Participatory Multi-Objective Planning for the Management of Natural Resources

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Ph.D.
University of Edinburgh
1997

Dedication

to

Kusum & Shwetank

Abstract

The research study provides a participatory planning methodology appropriate for the management of natural resources. The major natural resources, agriculture, forest and community lands are considered. A large proportion of these resources are degraded or are in various stages of degradation. The past and the present management practices have been inadequate to maintain these resources for sustainable use. In this study, a planning process for the management of these natural resources is demonstrated by selecting a typical site which consists of six villages, with their resources, at Sohna in Haryana State of India. It involves different participants, namely the local people, Village Panchayats (village level elected administrative bodies) and the government agencies which are responsible singly or jointly for the management.

In the planning, the natural resources and the goods and services derived from them along with people, livestock and their activities are viewed as an interactive and inter-dependent 'whole system'. A systems approach has been used, beginning with detailed analysis of socio-economic and bio-physical major sub-systems of the selected site, which is followed by integration of different components of the sub-systems to achieve the specified objectives (environmental amelioration and social welfare) and goals (demand of food, fuel, fodder, timber and other minor products, employment opportunities and maximisation of income) through the use of mathematical programming techniques, namely goal and linear programming. Two alternative management scenarios - village level and community level - are presented and discussed. The salient features of this study are integration of the agriculture resource with the management of common and forest lands, hitherto all of them managed singly, a holistic view of management and the participation of stakeholders in the management process.

Acknowledgements

Much of the material in this thesis results from contacts and discussion with many people at various times during the last few years. I am specially grateful to my supervisors Professor J. B. Dent and Dr. J. Blyth for overall supervision and guidance throughout the period of research work; and Professor M. McGregor, who gave invaluable guidance in the initial years as co-supervisor.

Thanks are due to the Government of India and Government of Tripura, India for allowing me to pursue this study; to the Commonwealth Commission in the United Kingdom for providing a Commonwealth Scholarship to carry out this research work.

I also thank the people of the study villages and the personnel of the Haryana Forest Department, in particular Mr R.K.Singh, IFS, Divisional Forest Officer, for their co-operation and help in various ways to conduct the field study, and Dr. O. P. Yadav, soil scientist, Haryana Agricultural University for help in soil analysis.

I would also like to extend my gratitude to the staff and friends at the Institute of Ecology and Resource Management, University of Edinburgh and Scottish Agricultural College, Edinburgh for providing help in various capacities. Special thanks, however, are to Mr. Jim Wright, Michie Research Fellow for his sincere help in the application of Geographical Information Systems.

Finally, this work would not have been possible without the patient and selfless support of my wife, Kusum Yadav. For this, I will always be indebted to her.

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Abbreviations

CF	Conservator of Forests
CP	Compromise programming
CPR	Common Property Resource
FAO	Food and Agricultural Organisation
FD	Forest Department
FSI	Forest Survey of India
GC	General Caste
GIS	Geographical Information Systems
GOI	Government of India
GP	Goal programming
ha	hectare
HFD	Haryana Forest Department
ICAR	Indian Council of Agricultural Research
IE	Indian Express
LF	Large Farmer
LINDO	Linear Interactive Discrete Optimizer
LP	Linear programming
LPG	Liquefied Petroleum Gas
LUP	Land Use Planning
m	Million
MAUT	Multi-attribute Utility Technique
MCDM	Multiple Criteria Decision Making
MOP	Multiple Objective programming
MP	Management Plan
NBSS	National Bureau of Soil Survey
NCA	National Commission on Agriculture
NGO	Non-governmental organisation
NRDMS	Natural Resource Data Management System
NWDB	National Wasteland and Development Board
PF	Protected Forest

PFM	Participatory Forest Management
PRM	Participatory Resource Management
RAC	Resource Assessment Commission
RF	Reserve Forests
SC	Scheduled Caste
SF	Small Farmer
SFD	Sohna Forest Division
SOI	Survey of India
SPWD	Society for Promotion of Wastelands Development
TBU	Tropical Bovine Unit
VFC	Village Forest Committee
VFPC	Village Forest Protection Committee
VP	Village Panchayat
WB	World Bank
WBFD	West Bengal Forest Department
WGP	Weighted Goal Programming
WP	Working Plan

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Part I

India - natural resources and their management

Chapter 1

Introduction

Forestry, common and agricultural lands are the major natural resources of India. A number of direct and indirect benefits are available from them. People, especially the rural poor get food, fuelwood, fodder, timber and fruits. These resources also help in environmental amelioration, maintenance of the water cycle, biodiversity preservation, wildlife conservation, tourism, fishing, employment generation and so on. Agricultural and forestry resources have been subjected to various kinds of management practices while virtually no concerted effort has been made to manage common land, also sometimes referred to as community land. Management practices vary from time to time and also from place to place. Most often, management practices have been influenced by subsistence and commercial considerations of the people.

Agricultural land is mainly privately owned. The owners (farmers) are free to manage their land as they wish, but the management practices on agricultural land are influenced by governmental policy and market forces such as pricing policy of agricultural inputs and outputs, subsidies, extension, mechanisation, etc. The farmers tend to change in favour of economically profitable activities.

Forestry land is mostly under the possession of the Forest Department (FD) of the State Governments. The principle of sustained yield was applied in the past. The main aim of forestry management was to achieve production and protection goals set by the administrative bodies. In meeting these goals, biological, technical and economic considerations were given top priority (Rao, 1992). In recent years, it has been proposed that forests are managed through participatory management, which focuses on meeting the local needs and on ecological maintenance (GOI, 1990). The ownership of common land is vested mostly in the local level administrative bodies called Village Panchayats (VP). In the past, common land was used as a free access resource and no particular management system was applied though there has been half-hearted developmental intervention through social forestry. The VPs seldom took initiatives to manage common land properly, rather they concentrated on extraction of maximum outputs.

As a result of over exploitation, mismanagement or no management, most of the forest, agriculture and common lands are presently degraded. Traditional management practices have been found inadequate to sustain the productivity. The seriousness of the problem has compelled concerned people and authorities to develop suitable management practices for these lands of India.

Not much has changed with regard to agricultural land management as the predominant criterion of management remains profit maximisation. Under the prevailing circumstances, there seems little scope to influence the agricultural management practices. Fortunately, the situation is not the same in the case of forest and common lands. With the adoption of participatory forest management policy (GOI, 1990), there appears to be ample opportunity to change the management practice of forest and common lands in accordance to the local and national socio-economic and bio-physical environment.

1.1 Study proposal

As discussed above, most of the natural lands in India are degraded or are in various stages of degradation. One such land area which is severely degraded and deforested in India is the Aravalli mountain range which spreads along north and north-west India for over 1100 km. The Aravalli consists of hills and undulating plain lands. Until three decades ago the site had dense vegetation cover in which a variety of wildlife lived and water springs existed. At present, much of the vegetation, wildlife and many water springs have disappeared and there are severe problems of soil erosion, air pollution and moisture loss.

Increased demand of various products due to ever increasing human and cattle populations coupled with unplanned quarrying have accelerated the process of degradation and deforestation of the Aravallis. There is a scarcity of forest products. The shrinking resource base has in turn resulted in pressure on the surrounding agricultural land and also has had a long term adverse impact on the environment of the region.

The seriousness of the situation in the Aravallis, therefore, requires urgent attention to bring them under a suitable management system in order to stop further degradation, and also to rehabilitate the degraded areas for ecological balance and for the well-being of the local people. This study makes an attempt to evolve a suitable management planning strategy for the Aravallis.

1.2 Objectives

The objectives of the study are:

1. to explore means to sustain the supply of food, fuel, fodder, timber and non-wood forest products to the local people and to seek their active participation in the management of the resource;

2. to investigate methods to restore and maintain the site ecology without compromising the people's needs and aspirations;

3. to systematise quarrying activity in harmony with ecology and wishes of the participants; and

4. to examine land use options that will maximise income generation.

1.3 Research approach

For the purpose of developing a management planning scenario for the Aravallis, a site was selected near Sohna in Haryana State of India. This site was selected because it provided a typical representative locations of the Aravallis where the degradation is relatively faster, and where recently, the State Government and the Government of India have attempted to manage the area under a participatory management regime. The other considerations were availability of data, accessibility and work facilities.

The forest and common lands are surrounded by agricultural land. Six human settlements (villages) are situated on the study site. The villages are densely populated and possess a large livestock population. The villagers derive food, fuel, fodder, timber and many other minor non-wood products from these lands. They also use the site for livestock grazing and quarrying. Quarrying of quartzite stone is a major economic activity which provides employment to a large number of local people and many outsiders have a major commercial stake in it.

The various steps followed in this study to develop a management planning strategy for the selected site are illustrated in Figure 1.1. The detailed description of each step is given in the related chapters in the thesis. The emphasis of the research was more towards the study and planning of forest and common lands. Agricultural activities were restricted to those currently existing. These were integrated with the management of forest and common lands as all of them are closely related. The methodology proposed here considers the resources - land, people and livestock - and supply and demand of goods and services in totality to evolve management planning for the site.

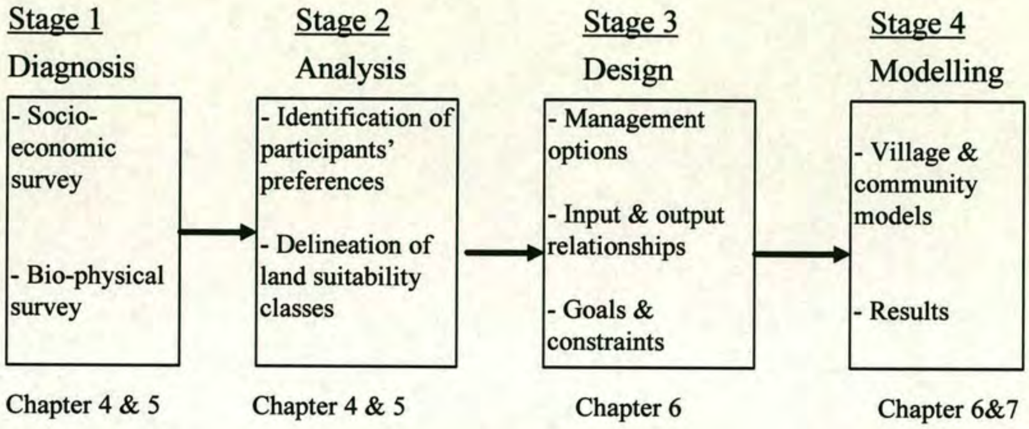


Fig. 1.1: Diagrammatic illustration of various procedural steps followed in the study

1.4 Layout of the thesis

The thesis is divided into three parts. Part I presents the basic outline of the natural resource situation and consists of three chapters. Chapter one sets out the research problem and its objectives followed by the work approach and outline of the thesis. Chapter two gives a general picture of India and Chapter three discusses the past and present management of agricultural, forest and community resources.

Part II of the thesis deals with analysis of the components of management considered in the study. Chapter four highlights the socio-economic environment of the study site along with the description of methodology used for socio-economic survey and the results. Chapter five presents a bio-physical survey of the study site.

It describes the procedure of classifying the forest and common lands through an application of Geographical Information Systems (GIS) and the land suitability classes are delineated for each village land.

Part III focuses on the development of management planning models and their application. Chapter six discusses the step by step development of mathematical models for villages and a community model for all the villages jointly. Chapter seven shows the application of mathematical models developed in Chapter six, and the results of the analysis of the models are presented and discussed. Chapter eight conclusions are drawn about the potential and limitations of the present study, and also includes some suggestions for future research.

Chapter 2

India: land and people

India is one of the oldest civilisations, with a diverse and rich cultural heritage. With an area of 3,287,782 km^2, it is the seventh largest country in the world. India is well marked off by mountains and seas which gives the country, a distinct geographical entity. Bounded by the great Himalayas in the north, it stretches southwards and at the Tropic of Cancer tapers off into the Indian Ocean between the Bay of Bengal on the east and the Arabian Sea on the west. The country comprises of 25 States and 7 centrally administered Union Territories.

2.1 Geographical features

Lying entirely in the northern hemisphere, the boundary of India extends from 8°4'28" to 37°7'53" north latitude and from 68°7'53" to 97°24'47" east longitude.

Physical features

The mainland comprises four distinct geographical regions, namely the Himalayas, the plains, the desert region and the southern Peninsula.

The Himalayas comprise three mountain ranges interspersed with large plateaux and valleys: the Greater Himalayas, The Lesser Himalayas and the Outer Himalayas (the Siwaliks). This region is fragile and prone to soil erosion and earthquakes. The ranges exhibit climatic regions ranging from tropical through sub-tropical, warm and cool temperate to alpine and arctic. Forest flora on the mountains changes with altitude and is marked by well defined zones of altitude.

The plains region is formed by basins of three distinct river systems - The Indus, The Ganges and The Brahmaputra. It is one of the world's greatest stretches of flat alluvium and also one of the most densely populated areas in the world.

The desert region can be divided into two parts - the great desert and the little desert. The whole of the Rajasthan-Sind Frontier runs through the great desert. The little desert extends from the Luni between Jaisalmer and Jodhpur. Between them lies a zone of absolutely sterile country, consisting of rocky land cut-up by limestone ridges.

The Peninsular Plateau is marked off from the plains by mountain and hill ranges varying from 460 to 1220 metres in height. Prominent among these are the Aravallis, Vindhya, Satpura, Maikala and Ajanta ranges.

Geological structure

The geological regions broadly follow the physical features and may be grouped into three regions: the Himalayas and their associated groups of mountains, the Indo-Gangetic plain and the Peninsular shield. The Himalayan mountain belt in north and the Naga-Lusai mountain in east was under marine conditions about 600 million years ago. The regions contain sedimentary and metamorphic rocks. The Indo-Gangetic plain are formed by alluvial river deposits. The Peninsula is a region of relative stability and of rare seismic disturbances.

Rivers

Rivers in India may be classified as the Himalayan rivers, the Peninsular rivers, coastal rivers and the rivers of the inland drainage basin. The Himalayan rivers are perennial as they are generally snow-fed and have a reasonable flow of water throughout the year. The Peninsular rivers are generally rainfed and, therefore, fluctuate in volume. A larger number of streams are non-perennial. The coastal streams are short in length and have limited catchment areas. Most of them are non-perennial subject to flash floods.

Climate

The climatic conditions of India vary greatly in different parts. The normal rainfall varies from less than 3" a year in south-west Rajasthan to 460" a year at Cherrapunji in Meghalaya. The rainfall pattern is actually changing over time. The frequency of floods and drought is increasing.

The rainfall is governed mainly by the monsoon, of which there are two: the south-west or wet monsoon and the north-east or dry monsoon. Of the two, the former is more important, bringing about 90% of the rainfall. The monsoon proper lasts from June to September (the rainy season), during which a greater part of India experiences rainfall. October to May is the dry period with occasional winter rains. The atmospheric humidity is highest in the coastal and hill regions amounting to almost super saturation in the rainy season and the lowest, almost zero, in drier regions during the hot dry season.

The ecology and climate of India are extremely varied. Various agro-ecological classification schemes have been adopted for different purposes. Singh (1987) identified eight agro-ecological regions. The Government of India (GOI, 1989) has classified the country into 15 agro-ecological regions on the basis of climate, soil type, topography, water resources and irrigation facilities. The All-India Co-ordinated Agroforestry Project of the Indian Council of Agricultural Research (ICAR, 1990) identified six agro-ecological zones. The National Bureau of Soil Survey and Land Use Planning has divided the country into 21 agro-ecological zones on the basis of temperature, rainfall, length of growing period and vegetation (NBSS & LUP, 1990).

