39D0,
     +                  0.39D0, 0.39D0, 0.39D0, 0.39D0, 0.39D0,
     +                  0.39D0, 0.39D0, 0.39D0, 0.39D0, 0.39D0,
     +                  0.44D0, 0.44D0, 0.44D0, 0.44D0, 0.44D0,
     +                  0.44D0, 0.44D0, 0.44D0, 0.44D0, 0.44D0,
     +                  0.44D0, 0.44D0, 0.44D0, 0.44D0, 0.44D0,
     +                  0.44D0, 0.44D0, 0.44D0, 0.44D0, 0.44D0,
     +                  0.61D0, 0.61D0, 0.61D0, 0.61D0, 0.61D0,
     +                  0.61D0, 0.61D0, 0.61D0, 0.61D0, 0.61D0,
     +                  0.61D0, 0.61D0, 0.61D0, 0.61D0, 0.61D0,
     +                  0.61D0, 0.61D0, 0.61D0, 0.61D0, 0.61D0,
     +                  0.78d0, 0.78D0, 0.78d0, 0.78D0, 0.78d0,
     +                  0.78D0,
     +                  0.78d0, 0.78D0, 0.78d0, 0.78D0, 0.78d0,
     +                  0.78D0,
     +                  0.78d0, 0.78D0, 0.78d0, 0.78D0, 0.78d0,
     +                  0.78D0,
     +                  0.78d0, 0.78D0,
     +                  1.0d0, 1.0d0, 1.0d0, 1.0d0, 1.0d0,
     +                  1.0d0, 1.0d0, 1.0d0, 1.0d0, 1.0d0,
     +                  1.0d0, 1.0d0, 1.0d0, 1.0d0, 1.0d0,
     +                  1.0d0, 1.0d0, 1.0d0, 1.0d0,
     +                  1.0D0/

*    .. Executable Statements ..
C       WRITE (NOUT,*) 'G05EXF Results'
C       WRITE (NOUT,*)
        CALL G05CBF(0)
        IFAIL = 0
        CALL G05EXF(P,NP,0,.TRUE.,R,NR,IFAIL)
        OPEN(21,FILE='DISCRT.DAT',STATUS='OLD',ERR=1234)
        CLOSE(21,DISPOSE='DELETE')
 1234   OPEN(21,FILE='DISCRT.DAT',STATUS='NEW')
*
        DO 20 I = 1, 1200
```

```
      IX = G05EYF(R,NR)
      WRITE (NOUT,99999) IX

 20   CONTINUE
      CLOSE (21)
      STOP
99999 FORMAT (1X, F10.4)
      END
```

Note: This programme is modified to generate empirical distribution for poles and fencing posts.

Programme 10.1.2 Correlated variables

1. Purpose:

This programme produces random pairs of correlated variables of the RDF component. The input file contains random number of two risk variables (poles and fencing posts) generated separately according to their respective distributions.

```
*************************************************************************
*       RDF component                                                   *
*       Programme for treatment of correlation condition                *
*                                                                       *
*                                                                       *
*************************************************************************
C       Declarations
        character*16 fname,fout
        integer c1,c2,c3
        dimension c1(10000),c2(10000),c3(10000)
        write(*,'(a,$)') 'Give input filename:'
        read(*,'(a16)') fname
        write(*,'(a,$)') 'Give output filename:'
        read(*,'(a16)') fout
        open(21,file=fname,status='old')
        do i=1,10000
          read(21,*,end=500) c1(i),c2(i)
        enddo
 500    npt=i-1
        close(21)
        do i=1,npt
        do j=i+1,npt
          if(c1(i).gt.c1(j)) then
            itemp=c1(i)
            c1(i)=c1(j)
            c1(j)=itemp
          endif
```

```
          if(c2(i).gt.c2(j)) then
            itemp=c2(i)
            c2(i)=c2(j)
            c2(j)=itemp
          endif
        enddo
        enddo
        do i=1,npt
          write(*,*) c1(i),c2(i)
        enddo
        do i=1,npt
          c3(i)=10000*c1(i)+c2(i)
        enddo
        ifail=0
        call g05ehf(c3,npt,ifail)
        open(21,file=fout,status='old',err=1000)
        close(21,dispose='delete')
1000    open(21,file=fout,status='new')
        do i=1,npt
          c1(i)=c3(i)/10000
          c2(i)=c3(i)-10000*c1(i)
          write(21,*) c1(i),c2(i)
        enddo
        close(21)
        stop
        end
```

Programme 10.1.3 Simulation

1. Purpose:

This programme calculates net present value and presents the frequency distribution of NPV. Discount rate and rotation length are directly entered from keyboard. The input file contains cashflow which in turn was calculated using output files of Programme 10.1.1 and Programme 10.1.2.

```
***********************************************************************
*       PROGRAMME SIMULATION                                          *
*       Programme for frequency distribution of NPV                   *
*                                                                     *
*                                                                     *
***********************************************************************

C       THIS PROGRAMME COMPUTES PROBABILITY OF NPV OF THE PROJECT
```

```
      INTEGER T,N
      REAL R,C(20),SUM,Ans(1000),Cl(20)
      Integer Freq(100)
      character*16 FNAME,FOUT
C     N IS ROTATION LENGTH. T IS A VARIABLE WHICH TAKES VALUE 0 TO N
C     B IS BENEFIT AND C IS COST
C     R IS INTEREST RATE EXPRESSED IN DECIMALS
      NN= 0
      WRITE(6,*) 'TYPE IN INTEREST RATE: '
      READ (5,*) R
      WRITE(6,*) 'TYPE IN ROTATION'
      READ (5,*)N
      WRITE (*,'(A,$)') 'GIVE INPUT FILENAME:'
      READ (*,'(A16)') FNAME
      WRITE (*,'(A,$)') 'GIVE OUTPUT FILE NAME:'
      READ(*,'(A16)') FOUT
c
      Sum= 0.0
      OPEN (21, FILE=FNAME,STATUS='OLD')
      OPEN (22, FILE=FOUT,STATUS='unknown')

10    READ (21,'(20f8.2)',end=400) (C(I), I=1, 20)
    WRITE(6,*)C(1),C(20)
      NN= NN+1
      Exp= 0.0
      do 20 I= 2,10
20      Exp= Exp + (C(10+I) - C(I)) / (1.0 + R)**(I-1)
c
      Sum= Sum + C(11)-C(1) + Exp
cc    write(6,*) C(1),C(20),Sum
cc    write(22,*) Sum
      Ans(NN)= Sum
      goto 10
c
400   continue
      Close(21)
C
      Rmin= Ans(1)
      Rmax= Ans(1)
      do 30 I= 2,NN
        Rmin= min(Rmin,Ans(I))
        Rmax= max(Rmax,Ans(I))
30    continue
      write(6,*) NN,Rmin,Rmax

      Diff= (Rmax-Rmin)/10
      Diff= 1.00001 * Diff
      RR= Rmin+Diff
      do  I= 1,10
```

```
         Freq(I)= 0
         Cl(I)= RR
         write(6,*) I,RR
         RR= RR+Diff
       enddo

       do 40 I= 1,NN
         do J= 1,10
           if (Ans(I).le.Cl(J)) then
                 Freq(J)= Freq(J)+1
                 goto 40
           endif
         enddo
40     continue

       Sfreq= 0.0
       do I= 1,10
         Sfreq= Sfreq+float(Freq(I))/NN
         write(6,*) Cl(I), Sfreq
         write(22,*) Cl(I), Sfreq
       enddo
       Close(22)
       end
```

Notes: 1. The programmes presented in Appendix 10.1 and 10.2 are written in Fortran 77 (extended version) as the most recent version - Fortran 90 is not yet available.
2. We use DEC (Digital Equipment Corporation) Alpha computer named 'thunder' for running these programmes. This machine runs a Digital UNIX (a version of UNIX operating system).
3. Debugging routines are retained in the main programme (using c or comments) to facilitate modifications (if any) in the main programme.

Appendix 10.2

Computer programmes for generation of pseudo random numbers from the defined disrtibutions

Programme 10.2.1 Uniform distribution (0, 1)

1. Purpose:

This programme generates pseudo random numbers from a uniform distribution between 0 and 1 after initialisation by G05CBF.

G05CAF and G05CBF are used in other programmes of theoretical distributions (beta, normal, Weibull etc.).

2. Specifications:

Double precision: X, G05CAF, G05CBF

3. Description

This programme generates pseudo random numbers from a basic uniform (0, 1) generator. It uses a multiplicative congruential algorithm defined as:

$$n_i = (a.n_{i-1}) \bmod m$$

The integers n_i are then divided by m to give uniformly distributed random numbers lying in the interval 0, 1. The Nag generator uses the values $a=13^{13}$ and $m=2^{59}$. This generator gives a cycle length (i.e., the number of random numbers before the sequence starts repeating itself) of 2^{57}. The initial value (seed) is set by default to $123456789(2^{32}+1)$.

For validation of simulation results, it is required to use different sequences (i.e., different seed value) in each simulation run of fixed size. It is cumbersome to change seed values in Nag subroutines. Therefore, different sections (of size 1000 or 1200) of the cycle are used which theoretically can give approximately 10^{14} ($2^{57}/1000$ or $2^{57}/1200$) sections of unique sequence.

```
**********************************************************************
*       UNIFORM DISTRIBUTION                                         *
*       Programme for generation of pseudo random number between 0, 1 *
*                                                                    *
*                                                                    *
**********************************************************************

c       Uniform distribution
        INTEGER NOUT
        PARAMETER (NOUT=21)
        DOUBLE PRECISION X, G05CBF, G05DAF
        INTEGER I
c       EXTERNAL G05DAF
c       EXTERNAL G05CBF
```

```
      WRITE (NOUT,*) 'RESULTS'
      WRITE (NOUT,*)
      CALL G05CBF(0)
      DO 20 I = 1,1000
*
      X=G05CAF(X)
*
      WRITE (NOUT,99999) X
 20   CONTINUE
      STOP
*
99999 FORMAT (1X,F10.4)
      END
```

Programme 10.2.2 Normal (Gaussian) distribution

1. Purpose:

This programme generates pseudorandom numbers following normal distribution of fuelwood quantity of FF component.

2. Specification

Double precision: X, A, B, G05CBF, G05DDF

3. Description

This programme generates a pseudo random real number taken from a normal distribution with mean a and standard deviation b after initialisation by G05CBF. The distribution has the following PDF (probability density function):

$$f(x) = \frac{1}{b\sqrt{2\pi}} \exp\left(-\frac{(x-a)^2}{2b^2} \right) \qquad \textit{for all real numbers } x$$

where a and b are mean and standard deviation respectively.

```
**************************************************************************
*     NORMAL DISTRIBUTION                                                *
*     Programme for generation of psedorandom from normal distribution  *
*     Mean, 50.1348; Standard Deviation, 25.1997                        *
*                                                                        *
**************************************************************************

      INTEGER NOUT
```

```
      PARAMETER (NOUT=21)
      DOUBLE PRECISION  X, G05CBF, G05DDF
      INTEGER I
c     EXTERNAL G05DDF
c     EXTERNAL G05CBF
c     WRITE (NOUT,*) 'RESULTS'
c     WRITE (NOUT,*)
      CALL G05CBF(0)
      open(21,file='normal.dat',status='old',err=1234)
      close(21,dispose='delete')
1234  open(21,file='normal.dat',status='new')
      DO 20 I = 1,1200
      X=G05DDF(50.1348d0,25.1997d0)
      WRITE (NOUT,99999) X
 20   CONTINUE
      close(21)
      STOP
99999 FORMAT (1X,F10.4)
      END
```

Programme 10.2.3 Weibull distribution

1. Purpose:

This programme generates pseudo random real numbers for the variable 'distance from depot' of FF component which follows Weibull distribution.

2.Specification:

INTEGER:	I, IFAIL
Double precision:	A, B

3.Description:

This programme generates pseudorandom real numbers from a two parameter Weibull distribution with shape parameter 'a' and scale parameter 'b' after initialisation by G05CBF. The distribution has the following PDF (range; 0, ∞):

$$f(x) = \begin{cases} ab^{-a}x^{a-1}\exp\left(-\dfrac{x}{b}\right)^{a}, & \text{if } x>0 \\ 0, & \text{otherwise} \end{cases}$$

where a is shape parameter and b is scale parameter. a>0; b>0

The routine returns the value $\{-b.\ln(y)\}^{1/a}$, where ys is a pseudo random number generated from a uniform distribution over 0,1 (G05CAF subroutine).