2.2 Bioresources

India is the second most populous country in the world. It is rich in plant and animal species.

Population

Increases in population is a major problem in India. Most of the present day problems, such as unemployment, poverty, deforestation, etc. can be related to rapid increase in population. Table 2.1 shows the increase in population of India since 1901. The ratio of rural to urban population is slowly changing: the urban population increased from 10.8% in 1901 to 26% in 1991. While the proportion of the rural population is decreasing the overall size has, in fact, increased. This has caused tremendous pressure on the forestry, agricultural and common property resources for the supply of food, firewood, fodder, timber and various other products.

Table 2.1: Growth of human population in India from 1901 to 1991

Year	Population (million)	Decadal growth rate	
		Percentage	Absolute
1901	238.40	-	-
1911	252.09	5.75	+13.69
1921	251.32	-0.31	-0.07
1931	278.98	11.00	+27.65
1941	318.66	14.22	+39.68
1951	361.09	13.31	+42.42
1961	439.23	21.51	+77.68
1971	548.16	24.80	+108.92
1981	683.33	24.66	+135.17
1991	844.32	23.50	+160.99

Source: Census of India, 1991.

Livestock

Livestock numbers in India are high and as shown in Table 2.2 have increased over the past forty years. Demand for fodder has increased proportionately. The fodder mainly comes from agricultural residues, lopping of trees and grass. Cattle need grazing areas in addition to stall feeding. This causes tremendous pressure on forest and common lands. Grazing is considered as one of the major causes of damage to natural regeneration in forests.

Table 2.2: Livestock population in India 1951-1982 (in million)

Category	1951	1956	1961	1966	1972	1977	1982
Cattle	155.30	158.65	175.56	176.18	178.34	180.14	190.79
Buffaloes	43.35	44.92	51.21	52.95	57.43	62.03	69.00
Sheep	38.43	39.42	40.02	42.02	39.99	40.91	48.07
Goats	47.08	55.41	60.86	64.59	67.52	75.62	94.72
Horses and ponies	1.51	1.48	1.33	1.15	0.94	0.91	0.93
Pigs	4.42	4.93	5.18	5.04	6.90	7.65	9.58
Camels	0.63	0.78	0.90	1.03	1.11	1.07	1.03
Other livestock	1.30	1.10	1.15	1.15	1.11	1.21	1.82
Total	292.02	306.52	336.21	344.11	353.34	369.54	415.94

Source: NWDB, 1990.

Flora and fauna

With a wide range of climatic conditions, India has a rich and varied vegetation. It is estimated that there are about 45000 species of plants. The vascular flora, which form the conspicuous vegetation cover, itself comprises of 15000 species, of which 35% are endemic. The fauna comprises of about 75000 known species. Of these, 2500 are fish, 150 amphibians, 450 reptiles, 2000 birds and 850 mammals. The remaining species are invertebrates (GOI, 1994).

2.3 Land use

Most of the available land is intensively used. Major uses are cultivation, forestry, habitation and pastures (Table 2.3).

Table 2.3: Estimated area of different land uses in India

Land Use	Area (m ha)	% of the total area
1. Total Geographical Area	328.80	100
2. Forests	64.20	19.52
3. Not available for cultivation		
(i) Non-agricultural area	20.40	6.20
(ii) Barren/Uncultivated	20.10	6.11
4. Other uncultivated land excluding fallow land		
(i) Pastures/Grazing land	11.90	3.61
(ii) Miscellaneous crops	3.40	1.03
(iii) Culturable waste	15.70	4.77
5. Fallow Land	24,90	7.57
6. Agriculture	144.11	43.82
7. Area for which no return exists	24.09	7.32

Source: FSI, 1990.

2.3.1 Agriculture

Fertile land has, for thousands of years, been the single most vital resource. It was, and still is, the major source of wealth and basis of occupation in the Indian sub-continent. Agriculture occupies about half of the total geographical area of India. Growing crops for food, cash or fodder is the main activity on agricultural land. The net area sown to agricultural crops has increased from 118 million (m) ha (41.8% of the geographical area) in 1950-51 to 142 m ha (46.5%) in 1989-90 (Lele et al., 1994). The annual rate of growth of India's food grain production increased from 2.3% (between 1950 and 1966) to 2.7% (between 1967 and 1990).

2.3.2 Forest

Although the total recorded forest area is approximately 77 m ha (23.4% of geographical area), the actual forest cover is 64.20 m ha (19.52%) only (FSI, 1993). In fact, the forest area has decreased considerably in the last few decades mainly due to diversion of forestry land for non-forestry purposes.

Major forest types of India are shown in Appendix 2.1 (WB, 1993). Of the area under forest cover, tropical moist deciduous forest and tropical dry deciduous forest together constitute the majority (66%)of the area. 8% is tropical wet evergreen forest and 26% is subtropical, temperate, alpine and other forests.

A large part of India's forests are degraded. Only about one half of the forests have a crown density of over 40% and in many places forest cover has already disappeared. Although the data base is weak, it is believed that in the past, deforestation has been up to one million ha per year prior to 1980. Diversion of forest land has slowed down after the promulgation of Forest Conservation Act (GOI, 1980). According to the Forest Survey of India (FSI, 1993), the net loss of forest cover has reversed and, in fact, there is now an increase in forest cover as shown in Table 2.4.

Table 2.4: Change in forest cover (in km^2) 1991-1993

Category of forest	1991	1993	Difference
Dense forest (crown density 40% or over)	385008	385576	+568
Open forest (crown density 10-40%)	249930	250275	+345
Mangroves	4244	4256	+12
Total	639182	640107	+925

Source: FSI (1993).

With this brief general background of India in this chapter, the various management practices regarding agricultural, forests and common lands followed in the past and the present, and future policy implications are discussed in the next chapter.

Chapter 3

Natural resource management

In this chapter, various strategies and policies being followed in regard to the management of natural resources in India are briefly discussed. The discussion follows the broad categorisation of land into agriculture, forests and common lands on the basis of prevailing use and legal status.

3.1 Agricultural land management

Most of the agricultural land is privately owned and the owners stay on site and cultivate it. In some cases, however, the actual owners do not work the land but cultivate it through tenants or sharecroppers. The cropping pattern and the productivity of crops is greatly affected by State policy towards subsidies, prices of agricultural inputs and outputs and credit. In fact, over the last few decades there has been a clear change in production and cropping pattern because of such governmental policies. Since there are perceptible differences in the agricultural situation between the past and the present, it will be appropriate to discuss growth and change in agriculture in India before and after independence in the year 1947.

Pre-independence agricultural scene (upto 1947)

Access to the resources of land was a major determinant of social and political power in pre-independence India. Most farmers grew crops for their immediate needs or for limited barter in the vicinity in exchange for basic necessities. The actual crop varied from area to area, according to soil and climate. Where rainfall permitted, rice was the basic crop, as in Bengal or near southern coasts. In the drier areas wheat, barley, millet and maize were staple crops and staple diet.

A large part of the total land available in a village remained uncultivated which was controlled by the ruler of the area or the government through a village headman.

Anyone wanting to extend cultivation could apply to the headman, and obtain land for cultivation.

Except for the introduction of charges on land cultivation, no efforts were made to improve the agricultural situation in the country. Development of infrastructural facilities, research and increase in productivity remained negligible.

Post-independence agricultural scene

Immediately after independence, the Indian government began the task of improving agriculture and rural development seriously. Though there is no exact dividing year, the post independence agricultural scene can be further divided into three distinct phases: 1947 to 1965; 1965 to 1980; and post 1980.

In the first phase, the main thrust consisted of institutional and agrarian reforms as well as the expansion of the agrarian base. Land reform legislation was enacted in all the States in the first few years of independence. The land reform laws empowered the State to take the following measures (Rao, 1996):

i. abolition of intermediary tenures;
ii. reform of the land tenure system;
iii. a ceiling on land holdings;
iv. re-settlement of landless agricultural workers; and
v. consolidation of fragmented holdings and reorganisation of the small farm economy.

These reforms were implemented in some States while in others it has not been possible for various social, political and economic reasons. The implementation of the reforms left many gaps and the process of change initiated by them proved uneven and slow-moving compared to the policy-maker's expectations (Rao, 1996). Further, community development programmes were launched in 1952 with a view to changing rural attitudes towards modernisation in agriculture. Other areas of focus of the first phase were building co-operatives, creation of extension networks and improving rural infrastructure including irrigation. During this phase the government encouraged the importation of food grains to meet shortfalls.

The second phase in agricultural policies came about due to food crises and the realisation that continuing reliance on food aid imposes a heavy cost in terms of political pressures and economic stability. It emphasised the increase of food production. There was rapid spread of high yielding varieties of wheat and rice, particularly in fertile areas with copious irrigation. It gave a quantum jump in yields. The production of wheat increased from 10 m tonnes in 1965-66 to 26 m tonnes in 1971-72 and nearly 36 m tonnes by the late 1970s. Rice production went up from 31 m tonnes in 1965-66 to 47 m tonnes in 1971-72 and further to 54 m tonnes in 1978-79. During this phase, popularly known as the green revolution, imports of food grains decreased to negligible levels.

The spectacular success of the green revolution made the government turn to technology-based strategies to face the problems of agriculture and rural development. The area of irrigation increased, fertiliser consumption went up and use of high yielding varieties became popular with farmers. The new technologies also provided avenues for investment in agriculture and rural credit institutions expanded. Along with increasing preoccupation with agriculture, however, came diminished interest in agrarian reforms and institution building.

Unlike the first and the second phases of agricultural development which are easy to characterise, the third phase since the early 1980s, lacks direction for agricultural development. Agricultural production remained almost stagnant. But a new change can be felt in the rural areas. In the 1990s, with the economic liberalisation process, the rural sector is experiencing a widening range of economic activities, many of them non-traditional in nature. They are now contributing to rural growth. The new opportunities are characterised by value addition beyond primary production, employment with improved skill content and wages, growing contractual relations with corporate bodies engaged in land based production activities and a more rapid integration of rural producers and consumers with markets of the outside world. With the change in rural scenario, rural communities are trying to make major adjustments in agricultural management.

3.2 Management of common property resources

Common property resources (CPRs) include a wide variety of land resources. Their nature varies from region to region: sometimes being forests and watersheds, sometimes water points and irrigation tanks, sometimes community pastures. Their extent also varies from region to region (Jodha, 1987). A common resource has three characteristics (Blaikie and Brookfield, 1987). First, it is subject to individual use but not individual possession. Secondly, it has a number of users who have independent rights of use. Thirdly, the users together have the right to exclude others who are not members.

The present condition of common property resources in India should be viewed in a historical perspective. In the early eighteenth century, a part of the total land of a village used to be cultivated for food crops referred to as agricultural land, and the remaining land was referred to as uncultivated land. The uncultivated portion of the land was the common property of the landlord. The people could graze their cattle on this land but no cultivation was allowed. Based probably on this understanding, the colonial rulers in late eighteenth and early nineteenth century started settling land with groups or individuals in return for payment of annual income. The two systems adopted for land settlement were known as *ryotwari* and *zamindari*.

In the *ryotwari* system, the uncultivable land became government property in western and southern India while under *zamindari* system the uncultivated land became a part of a *zamindar's* (landlord's) property in eastern and northern India. There were some local variations, though, to take care of existing land use practices. When forest reservation began, the unoccupied land outside the villages was declared as government land, and then reserved under the provisions of the Forest Act.

The area of uncultivated land not categorised as forests either remained the property of government or as in some states, it was transferred to Village Panchayats, that is, the land came under community control. In the 19th century up to two-thirds of the land in India was under community control (Singh, 1986). Privatisation and government appropriation have been the two processes which have reduced this proportion to about 32% (Lele et al., 1994). During the last two decades much of the common land has been allotted to the rural poor.

Both forest and government (revenue) lands have historically been common property resources. Revenue lands comprise two categories: government wastes which are owned by the government but used by the community; and grazing lands which are vested in village bodies. There is little *de facto* distinction between the two categories, as both are used for grazing, and are generally considered as degraded. They are also referred to as common or community lands. Generally, Village Panchayats are legally in charge of these lands.

Unlike management operations adopted on land classified as forest land, there was no particular management initiative taken to conserve or manage the common lands. Traditionally, some local level controls were applied to protect these lands especially when the population pressure was not high. Most CPRs had become an open access type resource and were characterised by indifference and complete neglect on the part of the villagers (Jodha, 1989).

Some initiatives were made in recent years to revive CPR management, notably the social forestry programme (see section 3.2.1), and some progress has been made. Arrangements for CPR management vary from place to place depending on the CPR endowment and use. Specific local level arrangements were made to look after the CPR related issues. Some of the examples are: Van Panchayats in Uttar Pradesh hills, Hill Resource Management Societies in Haryana, Village Development Committees in Himachal Pradesh, Forest Protection Committees in West Bengal, Village Councils in Rajasthan and Gram Vikas Mandals in Gujarat. A number of non-governmental organisations (NGOs) have been established to help in the management of CPRs.

3.2.1 Social forestry

Social forestry was the largest single initiative directed to improve the condition of CPRs. Efforts were made to take up the programme in an organised manner following a report of the National Commission on Agriculture (NCA, 1976). The concept evolved during the seventies but the programme initially suffered due to a shortage of finances. The programme spread over the entire country on a large scale in the eighties when large amounts of institutional funds started flowing from various sources. A National Wasteland Development Board (NWDB) was created in 1985 to supervise and monitor the progress of the social forestry schemes being implemented in various States.

Social forestry has many components: farm forestry, village woodlots, strip plantations and rehabilitation of degraded forests. Of these components, only community woodlots are mainly concerned with CPRs.

Forest departments raise plantations on community lands in agreement with the local Village Panchyats and manage the woodlots generally for three years and then hand them over to the Panchyats for further management and harvesting. Local needs and people's participation are the underlying ideas in all the components of social forestry. In social forestry the technical demands are much different from the plantation programme in forest areas since the quality and the character of the lands being covered under social forestry are different. Apart from technological requirements, there are a variety of other issues which come up while demanding people's participation (Cernea, 1991). A large number of such issues are related with socio-economic realities of rural life, community structure, social equity, land and tree tenure rights, marketability of tree products, etc., are required to be addressed.

3.3 Forestry management

Principles of forest management in India have been changing since the time of their inception. The forests were under no management at one time, then they passed through a phase of consolidation and systematic management. Recently, a new system called 'participatory forest management' is being applied because of the inadequacy of the traditional management system. The control and ownership of forests has also changed hands over the time. Forest policies were framed and reframed.

3.3.1 Historical perspective

Three distinct phases can be discerned in the history of forest management in India.

Pre-colonial period upto 1800 AD.

The country had a great spread of forests in ancient times. The population was small and there was no pressure for products people needed from them. The forests were considered inexhaustible. Certain trees were declared as 'royal trees' by the rulers of the territories in which they flourished. With these few exceptions, however, forests were free for all, although they belonged to the ruler of the territory (Stebbing, 1926). The large tracts of forests and a relatively small population gave an impression of forests being an inexhaustible resource.

The colonial period (1800 - 1947)

This period witnessed rapid exploitation of forests both by the people and the government. During this period, control of forests was taken over by the government through a series of legal enactments, forest boundaries were demarcated and these were reserved. Vast supplies of raw materials for the railways, ship-building, defence and industry became the first priority to be met from the forests. Meeting the huge supplies for these purposes, the then government tried to manage the forests on certain principles and created an organisation, the forestry department, to carry out these functions.

A Forestry Commission was set up in 1800 to make regulations prohibiting the felling of young teak trees in Malabar forests. Unauthorised felling was stopped and royalty rights over teak (*Tectona grandis*) trees were established. A Conservator of Forests (CF) was appointed in 1806 to exploit the forests for timber for the Navy. The CF had wide powers to interfere with the established rights of local people and he largely eliminated their private rights on forest lands. Elimination of private rights resulted in spreading discontent among the natives. The post of CF was abolished in 1823 but again revived in 1847 due to the increased need of teak timber by the government. The first major policy document, known as 'The Charter of Indian Forestry' was issued in 1855. This policy paper laid down the rules and principles of management of state forests and contemplated that the timber standing in the forests was state property and people had no rights or claims on the trees.

Scattered efforts continued, but on an all India basis the first effective steps for the formation of a forest organisation were, however, taken in 1864 when one Dr D Brandis, a German, was appointed the first Inspector General of Forests to the Government of India (GOI). He initiated forest management on scientific lines. The first Indian Forest Act was enacted in 1865, which was subsequently replaced by the more comprehensive Indian Forest Act of 1878 and later by the 1927 Act. The Forest Acts provided for consolidation, demarcation and reservation of forests. The forests were classified into various categories such as Protection Forests (PF), Reserve Forests (RF), Village Forests and Tree lands. The ownership of the government was absolute in the RF with very few rights and concessions to local people which were recorded. The PFs were also under government control but in those, rights and concessions were given to local people in order to meet their bonafide demands for fuelwood, fodder and small timber. These changes brought an end to any community interference over forest resource except the Village Forests.

The RF and the PF were generally situated away from the centres of habitation and the established forestry management systems were applied on them. The Village Forests (a part of CPR) mainly catered for the needs of local people for forest products and also for grazing their cattle. Due to lack of proper management care most of the Village Forest areas deteriorated and became wastelands.

The post independence period (1947 - Till date)

The post independence era witnessed a further strengthening of the policies and procedures pursued during the colonial period. The legal provisions of State property were extended to forest areas that had been under private control.

The 1894 Forest Policy was replaced by the new Forest Policy in 1952. The new policy proposed the classification of forests into Protection Forests (PFs), National Forests and Village Forests on a functional basis. In the Forest Policy of 1894, public benefit was professed to be the sole aim of the forests and agriculture was given prime importance. In the revised Forest Policy of 1952, the emphasis shifted to national needs. Even though the new policy accepted the concept of Village Forests to serve the needs of local population, the operational emphasis remained on reserving the forests for national needs.

Since the formulation of the policy of 1952, the human and cattle populations have increased, demand for forest products has become manifold and the pressure on land in general is increasing. A National Commission on Agriculture was asked to look into the forestry situation in India (NCA, 1976). The Commission recommended the classification of forest land into protection, production and social forests. The protection forests were supposed to protect the land mass against erosion and degradation particularly in hills, river banks, sea shores, etc. The need of raw material for forest based industries was supposed to be met from the production forests. The social forests, comprising of wastelands, village and Panchayat lands, lands on the side of roads, canal banks and railway lines, would serve the needs of local people. The Commission stressed the socio-economic importance of social forestry in the rural community as well as in the management of forest resource.

The social forestry programme taken up in early 1980s was aimed at relieving pressure on conventional forest lands by taking up afforestation activities on available lands outside the designated government forest lands with the active involvement of people.

After independence, substantial areas of the forest land were diverted to agriculture and other developmental activities. An area of 2.623 million hectares of forest land was transferred to agriculture between 1951 and 1980 (GOI, 1987). To prevent the diversion of forest land to non-forestry purposes, the 1980 Forest Conservation Act was passed by the central government (GOI, 1980). This made it mandatory for state governments to obtain prior authorisation of the central government before conversion of forest land to non-forestry purposes.

In the light of the above developments the Forest Policy of 1952 was again revised in 1988 (GOI, 1988) to improve the forestry situation. The new policy document noted the supply of fuelwood, fodder and small timber for rural people as one of the basic objectives. Economic benefits and revenue earning became secondary. The potential role of social forestry and the symbiotic relationship between tribals and forests were strongly stated. The forests are to be managed to achieve social welfare.

Consequent upon the Forest Policy of 1988, the Government of India passed a resolution in 1990 which supports the involvement of village communities and non-governmental organisations (NGOs) in the regeneration, management and protection of degraded forests (GOI, 1990). It specifies sharing arrangements in which village forest communities that, "successfully protect the forests, may be given a portion of the proceeds from the sale of trees when they mature", as well as non-timber forest products for subsistence use. The changed system of forest management is often referred to as participatory forest management (PFM), which is discussed in section 3.3.2.

3.3.2 Participatory forest management

Participatory forest management involves management of forestry resources by the government agencies by involving local people with or without the assistance from non-governmental organisations. The following factors led to the adoption of a participatory approach for the management of forest resources in India:

(i) Continuous deforestation and degradation of forest lands: It has been estimated that prior to 1980, there was loss of up to one million ha of forest cover. The country lost forests at the rate 47500 ha per annum between 1987 and 1989 (FSI, 1989), though the subsequent survey showed a marginal gain of 28000 ha per annum during 1991-1993 (FSI, 1993).

(ii) Scarcity of forest products: There was widespread scarcity of forest products to the rural people in many areas and the inability of the Forest Departments to meet the demand and to protect the remaining forests. The imbalance of supply and demand (Table 3.1) is brought out clearly in the estimates of the Forest Survey of India (FSI, 1987).

Table 3.1: Supply and demand of forest products in India

Product	Estimated demand	Silviculturally available biomass	Gap
Fuelwood	230 m m^3	40 m m^3	190 m m^3
Fodder	882 m ton	434 m ton	448 m ton
Industrial timber	27 m m^3	12 m m^3	15 m m^3

Source: FSI, 1987.

(iii) Success of participatory experiments: Realising the need to involve local people who derive benefits from these forests, some foresters in the Indian states of West Bengal and Haryana started experimenting with new approaches to forest management based on local people's participation (Palit, 1991; Kala, 1992; SPWD, 1992b). Success of these and other such experiments in the States of Gujarat, Orissa and Jammu and Kashmir and elsewhere in the world showed the effectiveness of people's participation in natural forest management.

(iv) Media campaign: Environmentalists, social scientists, ecologists, NGOs and other influential persons blamed the strict custodial policies of the government for forest degradation and deforestation. They emphasised the importance of socio-economic factors of the rural communities in resource management (Kulkarni, 1983; Agarwal, 1986).

(v) Conflicts and people's movements: Commercial management of forests often came into conflict with the interest of the forest-dependent people which effected the health of the forests and also lead to strained relations. During the 1970s the people on their own initiative started protecting forests in several parts of the country.

Fourteen States have already adopted the participatory forest management approach (SPWD, 1992a). Table 3.2 presents the essential differences between traditional and participatory forestry management approaches.

PFM is intended to reverse the old top-down policy of managing India's public forests which has been in place for nearly a century. Interventions in farm forestry and common property resources tended to emphasise monoculture plantations by seedling distribution by forest departments (Lele et al., 1994). PFM, on the other hand, gives greater responsibility to local communities for the management, protection and development of public forest in partnership with forest departments. In return, it allows an increased share of benefits from the land to the local groups. PFM is geared to provide for the subsistence needs of the local communities while regenerating and maintaining the natural forests on a sustainable basis.

Table 3.2: Comparison between Conventional and Participatory forest management

Conventional management	Participatory management
Centralised management (by FD)	Decentralised management (by FD, VP and/or NGOs)
Revenue orientation	Resource orientation
Focus on production	Focus on sustainability
Pre-set products (mostly timber)	Need based multiple products with biodiversity conservation
Large working plans	Micro plans
Unilateral decision making (Top-down approach)	Participatory decision making (Bottom-up approach)
Punitive rules	Self-denial rules
Control orientation	Facilitative orientation
Assured homogeneity	Recognised diversity
Area management	Site specific management
Single technical package	Management options
Fixed procedures	Experimentation and flexibility

Source: SPWD, 1992b.

There are various issues concerning both the concept of participatory forest management and the implementation of the programme. These are discussed in the following paragraphs.

Silvicultural

In PFM, the thrust of the programme has shifted from maximising commercial timber output and generation of revenue from forest resources to subsistence requirements of the tribal and the poor who live in and around forest areas. The shift in the silvicultural practices will be in the direction of providing fuelwood, fodder, non-timber forest products and small timber to the local people. Multi-purpose tree species will have to be included in the plantation programmes.

Social and cultural

The social and cultural diversity in the States of India and in different regions within a State requires flexible and site-specific responses. A plan is required for equitable distribution of benefits. Equal opportunity must be provided to all members of the society. There is every chance that in a heterogeneous social milieu charged with political leanings, the target group may be ignored.

During the process of PFM, forest areas are most likely to be closed for grazing and collection of forest produce. Some people who use these areas either for grazing or collection of fuelwood, minor forest products, etc., will no longer be able to do so in the new set up. How to provide alternative sources to those who suffer disproportionately from lost access and income from forest when these areas in early years of regulation are strictly closed for regeneration and establishment.

Ecological

An important cornerstone of PFM is a continuous flow of direct (biomass) and indirect (soil and moisture conservation) benefits to the local communities. There is a danger that PFM may lead to over exploitation leading to adverse ecological consequences. For example, the practice of the ten year rotation for harvesting of Sal (*Shorea robusta*) poles in the PFM areas of South West Bengal has been considered ecologically bad because of over-exploitation. Similarly, the practice of sweeping forest floors for dry leaves and twigs for energy biomass (permitted under existing rules) can have deleterious effect on soil productivity over a period of time. In this context, there is a need for modifying forest management practices to bring them in line with ecological appropriateness. This would call for greater understanding and care of ecological issues in PFM.

Political

Without a serious political commitment, it is virtually impossible to have a meaningful participation of people in management and protection of forests. The political force at the local level is the Village Panchayat. There can be various issues related to this. Most of the PFM arrangements have an interface with Panchayats through 'Forest Protection Committees'. This interface between PFM and Panchayats needs to be studied closely. It will be inappropriate to consider the participation of elected representatives of Panchayats and Protection Committees as being a substitute for common people's participation in forest management. Concentration of all the functions in Panchayats and Committees may deprive a number of people who are not elected political members. This issue has to be given thought to ensure common people's participation.

Economic factors

Questions about the cost of plantations verses natural regeneration, valuation of non-traded goods, revenue importance of some non-timber forest products to people, particularly the poorer sections of the society, etc. should be addressed with priority.

Legal and administrative

The provisions of PFM are not enforceable in a court of law. Their validity in relation to the Indian Forest Act, 1927, recorded rights of various communities in different forest lands, monopoly rights of State agencies in certain non-timber forest products is not clear. The administrative procedures to deal with the new management system and conflict resolution are not yet in place. Once the PFM programme is extended beyond degraded forest areas, it will be necessary to harmonise the provisions of the existing PFM resolutions with these changes. In this context, it is necessary to review the existing laws and status in the light of the mandate of the National Forest Policy of 1988.

Land production capabilities

Much of the forest soils on which PFM is envisaged to be practised at present are degraded. This gives rise to the suspicion whether the sustainability, in biomass terms, of the forests is compatible with the economic and social sustainability of the populations which are sought to be engaged in PFM agreements. Expectations from PFM may be high. In the event of expectations unfulfilled in the long run, there is chance of indifferent attitude on the part of communities.

3.4 Developing an optimal resource management system

In India, though, the food grain production, which was 72 m tonnes in 1965-66, rose to 191 m tonnes in 1995-96 (Kumar and Mathur, 1996), there seems no further improvement and future growth in production can only be input-based in many regions of the country. Much of the agricultural land is degraded and exhausted due to over-exploitation. Forest cover has marginally improved, but overall forest land has degraded. Measures adopted for the improvement of common lands have not been very successful. Land impoverishment coupled with increased demand to produce more from it, might result in further degradation.

In view of the deprivation and further degradation of the agricultural, forest and common lands, it becomes important to adopt measures for conservation and efficient use of these land resources. The management of these resources would entail careful understanding of different issues pertaining to them. Management issues generally involve interactions between social, economic and ecological systems; management goals and objectives, on the other hand, are often conflicting. There is a possibility of developing appropriate management systems by taking a holistic view of these resources vis-à-vis the local and national demands (Naveh and Liebermann, 1983; Savory, 1988; O'Callagham, 1995; Yadav et al., 1996). The management systems have to be socially acceptable, ecologically stable and economically viable (RAC, 1992; Jimenez-Osornio, 1994; Wyant et al., 1995). Development of such a management system will require integration of various bio-physical and socio-economic parameters related to the land resources (Syers et al., 1996).

In recent years, participatory approaches to land resource management has been emphasised as an alternative to maintain and improve the natural resources (WBFD, 1989; GOI, 1990; Poffenberger et al., 1990; Kant et al., 1991; SPWD, 1992b; Yadav, 1992; Yadav et al., 1993; Yadav et al.; 1995; Syers et al., 1996; Kothari and Vania, 1997). Agroforestry approaches can be part of the management plan as they have been found suitable to tackle most of the issues associated with optimal management of resources (Wiersum, 1982; Michon et al., 1983; Fernandes et al., 1984; Altieri and Liebman, 1986; Hoekstra, 1987; Srinivashan and Caulifield, 1989; Wannawong et al., 1991; Yadav et al., 1991; Nair, 1993; Yadav and Blyth, 1996).

This study makes an attempt to develop a participatory planning methodology for the management of forest and community land by integrating it with the management of agricultural land with the following hypotheses:

1. Degradation of the land resources in India is a reality. The existing management practices are inadequate to address the problem of degradation.

- It is possible to develop a suitable management planning system for the natural resource which can help to restore or improve and maintain the (site) ecology and biodiversity (of the area) without affecting the supply of forest and non-forest products to the local people.

2. A participatory approach to natural resource management is more likely to be successful.

- It is possible to include participants' (local people and others) needs, preferences, attitudes and perceptions in the planning and decision process.

3. A sustainable management system can be presented with enhanced income.

For the purpose of developing a participatory planning system, this research study takes into account various socio-economic and bio-physical issues associated with the management of natural resources in India which also include agroforestry interventions. The following chapters in this thesis describe a potential planning methodology step by step for a site selected for the purpose. Because of resource limitations on the researcher, a full participatory approach was not possible. With greater resource availability, interaction between the local people and the output from the planning methodology would have been possible and desirable. Alternative development options generated by the methodology would ideally have been the basis of such an on going debate.

Part II

Components of management

Chapter 4

Socio-economic framework

Profiling and assessment

In this chapter, the socio-economic environment of the study site is described. In the beginning, it gives a general picture of the social and administrative structure in India followed by more specific description of the socio-economics of the site. The later part of the chapter deals with assessment of the social and economic attributes relevant to the management of the site resources. The methodology of assessment and the results are also presented.

4.1 Need for socio-economic planning

Participatory management of natural resources is concerned with bio-physical principles and socio-economic objectives. The management should be ecologically and economically sound and at the same time it should take care of people's needs and sentiments. Fulfilment of the needs of the local people is the primary objective of management while commercial exploitation becomes a secondary objective in participatory management.

Success of any management programme depends on the social acceptability of the programme. Experience shows that one of the greatest causes for the failure or under performance of many schemes devised for the management of resources in India was the non-cognisance or non-inclusion of socio-economic issues related to the local populations (Sen and Das, 1987; Arnold and Stewart, 1989; Hudson, 1991; Cernea, 1992; Khanna et al., 1992). Many of the socio-economic issues, which were overlooked during the planning process, later became constraints or limiting factors to the successful implementation.