```
***********************************************************************
*       WEIBULL DISTRIBUTION                                          *
*       Programme for generation of psedorandom from Weibulll distribution *
*       Shape parameter, 1.46204; Scale parameter, 33.7973            *
*                                                                     *
***********************************************************************

        INTEGER NOUT
        PARAMETER (NOUT=21)
        double precision  X,G05CBF,G05DPF
        INTEGER I, IFAIL
c       EXTERNAL G05Dpf
c       EXTERNAL G05CBF
c       WRITE (NOUT,*) 'RESULTS'
c       WRITE (NOUT,*)
        CALL G05CBF(0)
        IFAIL=0
        open(21,file='weibull.dat',status='old',err=1234)
        close(21,dispose='delete')
 1234   open(21,file='weibull.dat',status='new')
        DO 20 I = 1,1000
     X=G05DPF(1.46204d0,33.7973d0,IFAIL)
     WRITE (NOUT,99999) X
 20     CONTINUE
     close(21)
     STOP
99999   FORMAT (1X,F10.4)
        END
```

Programme 10.2.4 Uniform distribution

1. Purpose:

This programme generates pseudo random real numbers for the risk variable 'grass price' of FF component which follows uniform distribution.

2.Specification:

```
Double precision x, G05CBF, G05DAF
INTEGER        A, B
```

3. Description:

This programme generates pseudorandom real numbers from a uniform distribution between 'a' and 'b' after initialisation by G05CBF.

The distribution has the following PDF (Range; a, b):

$$f(x) = \begin{cases} \left(\dfrac{1}{b-a}\right), & \text{if } a \le x \le 0 \\ 0, & \text{otherwise} \end{cases}$$

where a and b are real numbers with $a<b$; a is a location parameter and $(b-a)$ is a scale parameter. The routine returns the value:

$$x = a+(b-a)y,$$

where 'y' is a pseudorandom number from a uniform distribution over 0,1 (subroutine G05CAF).

```
************************************************************************
*        UNIFORM DISTRIBUTION-'grass price'                            *
*        Programme for generation of psedorandom number between a, b   *
*        a=175, b=215,                                                 *
*                                                                      *
************************************************************************

         INTEGER NOUT
         PARAMETER (NOUT=21)
         double precision  X,G05CBF,G05DAF
         INTEGER I
c        EXTERNAL G05DAF
c        EXTERNAL G05CBF
c        WRITE (NOUT,*) 'RESULTS'
c        WRITE (NOUT,*)
         CALL G05CBF(0)
         open(21,file='uniform.dat',status='old',err=1234)
         close(21,dispose='delete')
 1234    open(21,file='uniform.dat',status='new')
         DO 20 I = 1,1000
         X=G05DAF(175.0d0,215.0d0)
         WRITE (NOUT,99999) X
 20      CONTINUE
         close(21)
         STOP
 99999   FORMAT (1X,F10.4)
         END
```

Programme 10.2.5 Beta distribution

1. Purpose:

This programme generates pseudorandom variates for risk variable 'fuelwood price' of FF component which follows a beta distribution.

2.Specification:

INTEGER	I, IFAIL
Double precision	x(N), y(N), A, B G05CBF, G05FEF
Subroutine	G05CBF, G05FEF(A,B,N,x, IFAIL)

3.Description:

This distribution generates pseudo random variates from a beta distribution with parameters a = 2.0 and b = 1.4 after initialisation by G05CBF.

The beta distribution has the following PDF (Range; 0, 1)::

$$f(x) = \begin{cases} \dfrac{x^{a-1}(1-x)^{b-1}}{B(a,\ b)}, & if\ \ 0<x<1 \\ 0, & otherwise \end{cases}$$

where B(a, b) is the beta function, defined by,

$$B(Z_1,\ Z_2) = \int_0^1 t^{Z_1-1}(1-t)^{Z_2-1}\ dt$$

for any real number $Z_1>0$ and $Z_2>0$

```
***********************************************************************
*       BETA DISTRIBUTION- 'fuelwood price'                           *
*                                                                     *
*       Programme for generation of psedorandom from beta distribution *
*               Shape parameters, 2.0, 1.4                            *
*               Range, 200, 270                                       *
***********************************************************************