The need for planning socially oriented resource activities is now widely recognised (Bamberger, 1986; Colby, 1990; World Bank, 1991; Guggenheim and Spears, 1991;

Koch and Kennedy, 1991; Cernea, 1992; Dhar, Gupta and Sarin, 1992). Within an agro-ecological zone, a given management plan may be adopted at a differing rate and intensity due mainly to the differing socio-economic and cultural attributes. The greatest importance of assessing and incorporating socio-economic and cultural views and values in the participatory management lie in their efficacy of making a economically and ecologically sound management plan which is adaptable and is capable of being properly implemented.

Designing resource management programmes around socio-economic and cultural factors requires two fold action. Firstly, planners have to understand societal structure and secondly, society's needs, values, preferences and attitudes have to be assessed. The following paragraphs deal with these two issues.

4.2 Community structure in India

In a heterogeneous society as in India, people of different beliefs and affiliations interact with each other for individual gains and also for communal causes. The interactions may be smooth or unpleasant depending on the need and the customary modes of behaviour of the constituents of the community. These interactions are very important in participatory management of resources, in particular for common property resources.

4.2.1 Social heterogeneity

The Indian situation has been described as unity in diversity. Society in general is a congregation of people belonging to different religions, castes, professional and economic groups. In ancient times, society was divided into five groups, namely *Brahmanas* (priest group), *Kshatriyas* (military group), *Vaishyas* (merchant and agriculture group), *Sudras* (labour group) and *Achhutas* (untouchables). This old system still casts its shadow on present day society. Often, the line of distinction between the different groups is quite rigid but signs of its dilution are visible with economic and educational advancement.

Population clusters, stratified into groups and sub-groups show differing interests towards the management of resources. For instance, poor households are much more dependent on products from common lands than are better-off households (Jodha, 1986). What is an advantage for one group is not necessarily advantageous for another group. The widely different interests, views and perceptions of groups and sub-groups preclude the kind of collective unified action required for participatory resource management. In order to enlist participation of these groups and sub-groups, a management plan has to incorporate many diverse social values associated with the different social groups.

4.2.2 Factors of community grouping

Social relationships within a community are a fundamental part of social life. The relationships are directed by certain factors which provide the basis for individual and collective actions in the community. These factors help to explain the causes of social conflict and social cohesion (Taylor et al., 1990). The social relationships among members of a community can be related to historical, political, economic and ecological reasons. Some of the socio-economic factors relevant to the management of natural resources in India are briefly described below.

Religion

Followers of Hinduism, Islam, Christianity, Sikhism, Buddhism and Jainism can be found living in the same area or a village. The proportions of the main religious communities in India are: Hindus, 82%; Muslims, 12%; Christians, 3%; Sikhs, 2%; Budhists, 0.7% and Jains, 0.5%. They all have economic and ecological interests in the natural resources. In addition, some of them, particularly Hindus have spiritual relationship with certain trees and animals. They worship pipal (*Ficus religiosa*) and khejri (*Prosopis cineraria*) trees and 'the cow'. The spiritual values play a great role in deciding to plant or fell a particular species. Religious cohesion can be a strong force in collective working for the management of common resources.

Caste

The Constitution of India recognises three broad caste groups: General Castes, Backward Castes and Scheduled Castes. Caste considerations are very important in localities where people of two or more castes live together. In a locality where only one caste is found, economic status is an important factor.

Ethnicity

An ethnic group is a sub-caste of the larger society, having distinct cultural tradition and a sense of common identity (Nobbs et al., 1980). This factor has significant influence in certain parts of India.

Kinship

Kinship is a strong basis for social relationship in society. India has a long history of regions and small territories being governed by certain clans. Some have strong family bonds. This is more prominent in traditional and relatively well-off families. It is of particular interest in areas dominated by one caste.

Occupation

Persons from the same occupation such as farmers, teachers, industrial workers and traders tend to align together. They express similar ideas. For instance, those who are involved in timber trade irrespective of other affiliations, will prefer plantations of commercial timber species; graziers will go for pastures and plantation of fodder species.

Gender

In certain localities men and women differ in their views on management. In areas where women have to travel long distances to collect fuelwood, they will emphasise the planting of fuelwood species while male members may be driven by economically important species.

Land ownership

Some individuals own large areas, some have marginal lands and others are without land. Possession of land by individuals and households defines their views and actions. It is also an important yardstick of economic and, thereby, social status in the Indian countryside. Dependence of people on the common resources will depend on land area available to them. In fact, most of the landless people and marginal farmers depend on forest and other common lands and they also provide the major workforce for forestry and agriculture activities.

4.3 Social actors in resource management

Social actors in participatory resource management can be categorised into the following groups-

Government agencies

The most relevant government agency in the present context is the Forest Department (FD). The FD has a well established infrastructure, and trained and experienced staff. There are defined rules and regulations for the execution of forestry activities. Planning and instructions flow from top to bottom. The staff at various levels may have different perceptions and understanding because of different levels of education and backgrounds. The background at lower levels tends to be uniform because they generally come from the same locality or region while at higher levels in the administration the staff are from different regions of the country and have more exposure of forest management practices in other regions.

In addition to the FD, other government agencies are Agriculture Department, Animal Husbandry Department, Block Development Office, Horticulture Department, District Rural Development Agency and Forest Corporations. All of these agencies have their own vested interests and views on the use of resources.

Leaders

Elected leaders such as Members of Parliament, Members of Legislative Assemblies and Village Pradhans have their own ideas and interests. These politicians and their associates strive for the control of local opportunities for patronage, mainly for economic and political gains. They influence decisions to a great extent.

Villagers and their organisations

Various socio-economic and ethnic groups mentioned elsewhere in the preceding paragraphs are important actors in the participatory management of forest and common lands. Village organisations such as Village Panchayats and Village Forest Protection Committees (VFPC) are specifically convened for forest protection. The VP is going to be the principal agency for development and social reforms in India (IE, 1995).

Non-governmental organisations

A large number of Non-governmental Organisations (NGOs) have formed under assistance from different sources. They are mostly involved in extension and educational activities. In fact, they remain in direct touch with the local people and are very effective in motivating them. At times, they come into direct conflict with government agencies.

4.4 Socio-economic framework of the study site

The site selected for developing participatory planning is representative of the Aravallis (refered to section 1.3) in physical, social and economic terms. Ownership and control of the site land is shown below.

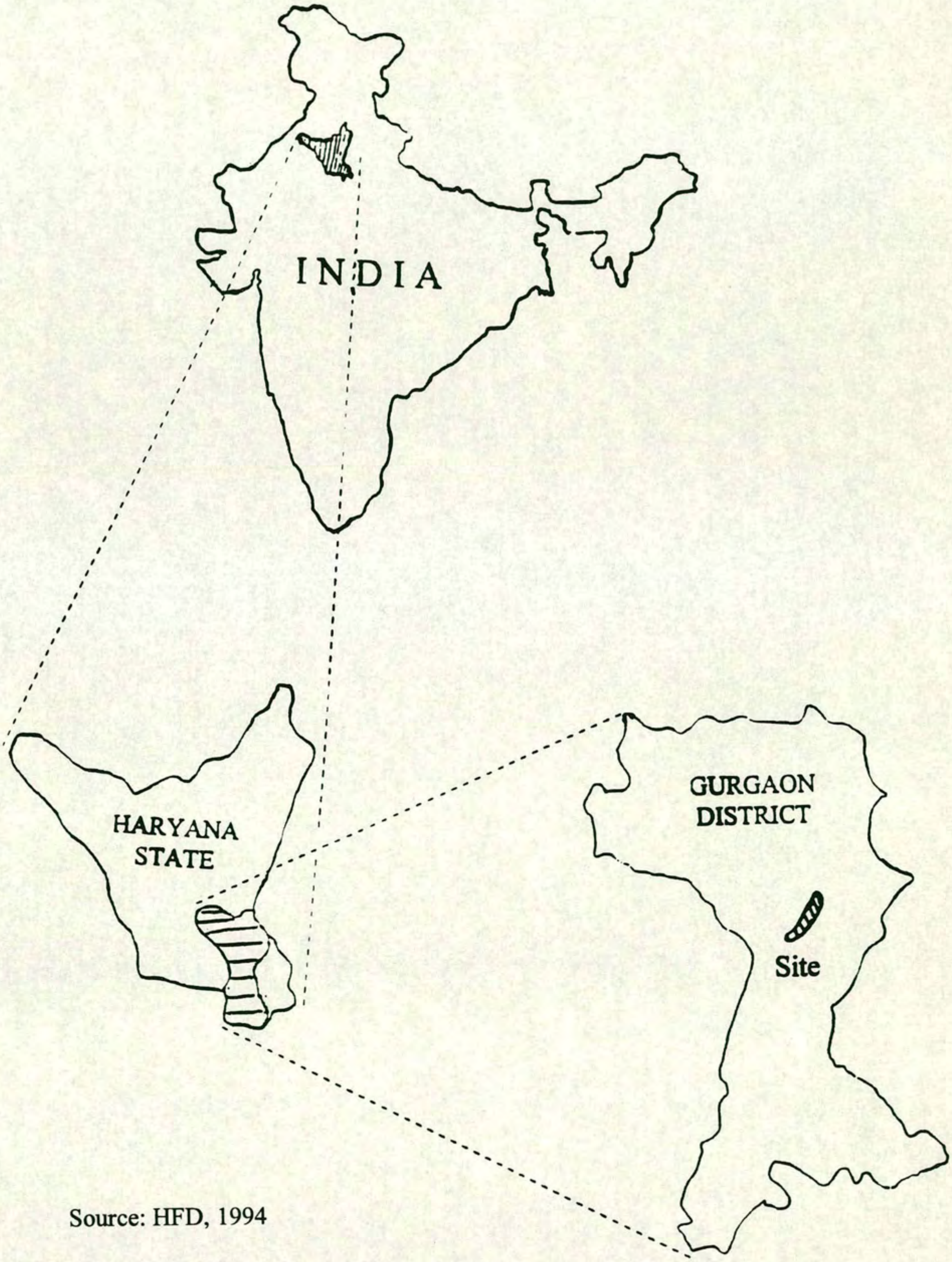
(i) Panchayat owned common land	635.00 ha
(ii) FD owned Reserve Forest land	69.00 ha
(iii) Privately owned agricultural land	2649.50 ha

4.4.1 Spatial features

The location of the study site is shown in Figure 4.1. The population of the study area reside in six villages (Figure 5.2, page 71). On south-eastern, eastern and northern sides are the villages of Khod, Mahrola, Rojka, Raipur and Sohna and village Sehsola is on the western side. The village Sehsola is made up of five settlements namely, Bhutlaka, Kiruri, Pipaka, Ghusbathi and Patuka. Rojka has a small settlement near it called Baika. Every village is connected by a metalled road and through a criss-cross of non-metalled paths. Information on infrastructure, markets, services, etc. in different villages is shown in Appendix 4.1.

The site area falls into a particular socio-political region, called Mewat, of the Haryana State. Mewat has been declared as a backward region by the State Government. Such a declaration provides for all round speedy development in the area through incentives for setting up industries. One such industrial estate is on the eastern side of Rojka where the state government has developed basic infrastructure facilities like external electricity, roads, public health service, etc. Already, some small and medium scale industries have established in the region. At the northern end of the site, the government has developed a beautiful tourist complex. A large area of land has been purchased by a private developer with a view to develop a residential colony and farm houses. Some farm houses are already in place adjacent to the site in the western side. There are two scientific installations namely an Antenna Test Site and a Radio Microwave Tower on the site.

Fig. 4.1: Location of the study site



Source: HFD, 1994

4.4.2 Administrative set up

The state of Haryana is divided into 16 districts. Gurgaon is one of the districts. It is further divided into sub-divisions and developmental blocks. The study site is a part of three development blocks of the Gurgaon district (Table 4.1). The sub-divisions make the basis for planning and implementation of development schemes. For the purpose of civil affairs such as law and order, revenue collection, land records, etc., the district is divided into tehsils (revenue regions).

Table 4 . 1: Site Villages and their locations

Name of the village	Name of Development Block	Distance from Development Block (km)
Khod	Nuh	15.0
Marola	Nuh	17.0
Rojka	Nuh	18.0
Raipur	Sohna	3.0
Sohna	Sohna	1.0
Sehsola	Taoru	15.0

There is a special 'Mewat Development Board' for the Mewat region. This agency was created with the objectives of ameliorating the conditions of poverty, unemployment, economic and social backwardness and raising the standard of living of the people in the region.

Of the two main relevant agencies involved in the management of forest and common lands of the site, the FD is represented by a divisional office and three range (a sub-region of a forest division) offices. The divisional office located near village Raipur (Figure 5.1) has been specifically established under a special project of the FD to rehabilitate the Aravalli hills through participatory afforestation.

The Village Panchayat (VP) consists of many members. The members and the head are democratically elected by the eligible village voters. The Scheduled Castes and women have special reservation to become members of the Panchayats. The VP can take decisions relevant to the welfare of village. It is the sole owner of the common land in the village. In the management of common and forest lands, the VP is supposed to play the role of a partner in planning, execution and benefit distribution. For this purpose a specialised agency called the Village Forest Committee (VFC) in the VP has been formed.

4.4.3 Population

Growth and backwardness

The human population of the six study villages is given in Table 4.2. The population growth of the villages is higher than the growth rate of the district and of the state (Table 4.3).

Table 4.2: Human population of the site villages

	Population		Caste		Religion	
	Male	Female	General	Scheduled	Muslims	Hindus
Khod	229	184	385	28	385	28
Marola	241	203	444	-	444	-
Rojka	763	621	1359	25	1354	30
Raipur	489	444	901	32	-	-
Sohna	907	811	994	724	-	-
Sehsola	2180	1835	3617	398	3594	421
	54.3%	45.7%	86.5%	13.6%	92.3%	7.7%

Source: District Statistical Office, Gurgaon (1994).

The people of the research villages are historically and culturally important but economically and educationally backward. They lag behind on almost every yardstick of development. Poverty and illiteracy are main reasons for their backwardness. About two-third of the people live below poverty line. Relatively low level of literacy in the study villages (Table 4.3) can be attributed, to a certain extent, to ethnic and socio-cultural factors. Women are not encouraged to take formal education particularly among the Muslims. Also most prefer to send their children to community teaching places to receive religious education.

Table 4.3: Comparative demographic variables

Unit	Decennial population growth rate (%)	Literacy (%)			Percentage of Schedule Caste population
		Male	Female	Total	
Haryana State	27.4	69.1	40.5	55.8	19.7
Gurgaon District	32.7	67.9	34.9	52.6	13.6
Study Villages	35.5	36.1	11.3	24.7	13.6

Source: Census of India, 1991.

Community groupings

The population of the villages is organised into various socio-economic groups. These groups based on religion, caste, occupation, land holding and sex are described in brief below.

Religious Groups: Two religious communities, namely Muslims and Hindus, live in these villages. The Muslims are in majority in Khod, Marola, Rojka, Raipur and Sehsola villages while the Hindus predominate in Sohna. The ratio of the Muslims and the Hindus in the site villages (Table 4.2) differs from their ratio at the national level (refered to section 4.2.2, page 31) because these villages fall into the Mewat region of the country which is dominated by the Muslims.

The Hindus differ from the Muslims in their traditions and outlook. They observe different festivals and marriage rituals. There is a tendency on the part of the Muslims to send their children to places where they can get religious education. Regarding the management of common and forest lands, the Hindus tended to be more enthusiastic to manage these lands than the Muslims.

Caste Groups: Two caste groups namely Scheduled Castes (SC) and General Castes (GC) are present in the study area. Their ratio in the villages follow more or less the district pattern (Table 4.2).

Occupational Groups: According to the 1991 Census of India, the population has been divided into main workers, marginal workers and non-workers. 25.36 per cent of the population of the research villages has been enumerated as main workers (Appendix 4.2). Of the main workers 42.30 per cent are engaged in agricultural activities which include cultivators and agricultural labourers. About 32.56 per cent of the main workers are engaged in various types of non-agricultural activities such as mining and quarrying, livestock, forestry, manufacturing, construction, trade and commerce, transport and communications. The rest of the main workers are employed either in services or in non-industrial activities. The proportion of people without work is very high (67.20%).

Landowners: Available private land is unevenly distributed among the residents of the villages. The FD differentiates population groups into large farmers (>4 ha), small farmers (2-4 ha), marginal farmers (<2 ha) and landless people. On the basis of available data of three villages, the proportion of large farmers, small farmers, marginal farmers and landless is 14.33%, 20.61%, 32.96% and 31.60% respectively.

Gender: Population of males and females in the villages is 54.30% and 45.70% respectively. Though the women have very little say in affairs outside the household it was still thought important to obtain their views for a number of reasons. Almost all the fuelwood and fodder collection is done by the women. Very few women are literate but with the recent government policy of reserving thirty per cent of seats in the Village Panchayats for females, their role is bound to increase in future in planning and decision making.

4.4.4 Economic activities

The main economic activities in the villages are agriculture, livestock rearing and quarrying. Some people are involved in the industrial and service sector too.

4.4.4.1 Agriculture

Crops

There are two main cropping seasons, namely 'Kharif' and 'Rabi'. Kharif is from June-July to August-September and the Rabi season spreads from October-November to March-April. The Kharif crops depend almost entirely on rain water. The main crops are pearlmillet (*Pennisetum typhoides*), jowar (*Sorghum bicolour*) and guar. Oilseeds and some pulses are also grown. The Rabi crops depend on soil moisture supplemented by some winter rains and irrigation. Mustard (*Brassica campestris*), a cash crop, is extensively grown in this season and to a lesser extent wheat is also grown where good water is available. A small area is cultivated for barley, gram (*Cicer arietinum*), rice and oilseeds and vegetables.

About half the land under agriculture is rainfed because good quality irrigation water is not sufficiently available in the area. The main source of irrigation is through tube-wells although canal water is available in some parts of Khod and Marola villages. The water table fluctuates according to the season around a depth of about 10 metres. Mostly the water is saline and not good for crops except in some areas near the foothills. Rainwater either gets collected in ponds in the site area or inundates low lying areas. This water percolates into the soil or evaporates within two to three months after the rainy season is over.

Farm trees

Trees on farm fields are few and sparse. Some of the tree species observed on farms are kikar (*Acacia nilotica*), neem (*Melia azadirackta*), siris (*Albizzia lebbek*), jand (*Prosopis cineraria*), beri (*Zizyphus jojobu*) and shisham (*Dalbergia sissoo*).

Productivity

Production of crops in the Mewat region is low in comparison to crops in other areas of the district. There are many handicaps to agricultural production in Mewat region. Some of them are lack of proper and adequate irrigation water, poor rainfed conditions (rainfall being erratic and inadequate), deficiency of micro- and macro-nutrients in the soil, low fertiliser application per unit area (30 kg/ha as compared to 55 kg/ha for the rest of the district); a low rate of adoption of newer technologies (partly due to lack of extension staff and higher costs of seeds and machinery), problems of salinity and alkalinity; poverty and illiteracy and fragmentation of land.

Historical changes in agriculture

The agriculture pattern and farming process has changed over the years. Recent extension of irrigation facilities has helped in changing the cropping pattern in favour of oil seeds, fodder, fruit trees and vegetables. Some farmers have adopted modern techniques of farming such as tractors in place of bullocks, using motorised threshers in place of traditional methods for grain separation. Although no definite data are available, there is an increase in net area sown, the use of chemical fertilisers and the use of improved varieties of crops since 1970s.

4.4.4.2 Livestock

Composition

Livestock are an integral part of the local village economy and ecology, comprising cows, buffaloes, goats, sheep, pigs and camels (Table 4.4). The majority of the households maintain some form of livestock. In recent years, a change in the composition of livestock is seen in favour of stall-fed animals, particularly buffaloes and a reduction in the number of free ranging animals, viz., sheep and goats and less productive cows of nondescript breeds.

Table 4.4: Livestock composition in site villages

Village	Cows	Buffaloes	Camel	Sheep	Goat
Khod	63	56	-	-	26
Marola	55	143	10	-	400
Rojka	138	138	6	200	50
Raipur	91	128	-	67	-
Sohna	672	754	18	280	417
Sehsola	1356	1340	11	87	268
Total	2375 (35.1%)	2559 (37.8%)	45 (0.7%)	634 (9.4%)	1161 (17.1%)

Source: NRDMS (1994).

Use

Most of the households keep livestock in order to meet their milk needs and to supplement their income from the sale of milk/milk products surplus to their needs. In addition to milk production, livestock provide meat, fur and draft power. Cows and goats are the main sources of meat and bullocks and camel provide the draft power for ploughing and transportation. Their use for the latter purposes has drastically reduced in recent years due to the adoption of tractors in agriculture and other mechanised modes of transportation.

Feeding

Feed for livestock comes from crop by products and from common and forest lands. Some of the feed is imported from other areas. The mode of feeding is either stall-feeding or grazing or both. Sheep, goats and to some extent cows are mainly maintained on free grazing and tree lopping. Most of the large farmers resort to stall-feeding because sufficient fodder is produced from their fields. On the other hand, the marginal farmers and the landless people graze their cattle on common or forest lands for grazing.

4.4.4.3 Activities on common and forest lands

Quarrying on the common and forest lands is an important activity which provides work to a large number of local people, especially the poor and landless (Appendix 4.3). Products of quarrying are quartzite stones, crushed stone pieces, stone dust and sand called 'bajri'. All these materials have a ready market in cities, mainly Delhi, and are used for road making and building construction.

There are a number of stone crushers located in different places. This is a highly profitable business so it attracts traders from other places as well. It employs a large number of people. Benefits from quarrying are coupled with degradation of land and vegetation. Scree formed as a result of stone breaking rolls down and fill up water channels and the soil in the foothills is covered.

4.4.4.4 Industrial activities

Forest based activities

Sand called 'bhur' is used for land filling, and for raising seedlings in nurseries. Very few people work in this activity. There are 12 saw mills in the area. These mills take timber from the villages and also import timber from places as far as 2000 km and from abroad. Local timber of sufficient size is mainly converted into planks, small sawn timber and fuelwood.

Quite a number of people are engaged directly or indirectly in making and supplying furniture using mostly local timber, including eucalyptus. There is a big market for furniture in schools, government offices, private units and private households. A number of other activities based on forest products include rope and basket making, agricultural implements, cot and cart making.

Other industries

A number of large and medium industries are developing on the industrial site near village Rojka such as manufacturing of dairy products, motor vehicle spare parts and machine engines and cement. The aim of setting up industrial units in the area is to create job opportunities especially for the local people. Unfortunately, very few people from the study villages have directly got the jobs mainly because of lack of education.

Possible activities

There is the possibility of establishing cottage industries on a very small scale. Such units will fully depend for the supply of raw material from the area. Fruits of tint (*Capparis aphylla*), lasuda (*Cordia mixa*), amla (*Emlica officinalis*) and imli (*Tamarindus indica*) are frequently used in preparing pickles in India. These plants grow well in the site conditions. Neem (*Melia azadirakta*) grows luxuriously in the area and is quite liked by the people. Its fruits produces neem oil which is used in soap manufacture. Twigs of neem are good for cleaning teeth - they have a heavy demand in the urban areas. There is possibility of producing sized building blocks from quarrying stone on the site on commercial scale. Demand for them is huge. Some people can take up the job of charcoal making.

4.5 Socio-economic survey

A survey was conducted as a part of the socio-economic assessment. During the survey the socio-economic environment of the study site was minutely studied and relevant data were collected. It was also an opportunity to discuss the various aspects of the site management with the participatory agencies and village residents. The survey was completed in 73 days and the assistance of many people were taken to complete it.

4.5.1 Objectives

General objectives of the survey were:

(i) to assess the entire demographic and geographic situation;
(ii) to describe the local economy and the dependence of various socio-economic groups on the site;
(iii) to identify key variables and social actors likely to influence the participatory resource management;
(iv) to identify significant social and cultural values, views and perspectives of different sections of the society particularly on resource management and to get an insight into the socio-economic problems and conflicts;
(v) to explore the indigenous knowledge on management, conflict resolution, etc.;
(vi) to gather information on the attitudes, preferences, perceptions and beliefs of the government staff and also to assess their commitment, understanding and co-operative approach.

4.5.2 Survey methodology

Choice of method

The survey was conducted by both formal and informal methods. Informal procedures were adopted because it was essential in the preliminary works to find the deeper details of the individual's attitudes and feelings. People answered more truthfully in a friendly atmosphere of an informal interview and such a method was more of a qualitative nature. Formal interviewing method was adopted because the interviews had greater uniformity. The method was standardised to provide greater comparability of data. The formal approach is more quantitative, less vulnerable to interviewer's bias and inconsistency and allows for more sophisticated statistical treatment (Gardner, 1978).

The formal interviews were carried out with the help of well designed questionnaires. A face-to-face approach was adopted because it allowed an interaction between the interviewer and the respondent and because it also provided an opportunity to ask back-up questions.

Informal observations were recorded by continuously visiting the site and by discussing various related issues with local people, visitors, village guests and government functionaries. This technique was adopted because data collected from such observations are very important, and are likely to be more accurate than questionnaire data (Rowntree, 1981). With questionnaires, there are many reasons why people may give false information. For instance, they may misunderstand the question; or they may have forgotten the information asked for (for example, income and expenditure over the year on different items) or they may choose to record a deliberate lie (say, about their income).

Questionnaires

Two types of questionnaires were framed: one for the villagers (see Appendix 4.4) and the other for the FD and other government personnel (see Appendix 4.5). Initially, the questionnaires were designed on the basis of knowledge and experience of the area, and almost similar type of socio-economic surveys (Yadav and Khanna, 1993). These questionnaires were tested on the site and suitable modifications were made before the actual formal interviews.

The questionnaires contained open-ended as well as closed questions. Inclusion of both open ended and closed questions was essential to ensure flexibility and freedom to the respondents. The open questions permit greater freedom of expression and sound like an ordinary conversation. This puts the respondent at ease. These questions encourage a richness and depth in answering. The open ended questions are easy to ask but difficult to answer and analyse because they furnish more of subjective information. To overcome this practical problem, closed or pre-coded questions were introduced in the questionnaire. Such questions provided the respondents with an opportunity to assign relative weights to the questions. The questions have been grouped by topic context and branching of the questions have been done as and when required. Sensitive questions were kept to the last part of the questionnaire.

Sampling

The method of stratified random sampling was adopted in the survey because of the presence of socio-economic categories in the village population. The advantage of stratified sampling is that it offers the possibility of greater accuracy in comparison to either a simple random or a systematic sample by ensuring that each socio-economic group is represented in the same proportion as in the population. Members of individual groups or strata were considered homogenous but the two groups were treated as different from each other.

Data on population of the villages were collected from secondary sources such as census reports, district statistical office, panchayat records, government departments, etc. On the basis of these data the population was first divided into strata on the basis of caste, land holding, religion, gender and occupation. A simple random sample depending on the size of stratum was then taken from each stratum. The survey was completed in two steps, namely confidence building step and formal data collection step.

Confidence building step: After collecting basic information on population of various socio-economic categories, each village was visited many times and village leaders were approached to acquaint them about the purpose of visit. Similar gestures were extended to other village people. This process continued for sometime until the villagers were confident to talk frankly with the surveyors. Simultaneously, the site was surveyed during this period for topography, soil, vegetation and hydrological properties. To obtain 'willing' cooperation of people was not an easy task. It was necessary to spend considerable time to assure the villagers that they had nothing to fear and they could answer questions truthfully, and that the information would be treated confidentially.

Formal data collection: Once the confidence building exercise was complete, generally the heads of sampled households from each socio-economic category were interviewed individually. Their responses to questions were recorded.

4.5.3 Composition of households

A total of 140 households representing 11.75% of the total village households were interviewed. The proportions of village households in total and in the sample are presented in Table 4.5. A Chi-square test (p=0.1245) reveals that each village was represented in the sample proportional to its number of households.

The ratio of sampled households to the total village households was maintained as far as possible for each village. The ratio could not be maintained exactly in Sohna and Sehsola, although the difference is not statistically significant. Comparatively, the population of Sohna is predominantly more urban and lesser proportion of households use or have concern about the management of the site resource. That is why the proportion of sampled households to the total households in Sohna was less than the other villages. In the case of Sehsola, there was a greater ratio of sampled households to the total village households because, a large part of the forest and common land belonged to Sehsola hence, a greater say in participatory management.

The average family size of the sampled households was 9.4 members while the average for all village households was 7.59 members. The average family size for the villages was lower because the village data were based on 1991 Census and the sample data were collected in 1994. It was also observed from the sample data that the number of family members above and below 18 years of age (defined as major and minor members on the basis of legal voting age) was almost equal.

Table 4.5: Number of sampled and total households in the study villages

Village	Sampled	Total
Khod	9(6.4%)	63(5.4%)
Marola	10(7.1%)	61(5.2%)
Rojka	21(15.0%)	202(17.2%)
Raipur	17(12.1%)	144(12.2%)
Sohna	22(15.7%)	287(24.4%)
Sehsola	61(43.6%)	417(35.5%)
Total	140(100%)	1174(100%)

Representation of socio-economic categories

Of the sampled households, 110 (78.60%) were from the General Castes (GC) and 30 (21.4%) were from the Scheduled Castes (SC). Their ratio is not exactly representative of the caste composition of village population as given in Table 4.2. (binomial test, p=0.0079). A large proportion of villagers, particularly the SC, were without land or have very little of it. It is these SC or the marginal farmers who really depend on the common and forest land. Therefore, their proper representation in the survey was important.

The proportion of households of the two religious communities in the study villages - Muslims and Hindus - was 97 (69.3%) and 43 (30.7%) respectively. The proportion of sampled households did not match the ratio of village population as shown in Table 4.2. In fact, it is difficult to compare the two, mainly because the exact number of households by religion was not available for all the villages. The proportion of the Hindus was kept higher because they mostly depend on common and forest lands.

There are 117 (83.6%) male and 23 (16.4%) female households in the sample. This ratio of male to female in the sample is not the same as their ratio in the total village population shown in Table 4.2 (binomial test, p=0.00005). This was because in the male dominated society of the research villages, fewer women came forward to give interview due to cultural taboos (mainly 'purdhah' system: covering face with a veil). The women generally do not talk with outsiders. Those who were interviewed were through people of their confidence and after much of persuasion. For that reason, male members of the household were the main source of information.

Another important factor of socio-economic division of the villagers was the area of land owned by individual households. The area owned by individual households varied from 0.2 ha to 23.2 ha with an average of 3.009 ha. The households were initially divided into four groups: large farmers, small farmers, marginal farmers and landless households (Table 4.6). On the basis of available data for three villages, their ratio in the sample was similar to their proportion in the population (Chi-square test, p=0.0482).