        INTEGER NOUT,N
        PARAMETER (NOUT=21)
```

```
      PARAMETER (N=1)
      DOUBLE PRECISION X(N),Y(N),G05CBF,G05FEF
      INTEGER I, IFAIL
C     EXTERNAL G05FEF
C     EXTERNAL G05CBF
C     WRITE (NOUT,*) 'RESULTS'
C     WRITE (NOUT,*)
      CALL G05CBF(0)
      IFAIL=0
      open(21,file='beta.dat',status='old',err=1234)
      close(21,dispose='delete')
1234  open(21,file='beta.dat',status='new')
      DO 20 I = 1,1000
      CALL G05FEF(2.0d0,1.4d0,N,X,IFAIL)
      Do 15 J= 1,N
15       Y(J)= 200. + (270. - 200.)*X(J)
*
      WRITE (NOUT,99999) Y
 20   CONTINUE
C
      close(21)
      STOP
99999 FORMAT (1X,F10.4)
      END
```

Note: This programme is also used for fencing post price and pole price as these variables also show beta distribution. The values of a and b and the range are suitably modified.

Appendix 10.3

Elicitation of risk attitudes of project managers

The questionnaire

As a member of the Indian Forest Service, you have been involved in implementation of several plantation projects. Probably you would have considered the survival percentage of the plantation as a measure of the success of the plantation project, as number of trees surviving is a major determinant of the project returns. Probably this has been a measure of assessment of your performance. As you may be aware, through your experience, not all plantation projects yield the most desirable 100% survival and there is a great degree of variability in survival, in turn introducing variability in the plantation returns. Hence, I am sure, all else being equal, you would prefer high survival in plantations. This questionnaire seeks to elicit your preferences in site selection on the basis of different degrees of survival, through a game involving the theoretically possible and desirable 100% as the upper limit and a lower limit of 30% survival (this being chosen as an average figure). This will be used for a serious research purpose. Therefore, you are requested to mark your preferences acting as a forest manager (not as a game player) taking decision as in a real situation after carefully considering alternatives.

The game is divided into three stages. In each stage, you are requested to choose between playing a gamble of 50/50 probabilities (represented by toss of coins) involving best and the worst outcomes and a sure outcome.

Stage 1: There are two options to choose from.

Options	Outcome
A. Plantation at site A	100% Survival or 30% Survival
B. Plantation at site B	a sure survival percentage of 70%

Choice:--------------------(A/B)

(If choice A is made, increase survival percentage in B to 75% and request the respondent to choose again either A or modified B. Alternatively if choice B is chosen, then reduce B by 5% (a percentage point) and request the respondent to choose either

A or modified B. Continue this process by increasing/reducing the survival % in B in increments of 5% till the preference of the respondent just shifts from one choice to another. Circle that value in the table at which the preference just shifts - call this encircled value c)

Choice A	**100%**	**30%**			
Choice B	**70%**	65%*	60%*	55%*	50%*
		75%"	80%"	85%"	90%"

* Modified choices if initially B is preferred to A

" Modified choices if initially A is preferred to B

Stage 2A: Choose from the following options

Options	Outcome
A. Plantation at site A	100% Survival or c* % Survival
B. Plantation at site B	A sure survival percentage of ? %

*Substitute the value encircled in stage 1.

? select any value between 100 and c

Choice:--------------------(A/B)

Now repeat the procedure outlined under stage 1 by increasing/decreasing the survival percentage in choice B by 2%, if A(B) is chosen, up to the point of just shifting of the preference. And encircle the value at this point and call this encircled value d.

Choice A	**100%**	**c%**			
Choice B	**c***	*	*	*	*
		"	"	"	"

* Modified (decrease) choices if initially B is preferred to A

" Modified (increase) if initially A is preferred to B

Stage 2B: Choose from the following options

Options	Outcome
A. Plantation at site A	30% Survival or c* % Survival
B. Plantation at site B	A sure survival percentage of ? %

*Substitute the value encircled in stage 1.

? select any value between 30 and C*.

Choice:--------------------(A/B)

Now repeat the procedure outlined under stage 1 by increasing(decreasing) the survival percentage in choice B by 2%, if A(B) is chosen, up to the point of just shifting of the preference. And encircle the value at this point and call this encircled value e.

Choice A	**c* %**	**30%**			
Choice B		*	*	*	*
		"	"	"	"

* Modified (decrease) choices if initially B is preferred to A

" Modified (increase) if initially A is preferred to B

Stage 3A': Choose from the following options

Options	Outcome
A. Plantation at site A	100% Survival or d* % Survival
B. Plantation at site B	A sure survival percentage of ? %

*Substitute the value encircled in stage 2A.

? select any value between 100 and d

Choice:--------------------(A/B)

Now repeat the procedure outlined under stage 1 by increasing(decreasing) the survival percentage in choice B by 2%, if A(B) is chosen, up to the point of just shifting of the preference. And encircle the value at this point and call this f.

Choice A	**100%**	**d%**			
Choice B	**d %**	*	*	*	*
		"	"	"	"

* Modified (decrease) choices if initially B is preferred to A

" Modified (increase) if initially A is preferred to B

Stage 3A": Choose from the following options

Options	Outcome
A. Plantation at site A	d* % Survival or c % Survival
B. Plantation at site B	A sure survival percentage of ? %

*Substitute the value encircled in stage 2A.

? select any value between c and d*.

Choice:---------------------(A/B)

Now repeat the procedure outlined under stage 1 by increasing(decreasing) the survival percentage in choice B by 2%, if A(B) is chosen, up to the point of just shifting of the preference. And encircle the value at this point and call this g.

Choice A	**c%**	**d%**			
Choice B		*	*	*	*
		"	"	"	"

* Modified (decrease) choices if initially B is preferred to A

" Modified (increase) if initially A is preferred to B

Stage 3B': Choose from the following options

Options	Outcome
A. Plantation at site A	30% Survival or e* % Survival
B. Plantation at site B	A sure survival percentage of ? %

*Substitute the value encircled in stage 2B.

? select any value between 30 and e

Choice:--------------------(A/B)

Now repeat the procedure outlined under stage 1 by increasing(decreasing) the survival percentage in choice B by 2%, if A(B) is chosen, up to the point of just shifting of the preference. And encircle the value at this point and call this h.

Choice A	**30%**	**e%**			
Choice B	e%	*	*	*	*
		"	"	"	"

* Modified (decrease) choices if initially B is preferred to A

" Modified (increase) if initially A is preferred to B

Stage 3B": Choose from the following options

Options	Outcome
A. Plantation at site A	c % Survival or e* % Survival
B. Plantation at site B	A sure survival percentage of ? %

*Substitute the value encircled in stage 2B.

? select any value between c and e*.

Choice:--------------------(A/B)

Now repeat the procedure outlined under stage 1 by increasing(decreasing) the survival percentage in choice B by 2%, if A(B) is chosen, up to the point of just shifting of the preference. And encircle the value at this point and call this i.

Choice A	**c %**	**e%**			
Choice B		*	*	*	*
		"	"	"	"

* Modified (decrease) choices if initially B is preferred to A

" Modified (increase) if initially A is preferred to B

Annexure 4.1

RDF plantations: height measurement and statistical tests of sampled data

Plot	M	SD	95% CI of Mean	SE	Skw	S.E of Skw	Kts	S.E of Kts	S-W test statistic	K-S test statistic
GRS1.1	24.2	0.5254	23.9823, 24.4260	0.1073	-0.1276	0.4723	-0.3716	0.9178	0.9864*	0.0697†
GRS1.2	26.5	0.5776	26.2894, 26.7772	0.1179	0.0994	0.4723	-0.4286	0.9178	0.9860*	0.1063†
GRS1.3	26.3	0.5797	26.0594, 26.5490	0.1183	-0.0759	0.4723	-0.3621	0.9178	0.9834*	0.0761†
GRS2.1	25.8	0.6013	25.5836, 26.0914	0.1227	0.4913	0.4723	-0.3194	0.9178	0.9539*	0.1321†
GRS2.2	25.5	0.5990	25.2804, 25.7863	0.1223	0.5211	0.4723	-0.2564	0.9178	0.9517*	0.1472†
GRS2.3	26.3	0.6753	26.0107, 26.5810	0.1379	0.1411	0.4723	-0.9181	0.9178	0.9493*	0.0981†
GRS3.1	18.9	0.4067	18.8033, 19.1467	0.0830	0.5017	0.4723	0.3650	0.9178	0.9185*	0.1838#
GRS3.2	22.4	0.5830	22.1955, 22.6879	0.1190	0.4056	0.4723	1.8520	0.9178	0.9113*	0.1952#
GRS3.3	21.6	0.4761	21.3823, 21.7844	0.0972	0.5269	0.4723	1.3410	0.9178	0.9210*	0.2361#
SGH1.1	20.7	0.2953	20.5503, 20.7997	0.0603	0.4105	0.4723	-0.2950	0.9178	0.9629*	0.1419†
SGH1.2	19.5	0.2934	19.3303, 19.5780	0.0599	0.4612	0.4723	-0.2470	0.9178	0.9636*	0.1149†
SGH1.3	19.1	0.2869	19.0122, 19.2545	0.0586	0.5619	0.4723	-0.0816	0.9178	0.9510*	0.1581†
SGH2.1	18.3	0.5349	18.0637, 18.5154	0.1092	-0.0280	0.4723	-0.5216	0.9178	0.9842*	0.0968†
SGH2.2	18.2	0.5169	17.9692, 18.4058	0.1055	-0.1011	0.4723	-0.6329	0.9178	0.9682*	0.0999†
SGH2.3	18.6	0.5082	18.6396, 19.0688	0.1037	0.1511	0.4723	-0.3481	0.9178	0.9717*	0.1192†
SGH3.1	19.9	0.6050	19.6862, 20.1971	0.1235	0.4768	0.4723	-0.3876	0.9178	0.9545*	0.1342†
SGH3.2	20.5	0.6093	20.2844, 20.7989	0.1244	0.4045	0.4723	-0.2661	0.9178	0.9604*	0.1336†
SGH3.3	19.8	0.5912	19.5003, 19.9997	0.1207	0.4991	0.4723	-0.1988	0.9178	0.9547*	0.1170†

Key: M=Mean, SD= Standard Deviation, SE= Standard Error, Skw= Skewness, Kts= Kurtosis, S-W test statistic = Shapiro-Wilks test statistic, K-S test statistic= Kolmogorov-Smirnov (lillefors) test, * distribution is normal ($P<0.05$), † distribution is normal ($P<0.05$), # distribution is not normal ($P<0.05$).

Notes: 1. Since, * S-W Statistic<S-W $_{crit}$=0.884, $P<0.05$, distribution is normal.

2. Since, † K-S Statistic>K-S $_{crit}$=0.173, $P<0.05$, distribution is normal.

Annexure 4.2

Questionnaire for Field Survey in Bihar

	VARIABLE	VALUE OR CODE
1.0 Zone	ZONE	/__/
1.1 District	DISTRICT	/__/
1.3 Village	VILLAGE	/__//__//__/
1.4 Questionnaire serial number	QSNUM	/__//__//__//__/
1.5 Age	AGE	/__/
1.6 Sex 1.Male	SEX	/__/
2.Female		
1.7 Caste 1.S.C.	CASTE	/__/
2.S.T.		
3.Others		
1.8 Number of family members	HHPOP	/__/
1.9 Education 1.Literate	LITERACY	/__/
2.Illiterate		
1.10 Numbr of years in school and college		
(If answer of 1.9 is 1)	YRSCOL	/__/
2.0 Occupation and assets		
2.1 What is your occupation?	OCCUP	/__/
1.Agriculture		
2.Agriculture labour		
3.Labour in government scheme		
4.Artisan		
5.Dairying		
6.Employment(Government or private)		
7.Others (specify)		
2.2 How much land do you own?		
2.2.1 Land ha	LAND	/__//__//__/
2.3 Your monthly income from different sources		
2.3.1.Agriculture	AGGRI	/__//__//__//__/
2.3.2.Wage (Agricultural)	WAGEA	/__//__//__//__/
2.3.3.Wage (Non-Agriculture)	WAGENA	/__//__//__//__/
2.3.4.Urban	URBAN	/__//__//__//__/
2.2.5.Total	MONINCOM	/__//__//__//__/
2.4 How many live stock do you own?		
2.4.1.Cow and buffalo	COWBUFF	/__//__//__//__/
2.4.2.Goat and sheep	GOSHEEP	/__//__//__//__/
2.4.3.Poultry	POLTRY	/__//__//__//__/
2.4.4.Others	OTHLIV	/__//__//__//__/
2.5 Irrigation faciities in your land is	IRRFTL	/__/
1.Tube well		
2.Well		
3.Canal		
4.Chuan		
5.Other (specify)		
2.6 Transport and agriculture machinery you own	MACHINE	/__/
1.Tractor		

2.Bullock cart
3.Motorcycle
4.Pumpset
5.Other (specify)

3.0 Knowledge and awareness about the programme

3.1 What is the main reason for your participation in this programme? PARTCIP /__/
1.Fuelwood
2.Fodder
3.Timber
4.Income (present)
5.Income (future)
6.Other (specify)

3.2 Who informed you about this programme? AWARE /__/
1.Forest department
2.Revenue department
3.Contact man
4.through radio
5.in village market

3.3 Is there any village forest committee (VFC) in your village? VFC /__/
1.Yes
2.No

3.4 Are you aware about the resolution by the Government of Bihar giving you and your panchayat rights over the forest? RESOLUTN /__/
1.Yes
2.No

3.5 Are you aware about the joint management plan (JMP)?
1.Yes JMP /__/
2.No

4.0 Selection of the species

4.1 Specify the names and numbers of the species you have planted

	Names	Number	SPSCODE	NUM
4.1.1			/__//__/	/__//__//__//__/
4.1.2			/__//__/	/__//__//__//__/
4.1.3			/__//__/	/__//__//__//__/
4.1.4			/__//__/	/__//__//__//__/

4.2 Who selected the species? SPSLECT /__/
1.Self
2.Forest department
3.both

4.3 Specify the reasons for selecting these species WHYSLECT /__/
1.Fuelwood
2.Fodder
3.Easy to grow
4.Small timber
5.Other

4.4 Were all the species you wanted, available in the

nursery in required number? SPSCHOSE /__/
1.Yes
2.No

4.5 Which species were not available? SPSCODE
4.5.1 /__//__/
4.5.2 /__//__/
4.5.3 /__//__/
4.5.4 /__//__/

4.6 If not, where did you get them from? PLTSORS /__/
1.Market/private nursery
2.Nursery of other government department
3.Not planted these species
4.Any other source (specify)

4.7 Do you think species selected were suitable for the land?
1.Yes SPSSLT /__/
2.No
3.Do not know

5.0 Training and extension service

5.1 Did you get advice from the forest department about the following?

1.Yes 2.No

5.1.1.Selection of the species	SPSELT	/__/
5.1.2.Pit size	PITSIZE	/__/
5.1.3.Spacing	SPACE	/__/
5.1.4.Fertiliser and insecticide	FERTICIDE	/__/
5.1.5.Weeding	WEEDING	/__/

5.2 Since planting have you received any advice from any organisation(s)? If so, how often? 1.Yes 2.No

Number of times		SERVE	NUM
5.2.1.Forest department	FORTDP	/__/	/__//__/
5.2.2.Agriculture department	AGRIDP	/__/	/__//__/
5.2.3.Revenue department	REVDP	/__/	/__//__/
5.2.4.Non-government Organisation	NGO	/__/	/__//__/

6.0 Acquisition and planting of seedlings

6.1 Do you feel that land used for farm forestry was appropriate for growing APROPLND /__/
1.Trees
2.Crops
3.Grazing land
4.Other (specify)

6.2 Where did you plant seedlings? PLANTLOC /__/
1.Permanently fallow land
2.Grazing land
3.Land was previously under cultivation
4.Bunds and boundaries
5.Homestead
6.Other (specify)

6.3 How much (if any) did you pay for seedling and how many seedling did you get free?

6.3.1.Rs. paid PAID /__//__//__//__/
6.3.2.Got free(no.) FREE /__//__//__//__/

6.4 What was the distance from the nursery to the plantation site? Km PLTRNPRT /__//__//__//__/

6.5 At what spacing were the seedlings planted? PLTSPACE /__//__//__//__/
1.2m by 2m
2.Single row 2 m apart
3.Other (specify)
4.Irregular

6.6 Did you weed after planting? WEEDING /__/ Num /_/
1.Yes, How often?
2.No

7.0 Protection problems for farm forestry

7.1 What were the total number of seedling planted and survived?
7.1.1.Total planted PLANTED /__//__//__//__/
7.1.2.Total survived SURVIVED /__//__//__//__/

7.2 Please indicate the means of protection used PROTECT /__/
1.No protection
2.Barbed wire fencing
3.Bush fencing
4.Watchman
5.Other (specify)

7.3 What is/was the main problem of protection in the plantation? PROBPROT /__/
1.Grazing
2.Fire
3.Illicit felling
4.Drought/flood
5.Other
6.Both 1 and 3 above

7.4 Do you need help in protecting plantation? PROTHLP /__/
1.Yes
2.No
If yes, suggestions A
B

7.5 Can you suggest the causes of mortality/failure of the plantation
1.
2.
3.

8.0 Benefits and income from farm forestry

8.1 Which of the following produce did you get from the farm forestry plantation? BENEFIT /__/

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1.Fodder								

2.Minor forest produce								
3.Fuel wood								
4.Poles								
5.None								
6.Other(specify)								

8.2 How did you use the intermediate produce? INTPROD /__/

1.Own consumption
2.Sold
3.Partly sold partly consumed
4.Other

8.3 What was the amount you received from the forest department?

8.3.1.For planting etc. PLTING /__//__//__/
8.3.2.As societal compensation SOCCOM /__//__//__/

8.4 How will you dispose off the plantation? HARVEST /__//__//__/

1.Sell in the market
2.Sell to the forest department
3.Own consumption
4.Other (specify)

8.5 How will you spend the money received after harvesting? HARVEMON /__/

1.Purchase land
2.Repay debt
3.Plant more trees
4.Don't know
5.Other (specify)

8.6 Did you engage hired labour for plantation? HIRLBR /__/

1.Yes
2.No

9.0 Motivational activity

9.1 In which year(s) and how many seedlings have you planted? YEAR NUM

9.1.1.1980 to 1985 8085 /__//__//__//__/
9.1.2.1986 to 1990 8690 /__//__//__//__/
9.1.3.1991 to 1994 9194 /__//__//__//__/

9.2 Do you feel the scheme should be restarted again? RESTRT /__/

1.Yes
2.No

9.3 If yes, 1.Same programme should be includedSHMMOD /__/
2.The scheme should be modified
suggestions, A
B
C

10.0 Fuel needs of the farmers

10.1 How much of the following materials does your family need daily/annually

10.1.1.Fuelwood (kg) FLWOOD /__//__//__//__/
10.1.2.Dung (kg) DUNG /__//__//__//__/

10.1.3.Coal (kg)	COAL	/__//__//__//__/
10.1.4.Kerosene oil (lit)	KOIL	/__//__//__//__/
10.1.5.Fodder (kg)	FODDER	/__//__//__//__/
10.1.6.Timber (cu ft)	TIMBER	/__//__//__//__/
10.1.7.Poles (no.)	POLES	/__//__//__//__/
10.1.8.Other (specify)	OTHS	/__//__//__//__/

10.2 You get fuel for cooking from the following sources

	1.Full 2.Part %		FUL/PT%
10.2.1.Government forest	GOVFORT	/__/	/__//__/
10.2.2.Own plantation	OWNPLT	/__/	/__//__/
10.2.3.Crop residue	CROPRES	/__/	/__//__/
10.2.4.Dung	DUNG	/__/	/__//__/
10.2.5.Purchased wood	PURWOOD	/__/	/__//__/
10.2.6.Other (specify)	OTHS	/__/	/__//__/

11.0 Rehabilitation of degraded forests

11.1 Do you get adequate forest produce from the forests for your domestic needs? FORPROD /__/
1.Yes
2.No

11.2 If answer is no, the reasons NOPROD /__/
1.No forest close by
2.Not adequate number of trees in forest

11.3 How far you have to walk to collect firewood FWOODKM /__/
Km.

11.4 What is the condition of the RDF plantation? RDFPLT /__/
1.Very good
2.Good
3.Bad
4.Very bad

11.5 Did the villagers get work in the plantation? WRKPLT /__/
1.Yes
2.No

11.6 Who is responsible for protection of this plantation? PROTPLT /__/
1.Forest department
2.Village forest protection committee
3.Both
4.Do not know

11.7 Where do you send your animals for grazing now? GRZLOC /__/
1.Same plantation area
2.Other forest
3.Do not send at all

11.8 Are you aware that panchayat, farmers and forest department will share the produce of this plantation on harvesting? SHRFORPD /__/
1.Yes
2.No
3.Do not know

Annexure 4.3

Questionnaire for Field Survey in Bihar (for non-participating villagers)

	VARIABLE	VALUE OR CODE
1.0 Zone	ZONE	/__/
1.1 District	DISTRICT	/__/
1.2 Village	VILLAGE	/__//__//__/
1.3 Questionnaire serial number	QSNUM	/__//__//__//__/
1.4 Name of the respondent		
1.5 Age	AGE	/__/
1.6 Sex		
1.Male	SEX	/__/
2.Female		
1.7 Caste		
1.S.C.	CASTE	/__/
2.S.T.		
3.Others		
1.8 Number of family members	HHPOP	/__/
1.9 Education		
1.Literate	LITERACY	/__/
2.Illiterate		
1.10 Number years in school and college (If answer of 1.9 is 1)	YRSCOL	/__/
2.O Occupation and assets		
2.1 What is your occupation?		
1.Agriculture	OCCUP	/__/
2.Agriculture labour		
3. Labour in government scheme		
4.Artisan		
5.Dairying		
6.Employment (government or private)		
7.Others (specify)		
2.2 How much land you own?		
2.2.1 Land ha	LAND	/__//__//__/
2.3 Your monthly income from different sources		
2.3.1.Agriculture	AGGRI	/__//__//__//__/
2.3.2.Wage (Agricultural)	WAGEA	/__//__//__//__/
2.3.3.Wage (non-agriculture)	WAGENA	/__//__//__//__/
2.3.4.Urban	URBAN	/__//__//__//__/
2.3.5.Total	MONINCOM	/__//__//__//__/
2.4 How many live stock you own?		
2.4.1.Cow and buffalo	COWBUFF	/__//__//__//__/
2.4.2.Goat and sheep	GOSHEEP	/__//__//__//__/
2.4.3.Poultry	POLTRY	/__//__//__//__/
2.4.4.Others	OTHLIV	/__//__//__//__/
2.5 Irrigation facilities in your land is	IRRFTL	/__/
1.Tubewell		
2.Well		

3.Canal
4.Chuan
5.Others (specify)

2.6 Transport and agriculture machinery you own — MACHINE /___/

1.Tractor
2.Bullock cart
3.Motorcycle
4.Pumpset
5.Other (specify)

3.0 Knowledge and awareness about the programme

3.1 What is the main reason for your non-participation in this programme? — PARTCIP /___/

1.Do not have land
2.Land is used for agriculture
3.Could not get information in time
4.Any other reason (specify)

3.2 Do you want to participate in this programme in future ? — FPATI /___/

1.Yes
2.No
3.Cannot say

3.3 If not, suggest changes in the programme

A
B
C

3.4 Far forestry programme affects labour availability adversely — FFLBR /___/

1.Yes
2.No
3.Only during peak season

4.0 Rehabilitation of degraded forests

4.1 Do you get adequate forest produce from the forests for your domestic needs ? — FORPROD /___/

1.Yes
2.No

4.2 If answer is 2, the reasons — NOPROD /___/

1.No forest close by
2.Not adequate number of tree in the forest

4.3 How far you have to walk to collect firewood — FWOODKM /___/

Km.

4.4 What is the condition of the RDF plantation ? — RDFLTY /___/

1.Very good
2.Good
3.Bad
4.Very bad

4.5 Did the villagers get work in the plantation ? — WRKLT /___/

1.Yes
2.No

4.6 Who is responsible for protection of this plantation ? — PROTPLT /___/

1.Forest department
2.Village forest protection committee
3.Both

4.7 where do you send your animals for grazing now ? GRZLOC /___/
1.Same plantation area
2.Other forest
3.Do not send at all

4.8 are you aware that panchayat, farmers and forest department will share the produce of this plantation on harvesting ? SHRFORPD /___/
1.Yes
2.No

5.0 Fuel needs of the farmers

5.1 How much of the following materials does your family need daily / annually ?

5.1.1.Fuelwood (kg)	FLWOOD	/___//___//___//___/
5.1.2.Dung (kg)	DUNG	/___//___//___//___/
5.1.3.Coal (kg)	COAL	/___//___//___//___/
5.1.4.Kerosene (lit)	KOIL	/___//___//___//___/
5.1.5.Fodder (kg)	FODDER	/___//___//___//___/
5.1.6.Timber (cft)	TIMBER	/___//___//___//___/
5.1.7.Poles (no.)	POLES	/___//___//___//___/
5.1.8.Others (specify)	OTHS	/___//___//___//___/

5.2 You get fuel for cooking from the following source

1.Full 2.Part %		FUL/PT	%
5.2.1.Government forest	GOVFORST	/___/	/___//___/
5.2.2.Own plantation	OWNPLT	/___/	/___//___/
5.2.3.Crop residue	CROPRES	/___/	/___//___/
5.2.4.Dung	DUNG	/___/	/___//___/
5.2.5.Purchased wood	PORWOOD	/___/	/___//___/
5.2.6.Others (specify)	OTHS	/___/	/___//___/

Annexure 4.4

Description of the variables

Variables	Description	Measurements	Type	Used in analysis DA	CA