Table 4.6: Land ownership by caste categories

Landowning groups	GC (%)	SC (%)	Average for villages (%)
Large farmer	19(13.6)	-	19 (13.6)
Small farmer	18(12.9)	1(0.70)	19 (13.6)
Marginal farmer	42(30.0)	2(1.4)	44 (31.4)
Landless people	31(22.1)	27(19.3)	58 (41.4)
Total	110 (78.6)	30 (21.4)	140(100%)

For the purpose of further data analysis, the households were re-grouped into three categories, viz., Large farmers (>3 ha), Small farmers (<3 ha) and Landless in order to apply appropriate statistical tests. Their numbers in the sample were 28 (20%), 54 (38.6%) and 58 (41.4%) respectively.

Table 4.7 presents the occupation of the head of the sampled households. Most of them were either engaged in farm activities or earned wages from daily labour, mainly in quarrying. Very few people were in service. For grouping the population in this study on the basis of occupation, a slightly different approach from that of 1991 Census (see section 4.4.3 - community groupings) was adopted. The Census classification was not followed because in that, people of all ages were included while in this study only the occupation of the head of the household was considered. The other reason was that the classes in the Census classification are too many and have overlapping job dimensions.

Only 23 (16.5%) of the sampled households were educated: primary level - 12 (8.6%), secondary level- 10 (7.1%) and graduate level- 1 (0.7%). Because of illiteracy, the people of these villages find it difficult to get jobs in other places.

Table 4.7: Main occupation of the sampled households

Occupation	Households	
	Number	Percent
Self employed	18	12.9
Self farm & household work	66	47.1
Daily labour	41	29.3
Government service	10	7.1
Private job	4	2.9
No work	1	0.7

4.6 Survey results

The survey data were analysed using the SPSS computer package (Norusis, 1993). Where necessary the Chi-square test was applied. The results of analysis are discussed in the following sections.

4.6.1 Relationship between socio-economic groups

Table 4.8 represents the castewise position of respondents in occupation, education, religion, land holding and gender. No significant relationship exists between caste in relation to education, or gender but caste is significantly related with occupation, land ownership and religion. The GCs, mainly comprising Muslims, are less literate and mostly are engaged in farming because the majority of them possess land. On the other hand the SC, all Hindus, people are mostly in labour or in service because 90% of them are landless.

Table 4.8: Survey results- households by caste and other socio-economic groups (%)

Socio-economic category	General caste	Scheduled caste	Chi-square value
Occupation			
Service	18.2	40.0	
Mazdoori*	22.7	53.3	P=0.0000
Farming	59.1	6.7	
Education			
Literate	15.6	20.0	P=0.5654
Illiterate	84.4	80.0	
Religion			
Hindu	11.8	100.0	p=0.0000
Muslim	88.2	0.0	
Land ownership			
Landless	28.2	90.0	
Small farmer	46.4	10.0	p=0.0000
Large farmer	25.5	0.0	
Gender			
Male	85.5	76.7	p=0.2495
Female	14.5	23.3	

* Manual labour of any kind

The religion of respondents is highly correlated with occupation and land holding status (Table 4.9). The Hindus are mostly either in service or labour while the Muslims are mainly in farming, some are labourers and very few (16.5%) are in service. This is due to the fact that the Muslims have land to work and are less literate.

Table 4.9: Survey results- households by religion and other socio-economic groups (%)

Socio-economic category	Hindu	Muslim	Chi-square value
Education			
Literate	25.6	12.5	p=0.5506
Illiterate	74.4	87.5	
Occupation			
Service	37.2	16.5	
Mazdoori	41.9	23.7	p=0.0001
Farming	20.9	59.8	
Land ownership			
Landless	74.4	26.8	
Small farmer	18.6	47.4	p=0.0000
Large farmer	7.0	25.8	
Gender			
male	79.1	85.6	p=0.3385
Female	20.9	15.9	

There is no significant relationship between religion and education or religion and gender of the respondents. A high proportion of the Hindus (74.4%) are landless in comparison to only 26.8% of the Muslims.

There appears to be no relationship between the land area owned by individuals and education or sex of the respondent (Table 4.10). But there is a significant relationship between land area and occupation of the individuals. The large farmers are entirely in farming while small farmers and landless tend to go for service and labouring activities. Sex of the respondents is also related with education and occupation (Table 4.11). Females are 100% illiterate and, very few of them are in service.

Table 4.10: Survey results- household position of landowners vis-à-vis other categories (%)

Category	Landless	Small farmer	Large farmer	Chi -square value
Education				
Literate	17.2	20.8	7.1	p=0.2875
Illiterate	82.8	79.2	92.9	
Occupation:				
Service	36.2	20.4	0.0	
Mazdoori	56.9	14.8	0.0	p=0.0000
Farming	6.9	64.8	100.0	
Gender:				
Male	75.9	90.7	85.7	p=0.9896
Female	24.1	9.3	14.3	

Figure 4.2 shows the cross tabulated values between literacy and occupation of the households. Statistical analysis (p=0.0000) establishes that the occupation of people is highly related with their education level. More than half of literate people are employed while the illiterate people are mostly farmers or mazdoors.

Table 4.11: Survey results- household position of gender vis-à-vis education and occupation (%)

Socio-economic category	Male	Female	Chi Square value
Education			
Literate	19.7	0.0	p=0.0228
Illiterate	80.3	100.0	
Occupation			
Service	26.5	4.3	
Mazdoori	23.1	60.9	p=0.0007
Farming	50.4	34.8	

No definite relationship could be established between the occupation of the head of the family and the family size. There is some indication that when family size is small, less people are in farming than for the bigger families. But this is not a clear picture because of the lack of the complete information on the employment of family members. Actually, most of the small families belong to the landless group and thus they do not get opportunity to work on the land.

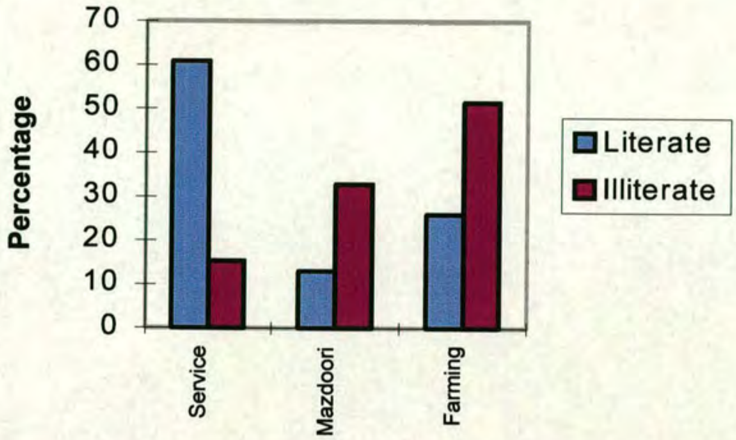


Fig. 4.2: Proportion of occupation and literacy of the head of household

4.6.2 Relevant socio-economic criteria for analysis

Agricultural management practices are decided by the farmers themselves. But the participatory management of common and forest lands depends very much on the co-operation of the villagers. All the villagers working as one cohesive group would be much more effective and useful in making the management of common and forest lands successful. On the other hand, if the villagers were divided, the management would be less likely to be successful.

There was no unanimous opinion among the households on whether the village society was divided or not. The number of people who believed that the villagers were divided (37.1%) and those who believed that the villagers were not divided (32.9%) are in roughly equal proportions. An almost equal proportion of people (30%) were found to be indecisive.

According to those who felt that the village society was divided ($p=0.0000$), the biggest single factor of division was income of the household followed by political affiliation. The other important factors responsible for division were caste, land holding and religion as shown in Figure 4.3. Occupation was not very relevant in affecting the psychology of the people to come forward for a common cause. Majority of the households were working either on farms or as labourers on farms as well as in other activities. Only a very small proportion of them (Table 4.11) are engaged in other occupation. In fact, it is not one but a combination of many factors, i.e., the category 'other' which appear most responsible for division in the society.

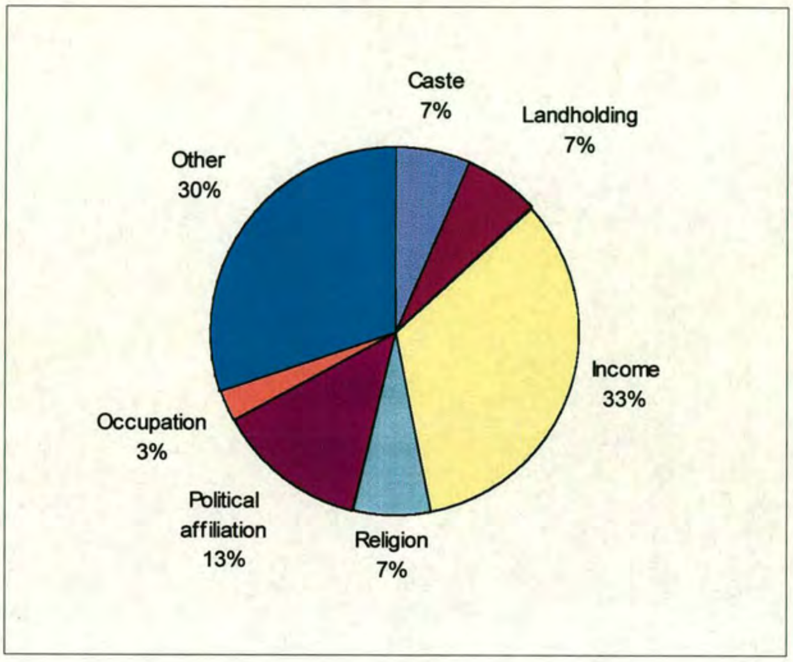


Fig. 4.3: Perceived factors of stratification in the village society among those who felt the village society was divided

Income of the household can, indeed, be very important criteria because it transcends the boundaries of caste, occupation, religion, land holding and education. People of a certain income tend to behave in a similar fashion. But in the absence of reliable information on individual household income it is not possible to apply this criterion with accuracy. Inspite of the best efforts, it was not possible to collect information on the income of the individual households. Estimation of income indirectly on the basis of land area owned, services or daily wages is quite difficult. For instance, production from land will vary depending on inputs and labour; many people have undisclosed sources of income; or individuals may not be able to calculate the actual income from all their sources particularly benefits from common resources.

In the present context two major sources of income in the area are farming and daily wages. Both of these are reflected in the extent (or absence) of land ownership.

Political affiliation (13.3%) appears to be the second largest cause of division in the society. This is a fact but people are not always prepared to reveal their affiliations. Moreover, the experience in this area shows that party affiliation goes along religious and caste lines and is also influenced by individual leaders. Thus, in the absence of a true picture about political affiliation of people it can not be taken here as a definite criteria for grouping the population.

Similarly, education level is not effective in locality groups for or against collective action. The education level is not so high that it becomes a dominant factor in changing people's attitude towards the management of common property. Neither is gender an influential character as far as the management of this site is concerned. Firstly, because the families tend to follow the male head for activities outside their houses and secondly, because both sexes are not properly represented proportionately in the sample.

In the light of the limitations as discussed, religion, land possession and caste were selected as appropriate criteria on which to analyse views, attitudes, perceptions, needs, etc. of the people.

4.6.3 Social stratification and collective action

There is a definite relationship between different socio-economic groups and their responses regarding the existence of stratification in the society. The advantaged socio-economic groups, i.e., large farmers, GC and the Muslims tend to deny the existence of stratification in the society while the relatively disadvantaged groups such as the SC, the Hindus and the landless people say that stratification is very much prevalent.

Stratification in and collective action by the society are closely related ($p=0.0000$). Stratification affects the collective action by the society. Of those who perceive stratification in the society, about 87% of households irrespective of caste, religion and land ownership think that it affects any collective action by society. No particular trend is visible among the different socio-economic groups.

The effect on the collective action is due to conflicting views or indifference among the members of the decision making bodies. The results of the survey show that 45.7% of the people believe that there are no conflicts and only 20.7% think that there are. Surprisingly, a large proportion of the population (33.6%), comprising of mostly the Hindus, the SC and the landless, are either uninterested or unaware or aloof from the process. It indicates that they are either not involved or not concerned with the management of the site. For making people participate, the management plan has to touch these indifferent people and also help in conflict resolution. Public awareness and transparency in decision making may help in this direction.

Opportunity for collective action

As mentioned above stratification does affect collective action by the society. Participatory management of the site requires the people of different socio-economic groups to work together. There are various cultural events and traditions when people feel inspired to work together for a common cause. These opportunities related with the site are religious festivals, elections, village fairs, etc. Responses of the people are presented in Figure 4.4.

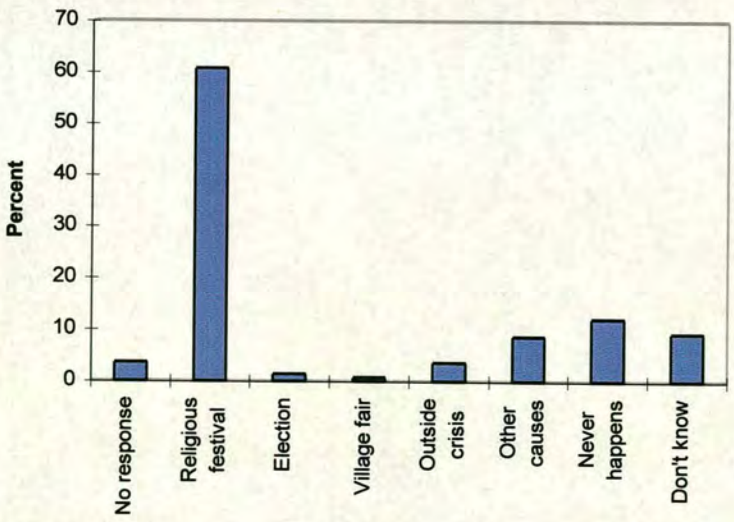


Fig. 4.4: Perceived opportunities for collective action by the village households

The biggest force encouraging people together in the area is religion. This is true for both the religious communities. This factor should be exploited to aid participatory management. The castes and the landowning groups also have more or less the same view except that more of the SC people (40%) are indifferent in comparison to the GC (20.9%). The fact that quite a number of people (12.1%) say that the population as a whole never works makes the concept of participatory management challenging.

4.6.4 Site management and people's participation

Traditional versus participatory management

Given a choice between traditional and participatory management systems, most of the people (81.4%) favoured the participatory system irrespective of caste, religion or land ownership. There is no difference in the views of the two castes (p=0.1985) and the two religious communities (p=0.1555) in this regard but the views of landowning categories differed from each other (p=0.0038). More of the farmers (90%) are in favour of participatory management than the landless people (69%). This may be due to the impression that in participatory management, farmers get an upper hand and a greater say. On the other hand the landless, because of their lower status, feel that the farmers would exploit the resource to their own advantage.

Although overall people like participatory management, the degree to which they would themselves wish to be involved varies among the various socio-economic groups. More GC (55.5%) want to participate than the SC (20%). The Muslims (58.8%) are more enthusiastic to participate in comparison to the Hindus (23.3%). Similarly, the farmers want to participate but the landless do not.