ADOPTDGR	% of land under tree	land under tree/total land	I	-	-
ADOPTIME	early and late adopters	not adopted=0, late adopted=1, early adopted=2	N	-	-
ADOPTION	adoption and non adoption	non adopters=0, adopters=1	D	-	-
ADVICE	advice from different department	no advice=0 number of times received advice=nos. Max. 8	I	+	+
AGASSET	agri. machinery	min.1(less value) max.4 (more value)	O	+	+
AGASSET1	agri. machinery	less=0, more=1	D	-	-
AGE	age	min.18, max. 65	I	+	+
AGGRI	income from agriculture	min. 0 max.5000	I	+	+
AGUPTINC	agriculture income/total income	min.=0, max.1	I	+	+
APROLAND	suitability of land for tree growing	not suitable=0 suitable=1 Q.6.1	D	+	-
AWARINDX	awareness index of forestry activity	not aware=0 fully aware=4 yes/no(1/0)score of q3.3,3.4,3.5 and11.8	O	+	+
CASTE	caste	SC and ST=1, others=0	D	+	+
COWEEP	number of cattle	cow+.5sheep min.0 max=12	I	+	+
DISTRICT	districts	min.1, max.6 Sighbhum (E)=1, Garhwa=2, Hazaibagh=3, Gumla=4, Ranchi=5, Sahebganj=6	N	+	-
EXPERNS	experience in tree growing	tree growing before 1985=1, if not=0	D	+	-

EXTNSN	advice on silviculture	no advice=0, got advice=5 combined score of Q.5.1	I	+	+
FORPROD	forest produce for domestic needs	yes=1, no=0	D	+	+
FWWOODKM	distance to collect firewood	min.1 max.15	I	+	+
GOVFORTP	% fuel from government forest	min.0% max.100%	I	+	+
HHPOP	no. of member in the household	min.1 max.18	I	+	+
HIRLBR	engagement of hired labour in plantation	yes=1, no=0	D	+	+
INCOME	total income from all sources	min. 500 max.6000	I	+	+
INTPROD	disposal of intermediate products	no product=0, consumed=1, sold=2, part sold part cons.=3	N	+	+
IRRFTL	irrigation facilities	inadequate=1, adequate=3	O	+	+
IRRFTL1	irrigation facilities	inadequate=0, adequate=1	D	-	-
LAND	land ownership	in ha	I	+	+
LANDOWN	land ownership	≤1.90 ha=0, >1.90=1	D	-	-
LANDOWN3	land ownership	≤1.50 ha=0, 1.51-2.40=1, ≥2.41=2	O	-	-
LITERACY	literacy	literate=1, illiterate=0	D	+	+
OCCUP	occupation	1 to 7 categories	N	+	+
OCCUP1	occupation	agri.=0, labour=1, other=2, urban employment=3	N	-	-
OCCUP2	occupation	aggri=0, other=1	D	-	-
PCFLWOOD	per capita weekly fuelwood requirement	min. .06, max. 2.0	I	+	+
PCPOLES	per capita annual pole requirement	min. O max. 25	I	+	+
PCTIMBER	per capita annual timber requirement	min. 0, max. 3.0	I	+	+
PLANTLOC	planting site	very bad to very good 0,1,2,3	O	+	+
PLTSPACE	spacing in plantation	regular=1, irregular=0	D	+	-
PLTTRP	distance from nursery to plantation site	in km. Min. 0 max.=3	I	+	+
PROTECT	plantation protection	no protection to very good protection 1,2,3	O	+	+

PROTECT1	plantation protection	no protection to very good protection 0,1,2,3	O	-	-
PROTHLP	help required from the FD in protection	yes=1, no=0	D	+	-
PURWOODP	proportion of purchased wood used	%	I	+	+
REGION	SGH and GRS	SGH=1, GRS=0	D	-	-
SEX	male and not male (female)	Male=1, female=0	D	+	+
SPSLECT	selection of species	farmer=1, FD=2, both=3	N	+	+
SURVIVAL	no survived/no.planted	min=0, max.=1	I	+	+
URBAN	urban income	min.=0, max.=3500	I	+	-
WEEDNO	weeding number	min.=0, max.=5	I	+	-
YRSCOL	number of years in school	min.=0, max.=14	I	+	+

Key: N=nominal variable, O=ordinal variable, D=dichotomous variable, I=interval variable, DA=Discriminant analysis, CA=cluster analysis, '+' used in analysis, '-' not used in analysis

Annexure 5.1

Estimation of volume under the threat of illicit felling using different illicit felling models

Table A5.1.1: District: SGH1, Initial plant density 2500 plants ha^{-1}

	SQ1				SQ2				SQ3			
Age	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.57	11.57	11.57	11.57	0.93	0.93	0.93	0.93	0.06	0.06	0.06	0.06
3	40.51	39.73	40.43	40.56	5.77	5.66	5.73	5.76	0.75	0.73	0.71	0.71
4	75.80	72.13	73.49	74.27	14.35	13.66	14.02	14.27	2.60	2.47	2.48	2.50
5	110.38	99.63	101.90	104.42	24.80	22.38	23.33	24.34	5.48	4.94	5.04	5.13
6	141.82	117.78	121.35	127.25	35.70	29.65	31.61	34.35	9.01	7.48	7.74	8.02
7	169.61	124.80	129.96	141.14	46.32	34.08	37.45	43.33	12.86	9.46	9.97	10.62
8	193.98	120.75	127.56	145.59	56.31	35.05	40.09	50.72	16.79	10.45	11.27	12.49
9	215.33	107.38	115.51	141.02	65.55	32.69	39.36	56.17	20.66	10.30	11.43	13.38
10	234.09	80.75	96.59	128.71	74.02	27.76	35.68	59.51	24.39	7.75	10.51	13.22
11	250.65	-		110.73	81.76			60.70	27.94			12.11
12	265.34	-		89.61	88.82			59.81	31.28			10.32

Key: NIF=volume without illicit felling, WM-INA, WM-IA1,WM-IA2=volume under the risk of illicit felling (the models).

Table A5.1.2: District: SGH1, Initial plant density 2500 plants ha^{-1}

	SQ1				SQ2				SQ3			
Age	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.57	11.57	11.57	11.57	0.93	0.93	0.93	0.93	0.06	0.06	0.06	0.06
3	40.51	39.90	40.56	40.67	5.77	5.68	5.74	5.77	0.75	0.74	0.71	0.71
4	75.80	72.61	73.87	74.57	14.35	13.75	14.06	14.29	2.60	2.49	2.49	2.51
5	110.38	100.21	102.31	104.78	24.80	22.51	23.37	24.36	5.48	4.97	5.06	5.15
6	141.82	117.60	120.96	127.10	35.70	29.61	31.44	34.31	9.01	7.47	7.72	8.01
7	169.61	122.25	127.21	139.31	46.32	33.39	36.65	43.09	12.86	9.27	9.76	10.48
8	193.98	114.02	120.61	140.48	56.31	33.10	38.06	49.99	16.79	9.87	10.68	12.04
9	215.33	95.36	103.10	131.02	65.55	29.03	35.54	54.58	20.66	9.15	10.25	12.41
10	234.09	70.97	78.94	112.86	74.02	22.44	29.91	56.58	24.39	7.39	8.66	11.56
11	250.65			89.33	81.76			55.92	27.94			9.73
12	265.34			64.44	88.82			52.75	31.28			7.37

Key: NIF=volume without illicit felling, WM-INA, WM-IA1,WM-IA2=volume under the risk of illicit felling (the models).

Table A5.1.3: District: SGH3, Initial plant density 2500 plants ha⁻¹

	SQ1				SQ2				SQ3			
Age	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.57	11.57	11.57	11.57	0.93	0.93	0.93	0.93	0.06	0.06	0.06	0.06
3	40.51	39.83	40.50	40.62	5.77	5.67	5.74	5.76	0.75	0.74	0.71	0.71
4	75.80	72.36	73.67	74.42	14.35	13.70	14.04	14.28	2.60	2.48	2.48	2.50
5	110.38	99.77	101.95	104.50	24.80	22.41	23.32	24.34	5.48	4.95	5.04	5.13
6	141.82	117.17	120.65	126.83	35.70	29.50	31.41	34.29	9.01	7.45	7.70	8.00
7	169.61	122.34	127.45	139.40	46.32	33.41	36.77	43.11	12.86	9.28	9.78	10.48
8	193.98	115.29	122.03	141.47	56.31	33.47	38.52	50.14	16.79	9.98	10.80	12.13
9	215.33	98.27	106.21	133.50	65.55	29.92	36.55	54.99	20.66	9.43	10.55	12.65
10	234.09	75.43	83.73	117.21	74.02	23.85	31.54	57.42	24.39	7.86	9.16	12.01
11	250.65			95.46	81.76			57.37	27.94			10.41
12	265.34			71.72	88.82			54.97	31.28			8.22

Key: NIF=volume without illicit felling, WM-INA, WM-IA1,WM-IA2=volume under the risk of illicit felling (the models).

Table A5.1.4: District: GRS1, Initial plant density 2500 plants ha⁻¹

	SQ1				SQ2				SQ3			
Age	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.57	11.57	11.57	11.57	0.93	0.93	0.93	0.93	0.06	0.06	0.06	0.06
3	40.51	39.26	40.04	40.23	5.77	5.59	5.69	5.74	0.75	0.72	0.70	0.71
4	75.80	70.96	72.59	73.52	14.35	13.44	13.92	14.22	2.60	2.43	2.45	2.47
5	110.38	98.20	100.93	103.51	24.80	22.06	23.25	24.27	5.48	4.87	5.00	5.09
6	141.82	117.67	121.78	127.22	35.70	29.62	31.88	34.37	9.01	7.48	7.77	8.02
7	169.61	128.54	134.26	143.79	46.32	35.10	38.76	43.68	12.86	9.75	10.29	10.82
8	193.98	131.24	138.61	153.32	56.31	38.10	43.37	51.76	16.79	11.36	12.20	13.17
9	215.33	126.91	135.77	156.35	65.55	38.63	45.57	58.43	20.66	12.18	13.34	14.87
10	234.09	117.07	127.08	153.68	74.02	37.02	45.48	63.63	24.39	12.20	13.67	15.84
11	250.65			146.28	81.76			67.37	27.94	12.17	13.25	16.10
12	265.34			135.22	88.82			69.71	31.28			15.70

Key: NIF=volume without illicit felling, WM-INA, WM-IA1,WM-IA2=volume under the risk of illicit felling (the models).

Table A5.1.5: District: GRS2, Initial plant density 2500 plants ha^{-1}

	SQ1				SQ2				SQ3			
Age	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.57	11.57	11.57	11.57	0.93	0.93	0.93	0.93	0.06	0.06	0.06	0.06
3	40.51	39.35	40.12	40.30	5.77	5.60	5.70	5.74	0.75	0.73	0.71	0.71
4	75.80	71.32	72.89	73.75	14.35	13.50	13.96	14.24	2.60	2.44	2.46	2.48
5	110.38	99.06	101.66	104.07	24.80	22.25	23.37	24.32	5.48	4.92	5.03	5.11
6	141.82	119.30	123.22	128.31	35.70	30.04	32.16	34.49	9.01	7.58	7.86	8.09
7	169.61	131.18	136.63	145.61	46.32	35.83	39.28	43.89	12.86	9.95	10.46	10.96
8	193.98	135.05	142.09	156.03	56.31	39.20	44.21	52.10	16.79	11.69	12.49	13.41
9	215.33	131.89	140.42	160.08	65.55	40.15	46.77	58.94	20.66	12.65	13.77	15.23
10	234.09	123.10	132.84	158.48	74.02	38.93	47.08	64.34	24.39	12.83	14.25	16.35
11	250.65			152.12	81.76		45.98	68.33	27.94	12.67	14.08	16.75
12	265.34			141.97	88.82			70.95	31.28			16.50

Key: NIF=volume without illicit felling, WM-INA, WM-IA1,WM-IA2=volume under the risk of illicit felling (the models).

Table A5.1.6: District: GRS3, Initial plant density 2500 plants ha^{-1}

	SQ1				SQ2				SQ3			
Age	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2	NIF	WM-INA	WM-IA1	WM-IA2
Years	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1	0.27	0.27	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.57	11.57	11.57	11.57	0.93	0.93	0.93	0.93	0.06	0.06	0.06	0.06
3	40.51	39.84	40.52	40.70	5.77	5.67	5.74	5.81	0.75	0.74	0.71	0.72
4	75.80	72.89	74.18	75.08	14.35	13.80	14.13	14.55	2.60	2.50	2.50	2.52
5	110.38	102.34	104.37	107.09	24.80	22.99	23.79	25.13	5.48	5.08	5.16	5.26
6	141.82	124.59	127.63	133.70	35.70	31.37	32.93	36.01	9.01	7.92	8.12	8.43
7	169.61	138.30	142.61	153.89	46.32	37.77	40.43	46.27	12.86	10.49	10.89	11.59
8	193.98	143.33	149.07	167.44	56.31	41.61	45.62	55.30	16.79	12.41	13.06	14.38
9	215.33	140.31	147.46	174.49	65.55	42.72	48.22	62.70	20.66	13.46	14.41	16.58
10	234.09	130.49	138.86	175.44	74.02	41.26	48.25	68.21	24.39	13.60	14.84	18.07
11	250.65			170.87	81.76		46.53	71.62	27.94	13.56	14.50	18.77
12	265.34			161.56	88.82			72.84	31.28			18.71

Key: NIF=volume without illicit felling, WM-INA, WM-IA1,WM-IA2=volume under the risk of illicit felling (the models).

Annexure 6.1

Cost and benefit tables for financial models

Table A6.1.1 Details of costs of *Eucalyptus* plantation

Wage rate Rs 21 per man day (1994-95); Spacing 2m × 2m; 2500 plants per ha

Year	Item of work	Man days	Amount (Rs)
0	**Advance work**		
	Survey & Demarcation	3	63.00
	Trench fencing	70	1470.00
	Nursery (part)	30	932.50
	Soil work	50	1050.00
	Misc. work	0	11.00
	Indirect cost	0	1225.81
	Total cost in 0 th year	153	4752.31
1	**Completion work**		
	Nursery (part)	30	630.00
	Planting work	50	1050.00
	Two weeding & hoeing	55	1155.00
	Fertilizer & insecticide	0	357.50
	Misc.	0	91.30
	Indirect cost	0	1177.24
	Total cost in 1 st year	135	4461.04
2	**Maintenance work**		
	One weeding & hoeing	35	735.00
	Repair of trench fencing	10	210.00
	Indirect cost	0	391.99
	Total cost in 2 nd year	45	1336.99

Note: The amount shown in column 4 includes costs of material.

Table A6.1.2 Details of harvesting costs 1994-95

Item	Fuelwood (Rs/m^3)	Fencing post (Rs per piece)	Pole (Rs per piece)
Harvesting cost	10.00	1.00	1.50
Post harvesting cost			
Loading/unloading	4.50	0.80	1.80
Transport coupe to depot	8.00	1.00	2.00
Making lots, stacking and marking	2.90	0.20	0.38
Miscellaneous	2.00	0.20	0.30
Administrative expenditure	22.50	1.60	3.00
Total harvesting cost	**49.90**	**4.80**	**8.98**

Table A6.1.3 Rates of Forest produce (ex-depot) 1994-95

Forest produce	Rate (in Rs)
Fuelwood (Rs/m^3)	225
Fencing post 2.44m to 3.64m (Rs/piece)	16
Pole (Rs/piece)	
(a) diameter 0.1016 to 0.124m and length 4.26m to 4.85m	30
(b) diameter ≥ 0.125m and length 4.26m to 4.85m	46
(c) diameter ≥ 0.125m and length 4.86m to 5.44m	57
(d) diameter ≥ 0.15m and length 4.84m to 5.44m	106
(e) diameter ≥ 0.15m and length 5.44m to 6.04m	135
(f) diameter ≥ 0.175m and length 5.44m to 6.04m	156

Note: Diameter of pole is measured 1' from thickest end.

Table A6.1.4 Price per unit estimated tree volume for Eucalyptus plantation (without illicit felling)

Year	Price(Rs/m^3)		
	SQ1	SQ2	SQ3
1	495.93	495.93	495.93
2	495.93	495.93	495.93
3	495.93	495.93	495.93
4	495.93	495.93	495.93
5	495.93	495.93	495.93
6	1553.44	495.93	495.93
7	1563.92	495.93	495.93
8	1596.08	495.93	495.93
9	1583.24	495.93	495.93
10	1524.06	495.93	495.93
11	2033.63	495.93	495.93
12	1930.92*	495.93	495.93
13	2108.86	2408.86	495.93
14	2211.67	2501.17	495.93
15	2140.17	2383.30	495.93

Note: *The reason for this unexpected 'dip' is that an increase in volume has not resulted in a proportionate increase in value because the value of individual forest produce (poles) is fixed by girth and height class-wise.

Annexure 6.2

Cost and benefit tables for FF and RDF case studies

Table A6.2.1 Details of total costs of RDF 1986 plantations

Wage rate Rs 13.56 per man day (1985-86); 1000 plants per ha (gross)

Year	Item of work	Man days	Amount (Rs)
0	**Advance work**		
	Survey & Demarcation	3	40.68
	Trench fencing	70	949.2
	Nursery (part)	12	283.72
	Soil work	20	271.20
	Misc. work	0	11.00
	Indirect cost	0	540.87
	Total cost in 0 th year	105	2096.67
1	**Completion work**		
	Nursery (part)	12	162.72
	Planting work	20	271.2
	Two weeding & hoeing	22	298.32
	Fertilizer & insecticide	0	143.00
	Misc.	0	45.00
	Indirect cost	0	329.88
	Total cost in 1 st year	54	1250.12
2	**Maintenance work**		
	One weeding & hoeing	14	189.84
	Repair of trench fencing	6	81.36
	Indirect cost	0	112.51
	Total cost in 2 nd year	20	383.71

Note: The amount shown in column 4 includes costs of material

Table A6.2.2 Calculation of indirect cost

Item	Expenditure (Rs million)			
	Year			
	0	1	2	3
	1985	1986	1987	1988
Indirect				
Establishment	10.19	10.51	12.38	17.94
Supportive activities	0.74	0.66	1.31	3.10
Total indirect (TI)	10.93	11.17	13.69	21.04
Direct				
Farm forestry (FF)	15.25	12.44	14.33	36.92
RDF	13.12	14.85	10.59	28.40
Harijan land plantation	0.00	0.00	0.00	4.17
Strip plantation	2.83	2.80	3.81	1.98
Maintenance	0.24	1.07	4.27	3.69
Total direct (TD)	31.44	31.16	33.00	75.16
Indirect costs for RDF Plantations				
• Physical work for RDF 1986 plantation (in ha) (PWRDF)	5857.00	5857.00	5857.00	
• Unit cost in (Rs)/ha gross (UC)	1550.80	920.24	271.20	
• Total indirect in RDF (TIRDF); [(TIx RDF)/TD]	4.5611	5.3233	4.3932	
• Total direct expenditure towards RDF 1986 plantation (TDRDF86); (PWRDF x UC x 10^{-6})	9.1123	5.3898	1.5884	
• % expenditure in RDF 1986 plantation (RDF%); (TDRDF86/RDF)	0.6945	0.3630	0.1500	
• Total indirect expenditure in RDF1986 plantation (TIRDF86); TIRDF x RDF%	3.1679	1.9321	0.6590	
• RDF1986 plantation per ha indirect cost (in Rs); (TIRDF86 x 10^{6})/ 5857	540.87	329.88	112.51	
Indirect costs for FF Plantations				
• Total indirect in FF (TIFF); (FF x TI)/TD	5.3016	4.4594	5.9448	10.3352
• Physical work for FF1986 plantation (seedlings in million) PWFF	14.4810	14.4810	0.0000	3.5913
• Total direct expenditure FF 1986 plantation (TDFF86); PWFFx(0.37 for year 0, 0.43 for year 1 and 0.20 for year3)	5.3580	6.2268	0.0000	0.7183
• % direct expenditure in 1986 plantation to the total expenditure of the year in FF (%FF); TDFF86/FF	0.3513	0.5005	0.0000	0.0195
• Total indirect expenditure towards FF1986 plantation (TIFF86); TIFF x %FF	1.8627	2.2321	0.0000	0.2011
• FF1986 plantation indirect cost (Rs/plant) TIFF86/PWFF	0.1286	0.1541	0.0000	0.0560

Table A6.2.3 Distribution of biomass in tree components

Species	Age	% of total biomass (dry weight)				
		Wood	Bark	Leaf	Twig	Branches
Eucalyptus	7	42.7	17.4	11.2	16.0	12.6
Acacia	8	38.9	5.4	11.9	23.5	20.4

Source: Pande et al., 1986

Notes:1gm dry weight=0.226g fresh weight for Eucalyptus; 1gm dry weight=0.229g fresh weight for Acacia (Kumar et al., 1993)

Table A6.2.4 Implicit Price Index and Wholesale Price Index
(The estimates relate to fiscal year beginning 1 April)

Year	Implicit Price Index (GDP Deflator) Base year 1980 = 100	Wholesale Price Index (average of weeks) Base year 1981 = 100
1965	30.9	
1966	35.0	
1967	37.8	
1968	37.9	
1969	39.4	
1970	42.6	
1971	44.9	
1972	49.8	
1973	58.7	
1974	68.5	
1975	67.5	
1976	71.5	
1977	75.5	
1978	77.6	
1979	89.7	
1980	100.0	91.1
1981	110.2	100.0
1982	118.5	104.9
1983	128.5	112.8
1984	138.1	120.1
1985	148.1	125.4
1986	157.8	132.7
1987	171.1	143.6
1988	183.6	154.3
1989	198.8	165.7
1990	220.7	182.7
1991	252.9	207.8
1992		228.7
1993		247.8
1994		275.5*

Source: Government of India, 1993 and International Monetary Fund, 1995
* Derived from Base year 1990

Table A6.2.5 Some selected interest rates (1970-1995)

YEAR	Bank rate*	Discount rate	Deposit rate		Lending rate†	Prime lending rate	
			Long term	Short term	General	IDB1	IFCI and ICICI
1970	5-6	8.5			8.5-12		
1980	9		10	10	19.4	11.9-14	11.9
1981	10		10	10	19.4	14	14
1982	10		11	10	19.5	14	14
1983	10		11	10	18	14	14
1984	10		11	10	18	14	14
1985	10		11	10	17.5	14	14
1986	10		11	10	17.5	14	14
1987	10			10	16.5	14	14
1988	10			10	16	14	14
1989	10			10	16	14	14
1990	10			11	16	14-15	14-15
1991	11-12	15.5-19		13	17-20	18-20	18-20
1992	12	16-18		11-13	19	17-19	17-19
1993	12	14-16		10	15-16	15.5-18.5	
1994	12	14				14.6-17.6	
1995	12	13-14.5					

Key: IFCI=Industrial Finance Corporation of India, ICICI=Industrial Credit and Investment Corporation of India Ltd., IDBI=Industrial Development Bank of India

Notes: 1. *Bank rate is the standard rate at which the Reserve Bank of India makes advances to Schedule Banks against government securities and commercial papers.
2. †Lending rate is the rate charged on advances from the State Bank of India to the commercial banks. This prime rate regulates interest rates charged by the commercial banks on various categories of loans.

Source: Reserve Bank of India (RBI), 1994, Government of India, 1993

Table A6.2.6 Details of total costs of FF 1986 plantations
Wage rate Rs 13.56 per man day (1985-86); rates per plant

Year	Item of work	Amount (Rs)
0	**Advance work**	
	Nursery (part)	0.27
	Soil work	0.10
	Total cost in 0 th year	0.37
1	**Completion work**	
	Nursery (part)	0.21
	Planting work	0.10
	Two weeding & hoeing (optional)	0.10
	Fertilizer & insecticide	0.12
	Total cost in 1 st year	0.43
2	**Maintenance work**	0.00
	Total cost in 2 nd year	0.00
3	**Maintenance work**	0.20
	Total cost in 3 rd year	0.20

Table A6.2.7 Schedule of rate for harvesting cost

Year	Forest produce	Harvesting cost	Post harvesting cost			
		Direct	Loading	Transport	Stacking	Misc.
1986, 1987	Fuelwood	5.50	2.64	0.09	1.70	1.17
	Fencing post	0.60	0.47	0.01	0.12	0.12
	Pole	1.00	1.06	0.02	0.22	0.18
1988	Fuelwood	5.50	2.98	0.11	1.92	1.32
	Fencing post	0.60	0.53	0.01	0.13	0.13
	Pole	1.00	1.19	0.03	0.25	0.20
1989	Fuelwood	6.00	3.29	0.12	2.12	1.46
	Fencing post	0.70	0.59	0.01	0.15	0.15
	Pole	1.10	1.32	0.03	0.28	0.22
1990, 1991	Fuelwood	7.00	3.50	0.12	2.26	1.56
	Fencing post	0.80	0.62	0.02	0.16	0.16
	Pole	1.20	1.40	0.03	0.30	0.23
1992	Fuelwood	10.00	3.50	0.12	2.26	1.56
	Fencing post	1.00	0.62	0.02	0.16	0.16
	Pole	1.50	1.40	0.03	0.30	0.23
1993, 1994	Fuelwood	10.00	4.50	0.16	2.90	2.00
	Fencing post	1.00	0.80	0.02	0.20	0.20
	Pole	1.50	1.80	0.04	0.38	0.30

Notes: 1. The harvesting rates for poles are for smallest pole size (diameter 0.1016 to 0.1240m and length 4.26m to 4.86m)
2. The minimum wage rates (Rs/manday) for unskilled labour were as below:

Year	1985-1987	1988	1989-1993	1994
Wage rate	13.56	17.85	21.00	27.00

Annexure 7.1: National data for estimation of EDR

Table A7.1.1 Estimation of marginal productivity of capital

Year	GDP Rs x10⁹	GCF Rs x10⁹	EAP x10⁶	K Rs x10⁹	K_R Rs x10⁹	q1	q2
1965	735.61	163.82	177.64	2868.82	4345.9	0.195284	0.194079
1966	744.54	171.68	181.57	3040.50	4517.6	0.186493	0.185342
1967	805.73	174.51	185.60	3215.01	4692.1	0.190866	0.189688
1968	827.40	163.81	189.74	3378.82	4855.9	0.186498	0.185347
1969	880.95	182.37	194.00	3561.19	5038.2	0.188398	0.187236
1970	1013.62	194.61	197.84	3755.80	5232.9	0.205539	0.204270
1971	1017.38	191.20	202.22	3947.00	5424.1	0.196307	0.195095
1972	1009.22	179.25	206.50	4126.26	5603.3	0.186273	0.185123
1973	1045.94	207.99	210.82	4334.25	5811.3	0.183787	0.182652
1974	1047.30	212.83	215.16	4547.08	6024.1	0.175412	0.174330
1975	1166.75	243.48	220.48	4790.56	6267.6	0.185487	0.184342
1976	1162.91	234.45	225.07	5025.01	6502.1	0.176251	0.175163
1977	1259.48	241.57	229.68	5266.58	6743.6	0.182131	0.181007
1978	1343.41	303.96	234.29	5570.54	7047.6	0.183668	0.182534
1979	1275.72	293.75	238.91	5864.29	7341.3	0.165677	0.164654
1980	1360.13	284.53	243.54	6148.82	7625.9	0.168465	0.167426
1981	1446.11	366.72	253.23	6515.54	7992.6	0.169033	0.167990
1982	1503.79	339.82	258.47	6855.36	8332.4	0.167062	0.166031
1983	1615.47	322.40	264.09	7177.76	8654.8	0.171408	0.170350
1984	1674.89	332.49	269.71	7510.25	8987.3	0.169845	0.168797
1985	1766.48	394.51	275.71	7904.76	9381.8	0.170193	0.169143
1986	1852.50	399.25	281.29	8304.01	9781.1	0.169899	0.168851
1987	1940.85	420.89	287.00	8724.90	10201.9	0.169415	0.168370
1988	2138.27	510.71	292.70	9235.61	10712.7	0.176327	0.175239
						0.179988	0.178877

GDP Gross Domestic Product at constant price of 1980
GCF Gross Capital Formation (fixed+increase in stock) at constant price of 1980
Source: NAS UN 1987, 1988, 1992 and IMF supppl ser. 8, 1984
Population Midyear Estimates
Source: IFS March 1978, Feb. 1983, Oct. 1988, Dec. 1993, Aug. 1995
EAP Economically active Population
Source: Mukhopadhyay, 1994: and Economic Survey 1993-94

Table A7.1.2 Estimation of National Domestic Product (NDP) for constant labour

(figures in Rs billion)

Year	GDP	CFC	NDP_C	NDP_T	PCE_C	ΔPCE_T	NDP_{TL}
1965	241.10	12.30	228.80	695.44	184.40	0.00	695.44
1966	276.60	14.00	262.60	704.02	216.50	19.94	684.08
1967	322.90	15.60	307.30	762.53	261.50	88.40	674.13
1968	332.80	16.80	316.00	784.12	261.90	89.39	694.73
1969	368.50	19.10	349.40	831.91	284.70	117.37	714.53
1970	402.60	22.20	380.40	876.50	298.03	126.22	750.28
1971	429.83	20.82	409.01	910.94	327.75	30.35	880.58
1972	470.37	24.95	445.42	894.42	356.03	15.32	879.10
1973	576.78	27.94	548.84	934.99	435.03	41.51	893.49
1974	684.57	34.09	650.48	949.61	437.77	-60.52	1010.13
1975	740.80	40.50	700.30	1037.48	527.50	81.88	955.60
1976	803.40	44.90	758.50	1060.84	541.70	58.02	1002.82
1977	901.00	50.10	850.90	1127.02	626.90	130.73	996.29
1978	974.40	57.60	916.80	1181.44	669.40	163.03	1018.42
1979	1061.50	68.00	993.50	1107.58	729.70	113.89	993.69
1980	1256.80	79.50	1177.30	1177.30	878.70	179.10	998.20
1981	1594.20	144.60	1449.60	1315.43	1135.60	330.89	984.54
1982	1775.90	168.80	1607.10	1356.20	1254.60	359.13	997.07
1983	2072.70	193.20	1879.50	1462.65	1456.10	433.55	1029.10
1984	2295.40	222.60	2072.80	1500.94	1603.20	461.30	1039.64