Perceived objectives of management

Perceived objectives of participatory site management are quite different from stated preferences to actually participate in the management process. The single most preferred objective of management expressed is to manage the site to meet local needs for fuelwood, fodder, small timber and other products (38.8%). They favour a multi-objective management approach. About 20% of people say they would like the site to be exploited for commercial uses and mining. Very few are concerned about ecological maintenance or environmental protection. The views of various socio-economic groups also differed (p=0.0022). More SC (46.71%) preferred local products than the GC (36.7%). More GC are for ecological maintenance and multi-objective management than the SC. Similarly, the Hindus like to fulfil local needs and commercial production as the Muslims (p=0.39). The landless are more for local products than the landed group (p=0.002).

Cause for individual participation

Not all individuals are interested to participate in site management. Only about half the number of people (47%) are prepared to participate for a variety of reasons as presented in figure 4.5. The biggest incentive for participation is income generation as the people need cash for a variety of purposes. The trend among the socio-economic groups show that income generation motive is favoured by SC, Hindus and landless people. Ego satisfaction is favoured by GC, Muslims and the large farmers in particular. Any management strategy should emphasise income generation activities by involving people either in decision making, implementation or in work.

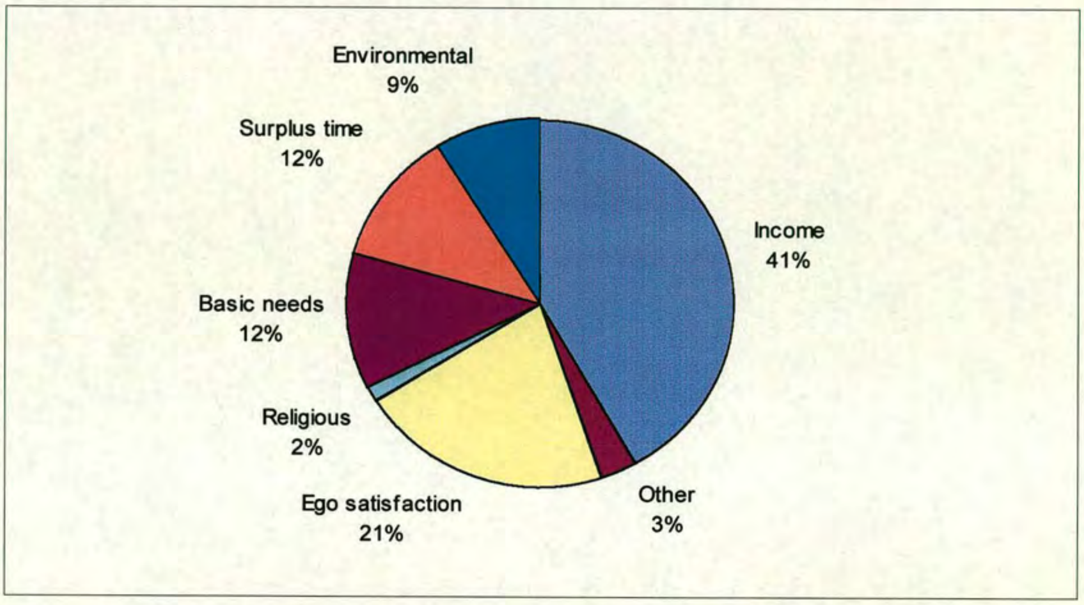


Fig. 4.5: Reasons for people wanting to participate in site management

People also want to participate to fulfil their basic needs (11.9%) of fuelwood, fodder, small timber and fruits. Equally some people (11.9%) have surplus time which they want to use for working in the management of site. Only 9% of people want to participate for maintaining the ecological balance or for improving the environment. Religious feelings do not have much to do with tree planting or management.

Non-participation

For those who do not want to participate, the main reasons are the lack of time (43.8%), lack of interest (35.6%) and other reasons (20.5%). Those who do not have time are mostly engaged elsewhere, either employed or work as labourers. No relationship is found between caste and land ownership and reasons for non-participation. Religious affiliation is significantly related with the non-participation ($p=0.008$). Hindus do not wish to participate because of lack of time and Muslims do not wish to participate because they have no interest.

It is seen that to encourage those who have a non-participatory attitude, the prospective of improved income should be explained (52.1%). This is true for all socio-economic groups. This supports the observation that the most important reason for participating in common resource management is the generation of additional income. Thus management plan should have activities which can generate cash.

4.6.5 Perceived difficulties in management

About half of the village population cited difficulties in the way of participatory management. Only nineteen percent of people think there would be no problem. They include mostly the Muslims, the GC and the farmers. A high proportion of 'mazdoors' and landless people were unable to think whether or not there would be problems. Perceived problems can be grouped broadly into three classes.

(i) Problems related with management planning, and implementation

About 29% of people think that poor planning and decision making, half-hearted implementation, poor maintenance and lack of protection are potent hurdles in the management of the site.

(ii) Problems related with people's attitude and perception

Vested interests in the different socio-economic groups, non-co-operation by people, insincerity, corruption and people's indifferent attitude, at times in association with other problems, have been pointed out as serious problems in the participatory management by a large number of people (74%). It is difficult to motivate people to work for common cause until they are assured of returns from it. In the present context, management of the site on ecological considerations can not provide immediate benefits.

(iii) Site related ecological and productivity problems

A small number of people (1.4%) cited slow and low benefits and harsh ecological conditions as serious problems. These are real and big problems. Water scarcity, extreme climate, rough topography and poor soil conditions are real and are responsible for many other problems such as poor productivity, lack of people's interest, etc.

4.6.6 Choice of tree species for planting

People were asked to name species of trees which they would like to be planted on the site. In total 42 species were named by the people (Appendix 4.6). No difference could be observed among different socio-economic groups. The majority of the people liked ronj (*Acacia leucoploea*) and neem (*Azadiracta indica*). Both are natural species of the area and yield fodder and firewood. Ronj also provides small timber and grows well in the difficult terrain and poor soil conditions, i.e., ideal for the hilly part of the site. Neem's timber is durable and is used in construction. A large number of medicines can be provided from it.

About 5% of the population was specifically against planting mesquite (*Prosopis juliflora*) while 32.2% liked. Mesqiute is a hardy and fast growing species. It can grow in places where other species can hardly survive. It is a good coppicer and produces good quality fuelwood. In fact, this is the only source of firewood for a large number of people in the area. The biggest disadvantage of this species is that it is thorny which causes injury to cattle and men; and makes it difficult to pass through areas covered by it.

4.6.7 Agricultural constraints

Scarcity of water is a big constraint in agricultural production. Of the households who possess land, 34.1% do not have irrigation while about 14.6% have their land fully irrigated. Large farmers have a bigger proportion of their land under irrigation than the small or marginal farmers. Obviously, another problem was scarcity of land and fragmentation of landholding.

Not many farmers have trees on their farms. According to the local farmers shortage of land, interference with agricultural crops and interference with agricultural operations are serious constraints to planting trees on farms. With increasing population, the farming units are becoming smaller and smaller. Planting of trees on these small farms is unlikely to take place as long as production of food grains is the top priority.

4.6.8 Livestock and feeding

Most of the GC households (84%) keep livestock of some kind but in comparison only 15.5% scheduled castes keep them.

Stall feeding is the main mode of feeding the livestock. Only 15% of people resort to grazing and about 20% use both stall fed as well as grazing. Grazing depends on the type of livestock, time of the year and socio-economic status of the farmer. Cows and goats are generally taken for grazing while buffaloes are mostly stall-fed. More of the landless people and small farmers resort to grazing than the large farmers. Often the grazing place is either common land or forest land but on rare occasions cattle are also let loose on the agricultural fields.

Source of fodder

The main sources of fodder are agricultural farms (48.6%), common and forest lands (43.1%) and supply from outside areas (8.3%).

Tree fodder

Fodder from the common and forest lands is obtained either from grasses in the rainy season and/or from trees throughout the year. Many species of trees which naturally grow in this area provide fodder. Popular species were identified (Table 4.12) and people's preference was estimated by ranking them on a scale of 1-9 (1=most preferred, 9=least preferred).

Table 4.12: Survey results - tree fodder species and their choice

Species	Preference order	People using it (%)
Acacia leucophloea	1	27.9
Zizyphus mauritiana	2	26.4
Anogeissus pendula	3	11.4
Butea monosperma	4	27.1
Cordia dichotoma	5	19.3
Acacia nilotica	6	5.0
Ailanthus excelsa	7	12.9
Holoptilia integrifolia	8	15.0
Azadiracta indica	9	9.3

A. leucophloea, the most highly preferred species, grows naturally in the area, is drought hardy and produces good quality fodder, fuelwood and small timber. Other preferred species such as *Zizyphus mauritiana, Anogeissus pendula, Butea monosperma* and *Cordia dichotoma* are all natural multipurpose species of the area.

4.6.9 Supply of fuel energy

Sources of various kinds of fuels are given in Table 4.13. Agricultural residues, fuelwood, dung, LPG (liquified petroleum gas) and kerosene oil are used for cooking and heating. Electricity is used primarily for lighting, running tubewells and to a small extent for running household appliances. Fuelwood is used by almost all the people to supplement their household supply. Crop residue is used by only 59.3% households and its supply comes from agricultural fields.

Table 4.13: Survey results - type of fuel and its source

Source	Crop residue	Dung	Fuelwood	LPG	Others
Agricultural fields	98.8 %	1.0%	15.4%	-	-
Common-forest lands	-	3.9%	80.1%	-	-
Other	1.2%	95.1%	4.4%	100%	100%

About 26% households do not use cowdung. The supply of cowdung is mainly from the cattle owned by individuals. The percent contribution of each type of fuel in average energy supply of the villagers is shown in Figure 4.6.

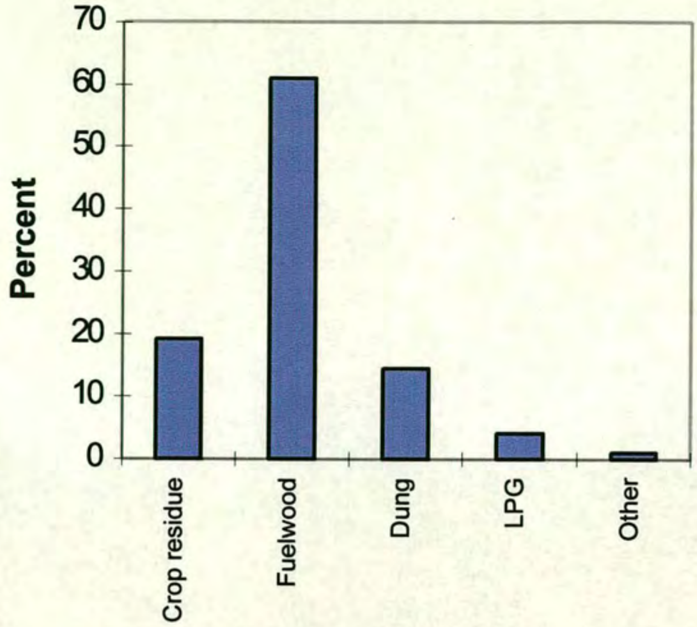


Fig. 4.6: Survey results - contribution of different fuels in the total energy supply

Table 4.14: Survey results - fuelwood species, their use and preference by the people

Species	Households	Preference
Acacia leucophloea	53(37.9%)	1
Prosopis juliflora	121(86.4%)	2
Acacia nilotica	75(53.6%)	3
Butea monosperma	56(40%)	4
Acacia senegal	73(52.1%)	5
Anogeissus pendula	23(16.4%)	6
Acacia tortilis	66(47.1%)	7

From Table 4.14 it is seen that there is no relationship between use and preference of a species for fuelwood. The most preferred species is not necessarily used by the largest number of people. It is, in fact, the second most preferred species which is used by the highest number of households (86.4%). This is because the use of a species depends on its availability: *Prosopis juliflora* is abundantly available while *Acacia leucophloea* is scarce. All the species mentioned in Table 4.14 are naturally found in the area except *Prosopis juliflora* and *Acacia tortilis.*

4.6.10 Supply of timber

People use timber for construction, furniture, agricultural implements, bullock carts, etc. Some of the works such as longitudinal beams for ceilings and long handles of carts require a special kind of timber. Such special timber is imported into the area. But for other purposes, local species provide good quality timber. These tree species were identified during the preliminary survey. Their use and preference by the villagers are given in Table 4.15.

Source of timber

Timber is sourced from farm lands, common and forest lands, the homestead area and market (Table 4.16). Very little timber is obtained from trees grown on the site. Farm fields and market are the main sources of local timber supply.

Table 4.15: Survey results - common timber species, and their preference by the people

Species	Number of people using it	Preference ranking
Dalbergia sisso	46.4%	1
Acacia nilotica	65.7%	2
Azadiracta indica	22.95	3
Albizzia lebbek	13.6%	4
Holoptilia integrifolia	8.6%	5
Ailanthus excelsa	6.4%	6
Acacia leucophloea	7.9%	7

Table 4.16: Survey results - source of different types of timber for the people (%)

Source	Kikar	Neem	Papri	Ronj	Shisham	Uloo neem	Siris
Farms	39.1	46.9	8.3	18.2	40	33.3	47.4
Common-forest	3.3	15.6	83.3	81.8	4.6	66.7	21.1
Homestead	2.2	3.1	-	-	-	-	5.3
Market	55.4	34.4	8.3	-	55.4	-	26.3

4.6.11 Non-wood forest products

The important minor products to the local people obtained from the common and

Table 4.17: Survey results - non-timber forest products, their source and use by the village households (%)

Product	Source			Use			
	Farm	Common -forest lands	Market	Construction	Household	Cash	Other
Thatch	29.3	10.0	30.7	68.6	7.1	-	1.4
Seed	1.4	58.6	3.6	-	61.4	0.7	-
Soil	-	20.0	-	-	-	-	-
Gum	-	20.7	-	-	-	-	-
Leaves	-	40.0	-	-	39.3	10.0	-
Stone	-	74.3	-	0.7	61.4	-	-
Medicine	0.7	52.9	-	-	55.0	-	-
Grass	o.7	62.1	-	-	62.9	-	-
Twig	2.1	82.9	-	-	85.0	-	-

forest lands are thatch, soil, seeds and fruits, gum, tree leaves, stones, medicines, grasses and twigs. These products play an important role in the local economy, and are useful in developing a suitable management plan for the site (Yadav et al., 1996). Some of these products are also obtained from farm lands and are purchased from the market as well. Table 4.17 presents source and use of these products. It can be seen that for most of the people the source of these products is the common and forest lands and these products are essentially meant for household consumption.

4.7 Results of interviews of government personnel

The Forest Department (FD) is the major government agency to take part in participatory management of common and forest lands. Views of personnel at various hierarchical levels in the administration of the FD were obtained concerning the management. Some personnel belonging to other government departments such as Agriculture, Horticulture, Animal Husbandry, etc., were also interviewed as they influence decisions indirectly. A total of 36 personnel were interviewed: FD (86.1%) and others (13.9%). Important observations on the outcome of the analysis of their responses are discussed below.

A high proportion of the personnel (94.4%) thought that village society was divided; the main bases of stratification were caste (13.9%), landholding (8.3%), religion (2.8%), political affiliation (2.8%), service (2.8%). 63.9% were of the opinion that not one but a combination of different factors caused stratification. Most (88.9%) believed that social stratification affected the management of common and forest lands. They also favoured participatory management (47.2%) over traditional management. Of the 19.4% who did not know which system was better, the majority (71.4%) belonged to lower levels in the administration. This indicates the need to take appropriate measures to attune junior members of the bureaucracy to the benefits of participation.