1985	2617.30	264.40	2352.90	1588.72	1743.80	477.85	1110.88
1986	2929.50	298.20	2631.30	1667.49	2000.00	567.83	1099.66
1987	3332.00	333.40	2998.60	1752.54	2240.60	609.93	1142.62
1988	3957.80	389.20	3568.60	1943.68	2574.20	702.47	1241.21

GDP= Gross Domestic Product at current price
CFC= Consumption of Fixed Capital at current price (CFC=GNP-National Income(NNP)
NDP_C =Net Domestic Product (GDP-CFC) at current price
NDP_T =Net Domestic Product at a constant price of 1980
PCE_C= Private Consumption Expenditure at current price
ΔPCE_T = Difference in Private Consumption Expenditure at a constant price of 1980
$NDP_{TL}=NDP_T - \Delta PCE_T$
Source: IFS March 1978, Feb. 1983, Oct. 1988, Dec. 1993, Aug. 1995, IFS suppl.ser 8, 1984

Table A7.1.3 Estimation of marginal propensity to save (s)

(figures in Rs billion)

Year	GNP (Y)	GC	PC	GNC (C)	GNS (S)	ΔY	ΔS	s=ΔS/ΔY
1965	239.50	23.00	185.30	208.30	31.20			
1966	274.30	25.00	217.70	242.70	31.60	34.80	0.40	0.0115
1967	320.40	27.90	262.60	290.50	29.90	46.10	-1.70	-0.0369
1968	330.20	30.50	262.40	292.90	37.30	9.80	7.40	0.7551
1969	365.80	34.20	285.10	319.30	46.50	35.60	9.20	0.2584
1970	399.80	38.01	298.03	336.04	63.76	34.00	17.26	0.5076
1971	426.92	44.32	327.75	372.07	54.85	27.12	-8.91	-0.3285
1972	467.35	47.22	356.03	403.25	64.10	40.43	9.25	0.2288
1973	573.54	50.57	435.03	485.60	87.94	106.19	23.84	0.2245
1974	681.09	59.79	437.77	497.56	183.53	107.55	95.59	0.8888
1975	738.30	73.50	527.50	601.00	137.30	57.21	-46.23	-0.8081
1976	801.10	82.10	541.70	623.80	177.30	62.80	40.00	0.6369
1977	898.60	86.70	626.90	713.60	185.00	97.50	7.70	0.0790
1978	972.90	96.20	669.40	765.60	207.30	74.30	22.30	0.3001
1979	1062.20	109.20	729.70	838.90	223.30	89.30	16.00	0.1792
1980	1257.40	127.90	878.70	1006.60	250.80	195.20	27.50	0.1409
1981	1594.60	153.60	1135.60	1289.20	305.40	337.20	54.60	0.1619
1982	1769.50	182.70	1254.60	1437.30	332.20	174.90	26.80	0.1532
1983	2063.30	211.40	1456.10	1667.50	395.80	293.80	63.60	0.2165
1984	2281.20	243.50	1603.20	1846.70	434.50	217.90	38.70	0.1776
1985	2603.00	292.60	1743.80	2036.40	566.60	321.80	132.10	0.4105
1986	2911.40	346.30	2000.00	2346.30	565.10	308.40	-1.50	-0.0049
1987	3305.80	408.40	2240.60	2649.00	656.80	394.40	91.70	0.2325
1988	3912.90	473.30	2574.20	3047.50	865.40	607.10	208.60	0.3436
							Average	0.2056

GNC (Gross National Consumption)=Government Consumption+Private Consumption
GNS (Gross National Savings)=GNP-GNC, GC=Government consunption, PC=Private consumption
All figures are at current price
Source: IFS March 1978, Feb. 1983, Oct. 1988, Dec. 1993, Aug. 1995, IFS suppl.ser 8, 1984

Annexure 7.2

Derivations of economic prices

Table A7.2.1 Shadow pricing of land

S.No	Description	Amount/quantity
a	Output per ha of Khesari (kg)	460.20
b	Market price of Khesari (Rs/kg)	4.00
c	Cost of input	
d	(i) Material (Rs)	200.00
e	(ii) Labour (40) @Rs28.13/workday	1125.20
f	Economic price of labour in Rs (ex0.49*)	551.35
g	Economic value of annual returns in Rs [{axb}-{d+f}]	1089.45
h	Present worth of annual return in Rs $\{gx(1+r)^n-1\}/r(1+r)^n$	6214.76

Notes: 1. r is economic discount rate (0.1024) and n is plantation rotation (9 years).
2. * is shadow wage rate (SWR_{PT})

Table A7.2.2 SWR on the basis of scarce and surplus labour (RDF plantations)

Wage rate Rs 13.56 (w) per man day (1985-86); 1000 plants per ha (gross) or 2500 plants net

Year	Item of work	Total Man days(TM)	Scarce labour (SL)	Surplus labour	SWR=SL/TM
0	**Advance work**				
	Survey & Demarcation	3	0	3	
	Trench fencing	70	0	70	
	Nursery (part)	12	0	12	
	Soil work	20	0	20	
	Total labour in 0 th year	105	0	105	0.000w
1	**Completion work**				
	Nursery (part)	12	0	12	
	Planting work	20	20	0	
	Two weeding & hoeing	22	22	0	
	Total labour in 1 st year	54	42	12	0.778w
2	**Maintenance work**				
	One weeding & hoeing	14	14	0	
	Repair of trench fencing	6	0	6	
	Total labour in 2 nd year	20	14	6	0.700w
	Overall Shadow wage rate				**0.313w**

Table A7.2.3 SWR on the basis of scarce and surplus labour (FF plantations) Wage rate Rs 13.56 (w) per man day (1985-86); mandays per plant

Year	Item of work	Total Man days(TM)	Scarce labour (SL)	Surplus labour	SWR=SL/TM
0	**Advance work**				
	Nursery (part)	0.0125	0.0125	0.0000	
	Soil work	0.0074	0.0000	0.0074	
	Total mandays in 0 th year	0.0199	0.0125	0.0074	0.628w
1	**Completion work**				
	Nursery (part)	0.0155	0.0155	0.0000	
	Planting work	0.0074	0.0074	0.0000	
	Total mandays in 1 st year	0.0229	0.0229	0.0000	1w
2	**Maintenance work**				
	Total mandays in 2 nd year	0.0000	0.0000	0.0000	0w
3	**Maintenance work**				
	Total mandays in 3 rd year	0.0147	0.0037	0.0111	0.252w
	Overall Shadow wage rate	**0.0576**	**0.0391**	**0.0185**	**0.68w**

Table A7.2.4 Economic pricing of harvesting costs (RDF) 1994-95

Item	Fuelwood (Rs/m^3)	Fencing post (Rs per piece)	Pole (Rs per piece)
Harvesting cost	0.00	0.00	0.00
Post harvesting cost			
Loading/unloading	0.00	0.00	0.00
Transport coupe to depot	8.00	1.00	2.00
Making lots, stacking and marking	2.90	0.20	0.38
Miscellaneous	2.00	0.20	0.30
Administrative expenditure	22.50	1.60	3.00
Total harvesting cost	**35.40**	**3.00**	**5.68**

Table A7.2.5 Economic costs for harvesting (FF)

Year	Forest produce	Harvesting cost	Post harvesting cost			
		Direct	Loading	Transport	Stacking	Misc.
1986, 1987	Fuelwood	0.00	0.00	0.09	1.70	1.17
	Fencing post	0.00	0.00	0.01	0.12	0.12
	Pole	0.00	0.00	0.02	0.22	0.18
1988	Fuelwood	0.00	0.00	0.11	1.92	1.32
	Fencing post	0.00	0.00	0.01	0.13	0.13
	Pole	0.00	0.00	0.03	0.25	0.20
1989	Fuelwood	0.00	0.00	0.12	2.12	1.46
	Fencing post	0.00	0.00	0.01	0.15	0.15
	Pole	0.00	0.00	0.03	0.28	0.22
1990, 1991	Fuelwood	0.00	0.00	0.12	2.26	1.56
	Fencing post	0.00	0.00	0.02	0.16	0.16
	Pole	0.00	0.00	0.03	0.30	0.23
1992	Fuelwood	0.00	0.00	0.12	2.26	1.56
	Fencing post	0.00	0.00	0.02	0.16	0.16
	Pole	0.00	0.00	0.03	0.30	0.23
1993, 1994	Fuelwood	0.00	0.00	0.16	2.90	2.00
	Fencing post	0.00	0.00	0.02	0.20	0.20
	Pole	0.00	0.00	0.04	0.38	0.30

Table A7.2.6 SWR on the basis of peak season and off season wages

Year and month	Average current wages (market)	WPI 1981 = 100	Wages at constant price, June, 1992=100	
			Peak season	Off season
July, 1991	29.7	202.8	32.82	
August, 1991	28.7	209.2	30.74	
September, 1991	33.9	210.4	36.11	
October, 1991	24.0	210.2		25.59
November, 1991	20.2	212.4		21.31
December, 1991	25.0	213.2		26.28
January, 1992	20.0	215.3		20.82
February, 1992	20.0	216.4		20.71
March, 1992	20.0	217.7		20.59
April, 1992	20.0	219.4		20.43
May, 1992	20.2	221.6		20.43
June, 1992	37.3	224.1	37.30	
Average wages			34.24	22.02

Key: WPI=wholesale price index, Source: Government of India, 1993

Table A7.2.7 Employment status of main and subsidiary workers

S.No	Work status (average number of days)	Main worker	Subsidiary worker	All worker
A	employed in the week	6.7264	1.9440	6.1262
B	unemployed in the week	0.1246	3.2015	0.5107
C	in work force in the week (A+B)	6.8510	5.1455	6.6369
D	neither working nor unemployed (7-C)	0.1490	1.8545	0.3631

Source: Government of India, 1991

Table A7.2.8 Shadow pricing of fertilizer

S.No	Description	Unit	Quantity /amount
A	Market price of urea (N) and SSP (P) (2:1)	Rs per tonne	2600
B	Total N+P production	'000 tonnes	7070
C	Total N+P import	'000 tonnes	2310
D	Total demand (B+C)	'000 tonnes	9380
E	Total subsidy (domestic and imported fertilizer)	million Rs	18970
F	Total subsidy per tonne (E/D)	Rs per tonne	2022
G	Total economic price (A+F)	Rs per tonne	4622
H	Economic price/market price (G/A)	ratio	1.778

Note: 1. Urea and SSP constitute the major part of imported nitrogenous and phosphatic fertilizers respectively.
2. 5% sales tax is not included in market prices.
3. The data given in the table pertain to year 1986.
Source: GOI, 1993 and FAO, 1988

Table A7.2.9 Estimation of Standard Conversion Factor (SCF)

(Rs in billion)

Year	Border Prices		Domestic Prices		SCF
	Export (f.o.b)	Import (c.i.f)	Export	Import	
1965	8.032	13.516	9.3	14.6	0.9016
1966	11.714	20.373	13.3	21.2	0.9301
1967	12.097	20.796	15.1	22.0	0.8866
1968	13.209	19.273	16.0	19.0	0.9281
1969	13.763	16.589	16.3	17.5	0.8980
1970	15.189	15.933	17.7	18.2	0.8669
1971	15.256	18.155	17.9	21.8	0.8416
1972	18.568	16.844	22.3	20.5	0.8274
1973	22.591	24.893	28.3	31.8	0.7901
1974	31.786	41.596	38.4	47.8	0.8513
1975	36.412	53.388	48.1	56.6	0.8577
1976	49.702	50.738	61.4	56.1	0.8548
1977	55.734	57.937	66.4	65.2	0.8638
1978	54.564	64.387	71.2	74.2	0.8181
1979	63.445	79.820	83.4	100.9	0.7773
1980	67.517	116.771	90.3	136.0	0.8144
1981	71.780	133.379	102.6	148.2	0.8180
1982	88.416	139.691	116.7	158.1	0.8301
1983	92.430	142.012	132.4	176.1	0.7599
1984	112.744	163.035	159.6	198.3	0.7705
1985	114.098	198.587	149.5	217.5	0.8520
1986	118.524	194.502	165.4	223.6	0.8047
1987	146.417	216.134	202.8	252.6	0.7961
1988	184.099	266.059	259.1	320.1	0.7772
1989	257.726	334.850	346.3	403.0	0.7908
1990	314.451	413.603	406.4	487.0	0.8149
1991	401.230	458.957	562.5	562.5	0.7646
1992	508.706	611.131	673.1	730.0	0.7981
					0.8316

Source: International Financial Statistics : various issues (IMF, 1984, 1989, 1995)

Table A7.2.10 Discounted cash flow (ECBA), Farm Forestry, Plot 1A1

a. Operation and physical benefits

Total planted=1000; Total survived=513; Area, 0.4ha; Spacing, 2m x 2m.

	Year						
	0	1	2	3	7	8	9
Opreation	Advance work	Planting & weeding	Weeding	Maintenance	Harvesting	Harvesting	Harvesting
Benefits (physical)	1000 kg grass	1000 kg grass	2000 kg grass	-	P=20; FP=120; FW=0.83 m^3	P=20; FP=120; FW=1.0 m^3	P=300; FP=1880; FW=24.78 m^3

Key: P=poles; FP=fencing post; FW=fuelwood

b. Price of forest produce

Forest produce	Year			
	0, 1, 2	7	8	9
Grass (Rs/kg)	0.20	-	-	-
Fuelwood (Rs/m^3)	-	202.5	202.5	225
Fencing Post (Rs/pc)	-	13.5	13.5	14.4
Poles (Rs/pc)	-	23.4	24.3	27

c. Economic cost of weeding and harvesting operation

	Weeding cost	Harvesting costs (Rs/pc, for P and FP and Rs/m^3, for FW		
Year	1,2	7	8	9
Financial (Rs/plant)	0.10	P=3.83; FP=2.08; FW=17.23	P=4.5; FP=2.4; FW=19.3	P=4.5; FP=2.4; FW=19.3
Economic cost (Rs/plant)	0.00	P=0.56; FP=0.34; FW=3.94	P=0.72; FP=0.42; FW=5.06	P=0.72; FP=0.42; FW=5.06

Notes: 1. Economic cost of weeding is taken as zero because the entire operation uses only surplus labour.
2. Economic costs for harvesting is calculated using scarce/surplus labour method (Table A7.2.5).
3. Economic cost of land is also taken as zero for this plot because this land was

previously not under cultivation.

d. Computation of economic costs of planting

(Rs/plant)

S.No	Costs	Material	Main worker	Subsidiary worker	Staff	Other expenditure
			Planting cost			
			Year 0			
a	Financial cost	0.1000	0.0852	0.1848	0.1196	0.0090
b	Economic cost	0.1000	0.0535$^{\alpha}$	0.1161$^{\alpha}$	0.1196$^{\tilde{\alpha}}$	0.0090
			Year 1			
a'	Financial cost	0.1200$^{\omega}$	0.0978	0.2122	0.1449	0.0092
b'	Economic cost	0.1978$^{\acute{\omega}}$	0.0978$^{\tilde{\alpha}}$	0.2122$^{\tilde{\alpha}}$	0.1449$^{\tilde{\alpha}}$	0.0092
			Year 3			
a"	Financial cost	0.0000	0.0631	0.1369	0.0476	0.0084
b"	Economic cost	0.0000	0.0159$^{\phi}$	0.0345$^{\phi}$	0.0476	0.0084

Notes: 1. Economic cost=Financial cost × Shadow wage rate; $^{\alpha}$ Shadow wage rate (SWR_{SS}=0.628); $^{\tilde{\alpha}}$ SWR_{SS}=1.000; $^{\phi}$ SWR_{SS}=0.252;
2. $^{\omega}$ Financial price include price of fertilizer (0.10) and insecticide (0.02); $^{\acute{\omega}}$ Economic price = (0.10× 1.778) + 0.02 =0.1978 (Table A7.2.8)

e. Cash flow

Year	Economic cost (Rs)	Economic benefit (Rs)	cash flow (nominal)	Inflating/deflating factor	Cash flow (real)
0	398.16	200.00	-198.16	1.9761	-391.58
1	661.90	400.00	-261.90	1.8674	-489.06
2	0.00	400.00	400.00	1.7256	690.25
3	106.40	0.00	-106.40	1.6060	-170.25
4	0.00	0.00	0.00	1.4955	0.00
5	0.00	0.00	0.00	1.3563	0.00
6	0.00	0.00	0.00	1.1925	0.00
7	55.27	2256.83	2201.56	1.0835	2385.42
8	69.86	2307.92	2238.06	1.0000	2238.06
9	1130.99	40784.06	39617.08	0.8995	35633.80
NPV (Discount rate, 10.24%)					**16655.48**
NPV (Discount rate, 15.77%)					**10679.18**
NPV (Discount rate, 17.94%)					**9005.89**

Annexure 8.1

Principal component analysis and logit model statistics

Table A8.1.1 Principal component analysis: the final statistics

Variables	Communality	Factor	Eigenvalue	% of variance	Cumulative % of variance
ADVICE	0.72172	1	9.81873	40.9	40.9
AGASSET	0.75953	2	2.99403	12.5	53.4
AGGRI	0.90055	3	2.16267	9.0	62.4
AGUPTINC	0.77918	4	1.39900	5.8	68.2
APROLAND	0.79702	5	1.17917	4.9	73.1
AWARINDX	0.82014				
COWEEP	0.62314				
EXTNSN	0.82192				
FWWOODKM	0.70855				
GOVFORTP	0.83322				
HHPOP	0.76691				
INCOME	0.80288				
IRRFTL1	0.70737				
LAND	0.66179				
PCFLWOOD	0.85158				
PCPOLES	0.52739				
PCTIMBER	0.80179				
PLANTLOC	0.51835				
PLTTRP	0.67019				
PROTECT1	0.67751				
PURWOODP	0.69573				
URBAN	0.80063				
WEEDNO	0.78466				
YRSCOL	0.52219				

Note: Initial statistics; Communality=1.00000 for all the variables, Eigenvalue<1.00000 for factors 6 to 24 and %of the variance explained by factors 6 to 24 are ≤3.5% for individual factors

Table A8.1.2 Descriptive Statistics of variables used in logit model

Variable	Mean			Standard Deviation			Expected signs
	Full model	Small farmer	Large farmer	Full model	Small farmer	Large farmer	
AGASSET1			0.65			0.48	-
AGE			44.09			7.19	-
AGGRI		1050.00			789.13		-
AGUPTINC		0.64	0.79		0.41	0.32	+
CASTE		0.64	0.54		0.48	0.50	-
COWEEP		2.73	4.72		1.87	2.57	+
FORPROD			0.32			0.47	+
FWOODKM			7.84			3.70	+
GOVFORTP	45.17	57.28		35.22	36.58		-
HHPOP		6.45			1.24		-
INCOME	2347.92			1324.36			-
IRRFTL	2.09	1.66	2.34	0.68	0.60	0.59	+
LANDOWN	0.63			0.48			?
LITERACY		0.31	0.71		0.46	0.46	?
OCCUP1			0.42			0.98	+
PCPOLES	4.16			4.22			+
PCTIMBER	0.39		0.41	0.29		0.27	+
PURWOODP		18.53			25.65		-
REGION		0.53			0.50		+
URBAN			545.62			1045.12	+
LOGITY	0.01	6.42	-1.34	1.19	7.77	3.26	N.A

Annexure 9.1

Estimation of social costs and benefits

Table A9.1.1 Estimation of the elasticity of marginal utility of consumption

Year	Population x10^6	GNP current Rs x10^9	GNP Rs x10^9	TPCE Rs x10^9	PCEF Rs x10^9	FPI	WPI	FNFPIR
1965	482.71	239.50	316.91	238.36	148.63	69.85	72.04	0.96
1966	493.39	274.30	316.60	243.82	149.58	79.64	80.53	0.98
1967	504.16	320.40	342.77	262.72	166.34	100.54	92.63	1.13
1968	515.41	330.20	354.91	270.56	169.63	98.62	92.24	1.10
1969	526.99	365.80	377.55	280.82	179.16	95.08	94.20	1.01
1970	539.08	399.80	399.80	298.38	187.79	100.00	100.00	1.00
1971	551.02	426.92	409.05	307.04	187.03	101.00	105.00	0.95
1972	562.67	467.35	405.99	300.70	178.77	107.90	113.00	0.94
1973	574.43	573.54	420.45	308.80	182.78	128.60	131.50	0.97
1974	586.27	681.09	421.46	311.43	190.75	165.30	169.20	0.97
1975	600.76	738.30	465.47	335.30	203.55	170.20	175.80	0.96
1976	613.27	801.10	470.65	334.77	190.74	152.20	172.40	0.84
1977	625.82	898.60	509.31	369.88	216.61	170.80	185.40	0.89
1978	638.39	972.90	544.07	387.72	222.55	173.30	185.00	0.91
1979	650.98	1062.20	520.90	368.95	202.19	181.30	185.90	0.97
1980	663.60	1257.40	555.89	410.88	239.03	200.70	248.10	0.75
1981	690.00	1594.60	585.91	424.50	241.46	230.30	278.40	0.77
1982	705.00	1769.50	600.70	439.60	239.96	244.70	285.30	0.81
1983	720.00	2063.30	645.02	474.77	267.75	275.60	308.50	0.85
1984	736.00	2281.20	665.22	483.66	265.39	294.60	334.00	0.84
1985	750.90	2603.00	708.03	497.56	268.86	312.40	353.30	0.84
1986	766.14	2911.40	804.53	569.24	288.09	331.63	367.66	0.87
1987	781.37	3305.80	841.48	590.51	297.33	386.90	393.03	0.98
1988	796.60	3912.90	923.84	626.96	313.42	400.72	427.36	0.91

Notes: 1. GNP, TPCE (total private consumption expenditure) and PCEF (private consumption expenditure on food) are at constant price of 1970. FPI=Food article price index; WPI= wholesale price index; FNFPIR= food/non food price index ratio.

2. FNFPIR=$(1-w_f)[(WPI/FPI)-w_f)]$, where w_f is weight for food articles in WPI (w_f=0.298)

Table A9.1.2 Social cost of planting (RDF component)

S.No	Costs	Material	Main worker	Subsidiary worker	Staff	Other expenditure
			Year 0			
a	Financial cost	132.00	449.21	974.59	503.01	37.86
b	Economic cost	132.00	0.00	0.00	503.01	37.86
c	Combined weight for CL	10.3504	10.3504	10.3504	10.3504	10.3504
d	SCCL1 (bXc)	1366.25	0.00	0.00	5206.35	391.87
e	SCCL2 [(a-b)c]	0.00	4649.50	10087.40	0.00	0.00
f	TSCCL (d+e)	1366.25	4649.50	10087.40	5206.35	391.87
g	Combined weight for CG	0.00	0.6071	2.4649	0.4364	0.00
h	TSCCG [(a-b)g]	0.00	272.72	2402.27	0.00	0.00
i	Net social cost to society (f-h)	1366.25	4376.78	7685.13	5206.35	391.87
			Year 1			
a'	Financial cost	188.00	231.02	501.22	310.09	19.79
b'	Economic cost	299.25	179.73	389.95	310.09	19.79
c'	Combined weight for CL	10.3504	10.3504	10.3504	10.3504	10.3504
d'	SCCL1 (b'Xc')	3097.36	1860.31	4036.13	3209.56	204.83
e'	SCCL2 [(a'-b')c']	-1151.48	530.84	1151.70	0.00	0.00
f'	TSCCL (d'+e')	1945.88	2391.15	5187.83	3209.56	204.83
g'	Combined weight for CG	0.00	0.6071	2.4649	0.4364	0.00
h'	TSCCG [(a'-b')g']	0.00	31.14	274.27	0.00	0.00
i'	Net social cost to society (f'-h')	1945.88	2360.01	4913.56	3209.56	204.83
			Year 2			
a"	Financial cost	0.00	85.56	185.64	101.26	11.25
b"	Economic cost	0.00	59.89	129.95	101.26	11.15
c"	Combined weight for CL	10.3504	10.3504	10.3504	10.3504	10.3504
d"	SCCL1 (b"Xc")	0.00	619.91	1345.01	1048.08	116.44
e"	SCCL2 [(a"-b")c"]	0.00	265.67	576.43	0.00	0.00
f"	TSCCL (d"+e")	0.00	885.58	1921.45	1048.08	116.45
g"	Combined weight for CG	0.00	0.6071	2.4649	0.4364	0.00
h"	TSCCG [(a"-b")g"]	0.00	15.58	137.28	0.00	0.00
i"	Net social cost to society (f"-h")	0.00	870.0	1784.17	1048.08	116.44

Notes: 1. CL=consumption loss; CG=consumption gain; SCCL1=social cost of consumption loss; SCCL2=additional social cost of consumption loss; TSCCL=total social cost of consumption loss; TSCCG=total social cost of consumption gain.
2. SCCL1 is due to economic cost of the project; SCCL2 is due to increased consumption by the workers.

Table A9.1.3 Social cost of planting (FF component)

S.No	Costs	Material	Main worker	Subsidiary worker	Staff	Other expenditure
			Year 0			
a	Financial cost	0.1000	0.0852	0.1848	0.1196	0.0090
b	Economic cost	0.1000	0.0535	0.1161	0.1196	0.0090
c	Combined weight for CL	10.3504	10.3504	10.3504	10.3504	10.3504
d	SCCL1 (bXc)	1.0350	0.5537	1.2031	1.2379	0.0932
e	SCCL2 [(a-b)c]	0.0000	0.3280	0.7116	0.0000	0.0000
f	TSCCL (d+e)	1.0350	0.8817	1.9129	1.2379	0.0932
g	Combined weight for CG	0.0000	0.6071	2.4649	0.4364	0.0000
h	TSCCG [(a-b)g]	0.0000	0.0192	0.1695	0.0000	0.0000
i	Net social cost to society (f-h)	1.0350	0.8625	1.7434	1.2379	0.0932
			Year 1			
a'	Financial cost	0.1200	0.0978	0.2122	0.1449	0.0092
b'	Economic cost	0.1978	0.0978	0.2122	0.1449	0.0092
c'	Combined weight for CL	10.3504	10.3504	10.3504	10.3504	10.3504
d'	SCCL1 (b'Xc')	2.0473	1.0123	2.1963	1.4998	0.0952
e'	SCCL2 [(a'-b')c']	-0.8053	0.0000	0.0000	0.0000	0.0000
f'	TSCCL (d'+e')	1.2420	1.0123	2.1963	1.4998	0.0952
g'	Combined weight for CG	0.0000	0.6071	2.4649	0.4364	0.0000
h'	TSCCG [(a'-b')g']	0.0000	0.0000	0.0000	0.0000	0.0000
i'	Net social cost to society (f'-h')	1.2420	1.0123	2.1963	1.4998	0.0952
			Year 3			
a"	Financial cost	0.0000	0.0631	0.1369	0.0476	0.0084
b"	Economic cost	0.0000	0.0159	0.0345	0.0476	0.0084
c"	Combined weight for CL	10.3504	10.3504	10.3504	10.3504	10.3504
d"	SCCL1 (b"Xc")	0.0000	0.1646	0.3571	0.4927	0.0869
e"	SCCL2 [(a"-b")c"]	0.0000	0.4885	1.0599	0.0000	0.0000
f"	TSCCL (d"+e")	0.0000	0.6531	1.4170	0.4927	0.0869
g"	Combined weight for CG	0.0000	0.6071	2.4649	0.4364	0.0000
h"	TSCCG [(a"-b")g"]	0.0000	0.0287	0.2524	0.0000	0.0000
i"	Net social cost to society (f"-h")	0.0000	0.6245	1.1646	0.4927	0.0869

Notes: 1. CL=consumption loss; CG=consumption gain; SCCL1=social cost of consumption loss; SCCL2=additional social cost of consumption loss; TSCCL=total social cost of consumption loss; TSCCG=total social cost of consumption gain.
2. SCCL1 is due to economic cost of the project; SCCL2 is due to increased consumption by the workers. There was no cost at year 2 except weeding costs incurred by farmers.

Table A9.1.4 Discounted cash flow (SCBA), Farm Forestry, Plot 1A1

a. Operation and physical benefits

Total planted=1000; Total survived=513; Area, 0.4ha; Spacing, 2m x 2m.

	Year						
	0	1	2	3	7	8	9
Operation	Advance work	Planting & weeding	Weeding	Maintenance	Harvesting	Harvesting	Harvestin g
Benefits (physical)	1000 kg grass	1000 kg grass	2000 kg grass	-	P=20; FP=120; FW=0.83 m^3	P=20; FP=120; FW=1.0 m^3	P=300; FP=1880; FW=24.7 8 m^3

Key: P=poles; FP=fencing post; FW=fuelwood

b. Price of forest produce

Forest produce	Year			
	0, 1, 2	7	8	9
Grass (Rs/kg)	0.20	-	-	-
Fuelwood (Rs/m^3)	-	202.5	202.5	225
Fencing Post (Rs/pc)	-	13.5	13.5	14.4
Poles (Rs/pc)	-	23.4	24.3	27

c. Weights

Assumptions: CA-I; BF-I

Item	Weights for costs				Weights for benefits
	Planting costs		Harvesting costs	Weeding cost	
	Consum ption loss	Consumption gain			
Material	10.3504	0.0000			
Main worker	10.3504	0.6071			
Subsidiary worker	10.3504	2.4649			
Staff	10.3504	0.4364			
Other expenditure	10.3504	0.0000	1.6535	1.6535	1.6535

d. Costs

	Planting costs			Weeding cost[a]	Harvesting costs (Rs/pc, for P and FP and Rs/m³, for FW		
Year	0	1	3	1,2	7	8	9
Financial (Rs/plant)	0.4986	0.5841	0.256	0.1	P=3.83; FP=2.08; FW=17.23	P=4.5; FP=2.4; FW=19.3	P=4.5; FP=2.4; FW=19.3
Social cost (Rs w/plant)	4.97201	6.04567	2.36864	0.1654	P=6.32; FP=3.432; FW=28.43	P=7.425; FP=3.96; FW=28.43	P=7.425; FP=3.96; FW=28.43

Notes: 1. Calculations for social costs for planting operations are given in Table A9.1.3
2. Social costs for harvesting and weeding are calculated by multiplying 1.6535 (wt) in financial costs. [a]weeding costs is for two weedings.

e. Cash flow

Social discount rate = 0.0293

Year	Social cost (Rs worth)	Social benefit (Rs worth)	cash flow (nominal)	Inflating/deflating factor*	Cash flow (real)
0	4972.01	330.70	-4641.31	1.9761	-9171.58
1	6211.02	661.40	-5549.62	1.8674	-10363.19
2	82.68	661.40	578.73	1.7256	998.66
3	1215.11	0.00	-1215.11	1.6060	-1951.42
4	0.00	0.00	0.00	1.4955	0.00
5	0.00	0.00	0.00	1.3563	0.00
6	0.00	0.00	0.00	1.1925	0.00
7	565.00	3731.66	3166.66	1.0835	3431.13
8	656.84	3816.14	3159.30	1.0000	3159.30
9	10483.69	67376.92	56893.23	0.8995	51172.93
				NPV	24684.58

Note: * Inflating/deflating factors are based on Wholesale Price Index (India) of all commodities (average of weeks).

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