In relation to the priorities for bureaucratic management, a large number of the personnel (27.3%) emphasised ecology and environmental conservation. The other objectives of management, in their view, were to fulfil basic needs, and commercial exploitation. About half of them said that planning should be multi-objective. On the relationship between the FD and the VP, about 44.4% desired; 38.9% expressed that only the FD should take care of management in case of forest land.

4.8 Inferences from the socio-economic study

From the socio-economic study of the site, the following points emerge as important from the point of view of the village population. If these points are observed while evolving a management plan of the site, it is anticipated that the villagers, irrespective of their religion, caste, land ownership, education level, occupation and political affiliation will participate in the management process. In case of viewpoints of government personnel, the important thing is to provide them with suitable training and understanding of PFM. They have to develop the right type of attitude to seek co-operation of the people.

i. Due to scarcity of water for irrigation, there is need for water conservation measures.

ii. The management strategy for the site should emphasise on employment generation.

iii. Food, fuelwood, fodder, small timber and non-wood forest products from local resources are required by the local people.

iv. Provision for grazing.

v. The management plan has to accommodate the increasing population.

vi. It is difficult to stop quarrying on the site because a large number of people get daily employment and also powerful people have vested interests in it. But quarrying has to be limited and definite areas must be assigned to it to avoid soil degradation and to reduce air pollution.

vii. Some money should be spared for the socio-religious functions to encourage the population and to bring them together.

viii. Care has to be taken that people who used to derive benefits from these lands continue to get them.

ix. Cash generation for the Village Panchayat is important so that they feel encouraged to devote time for management.

x. Provision for maintaining social status for certain people is essential.

xi. Continuous benefits are needed right from the beginning as people will not have the patience to wait for benefits over a long period.

xii. Tree species preferred by the people must be planted.

Chapter 5

Mapping and classification of the study site

In this chapter, the bio-physical environment of the study site is explored. Section 5.1 identifies the category of land which is to be classified. Then, after a brief discussion about site classification in section 5.2, a detailed description of the site (common and forest lands) is given in section 5.3. Methodology of the site survey is mentioned in section 5.4 and division of site land on the basis of site features is described in section 5.5. The last two sections 5.6 and 5.7 deal with classification of common and forest lands into land suitability classes by GIS. Figure 5.1 provides an overview of the approach of the site classification in this study.

5.1 Land categories

The land for which a management plan is to be developed was divided into three categories on the basis of ownership and prominent use: agricultural land which is under private ownership and is used for growing agricultural crops; common land which belongs to the Village Panchayat and is used for grazing, quarrying and planting; and forest land owned by the Forest Department and is used for non-agricultural activities mainly for forestry and quarrying. The common and forest lands are adjacent to each other and almost form a single block of uneven topography. In this study, the common and forest lands were amalgamated and treated as one category termed 'common-forest' land. Agricultural land surrounds the common-forest land except on the south-southwest side (Figure 5.2).

Agricultural land

For the present research, the agricultural land was treated as uniform throughout the whole area of the site. No appreciable differences in topography, vegetation or soil properties could be identified. Land use pattern by the farmers in all the surveyed villages was similar apart from those locations where irrigation water was available.

Farmers with irrigation facilities tend to grow different crops on the same piece of land as on land without irrigation facilities.

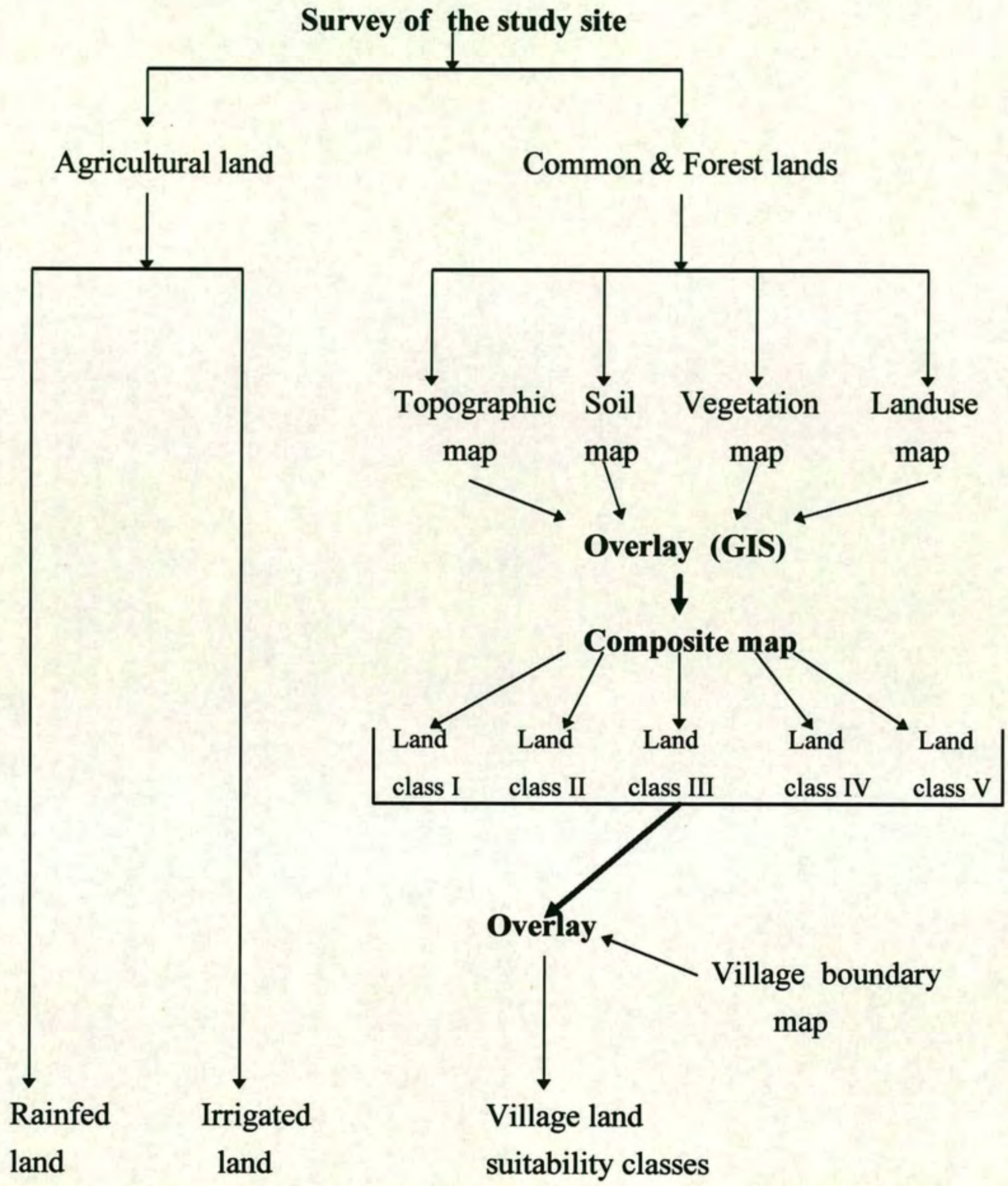


Fig. 5.1: An overview of the plan for the site classification

Common-forest land

The area of forest-common land was not uniform. There were marked differences in topographic features, soil properties, land uses and vegetation types over the site area. Because of the variations in characteristics, this land could not be treated as a single homogenous unit like the agricultural land for the purpose of developing a management strategy. Therefore, the forest-common land was categorised into land units which were uniform in site characters.

The remaining part of this chapter deals with mapping and classification of common-forest land only.

5.2 Mapping and classification

One important aspect of developing an appropriate management system for a land resource is to map and classify the area of the land into units which, for the purposes involved, can be considered homogenous. Mapping is representing the identified features of land in a spatial relationship. Classification is arranging objects into groups or sets on the basis of their similarities or relationship (Bailey et al., 1978). The relationship is generally based on observable or inferred properties (Sokal, 1974). The classification of a land area can be split into terrain classification and site classification on the basis of observable properties. Site classification is a means of grouping land sites according to their capability of growing trees and terrain classification is a means of grouping land according to the ease or difficulty of carrying out a forest operation. The distinction between terrain and site classification is generally followed in forestry (Löffler, 1986).

Classification approaches

Various classification approaches have been used in the past. Surfacial and geomorphic features have remained dominant considerations in site classification. Surface configuration is the one property that is easily observed, and can be measured in the field and by remote sensing. A geomorphic approach to site delineation enables the resource manager to assess the resources at his disposal, and assists in the evaluation of management opportunities and risks.

Bourne (1931) is usually regarded as the pioneer of the geomorphic approach to site delineation and his suggestion that sites are "areas which for all practical purposes had similar physiography, geology and edaphic factors" is viewed as the forerunner of hierarchical classification systems (Howard and Mitchell, 1980). Morphological mapping techniques were developed by Savigear (1965), who recognised five basic geometric forms. These forms could be separated one from the other in the landscape by slope breaks, slope changes, or inflections. Subsequently, hill slope models were proposed to organise a number of slope categories (Young, 1975;

Conacher and Dalrymple, 1977). These models were recognised by Grey (1979, 1986) and developed into a useful framework for the delineation of forest sites.

Mashimo and Arimitsu (1986) classified sites by forest functions. They used timber production, water-resource cultivation, flood control, soil conservation and forest recreation functions for site classification in Japan. Victor et al. (1986) determined homogenous units on the basis of natural vegetation, topographic conditions, ecological forest units (which determine the development of species) and land value. Sokal (1974) suggested a convenient way of developing a classification which involves computation of functions that yield similarities or dissimilarities (distances) between all objects (site factors) taken a pair at a time. A symmetric matrix of such similarity and dissimilarity coefficients is then analysed to represent their relationships as clusters or in various other ways. Elsewhere, physical factors of soil, topography and climate which impose limitations on growth of trees and on silvicultural practices (Dry and Hipkin, 1989) and bioecoclimatic ecosystem classification, incorporating primarily climate, soil and vegetation data (Meidinger and Pojar, 1991) have been used to classify forest and range lands for management purposes.

Site mapping methods purport to take into account the main ecological factors of the habitat, viz., regional climate, topography, geology, soil properties and features of the vegetative cover. These factors may or may not be mapped separately but they are all synthesised to form the ultimate site map. In the final mapping, it is quite possible to emphasise a particular point according to the need of the management practices or other factors (Rennie, 1963).

In the present context the size of the study site was too small for any appreciable change in climatic conditions over the area of the site. Hence, climatic factors were not considered here for the purpose of site mapping and classification. The main site features used for site mapping and classification in this study were topography, vegetation, soil type and land use. The approach combined site classification and terrain classification as suggested by Löffler (1986). It was based on grouping land areas which have similar multiple characteristics into defined homogenous land management units called in this study land suitability classes.

5.3 Site description

The study site is situated on Delhi-Alwar road in the Gurgaon district of Haryana State in India (Figures 4.1 and 5.2). It lies between 28°11' - 28°15' N latitude and 77°1' - 77°5' E longitude. Distance from district headquarters (i.e. Gurgaon) is 25 km and 60 km from the metropolitan city of Delhi.

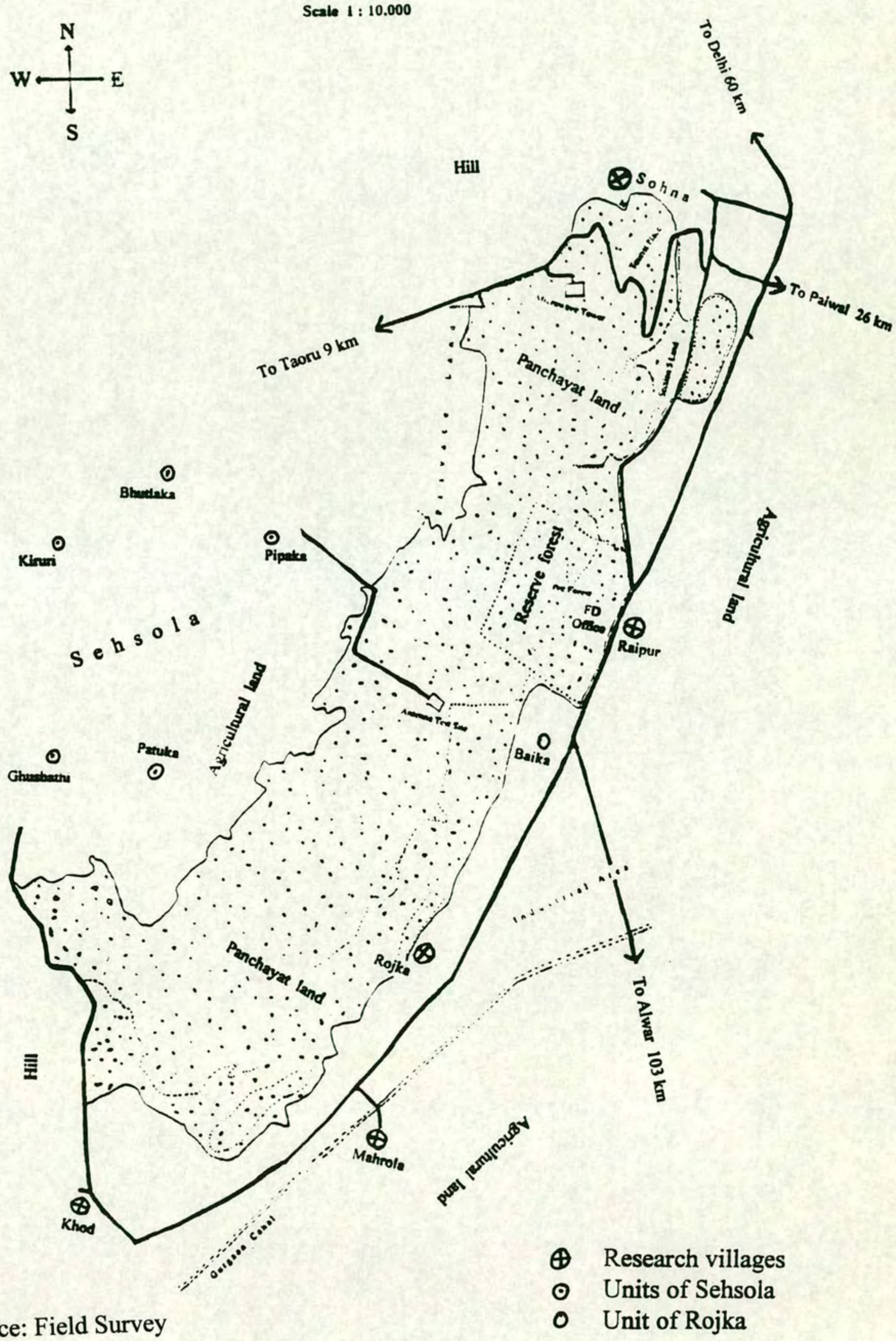
The total area of forest-common land is about 700 ha. The maximum width and length of the area are 2.3 km and 6.1 km respectively. The altitude varies from 200 to 306 metres above the mean sea level. There are two water springs: one, a hot sulphur spring in the north and the other, at the south end of the site. The area can be divided into two distinct parts: one part is hilly and the other is gently undulating pediments. The hilly part covers about 75 percent of the total geographical area of the site.

The hilly part extends from Sohna in North to Khod in South; general orientation is NNE to SSW (Fig. 5.2). In the north, the hill abruptly ends at the edge of Sohna township and then turns in a western direction while in the south it extends beyond the site boundary. The pediments are adjacent to the hills and extend along a north-south direction on the eastern side of the hill. They mainly consist of sloping lands generally covered by aeolian sand. Agricultural land lies on the eastern and western sides. The rest of the chapter deals with the mapping and classification of common-forest land.

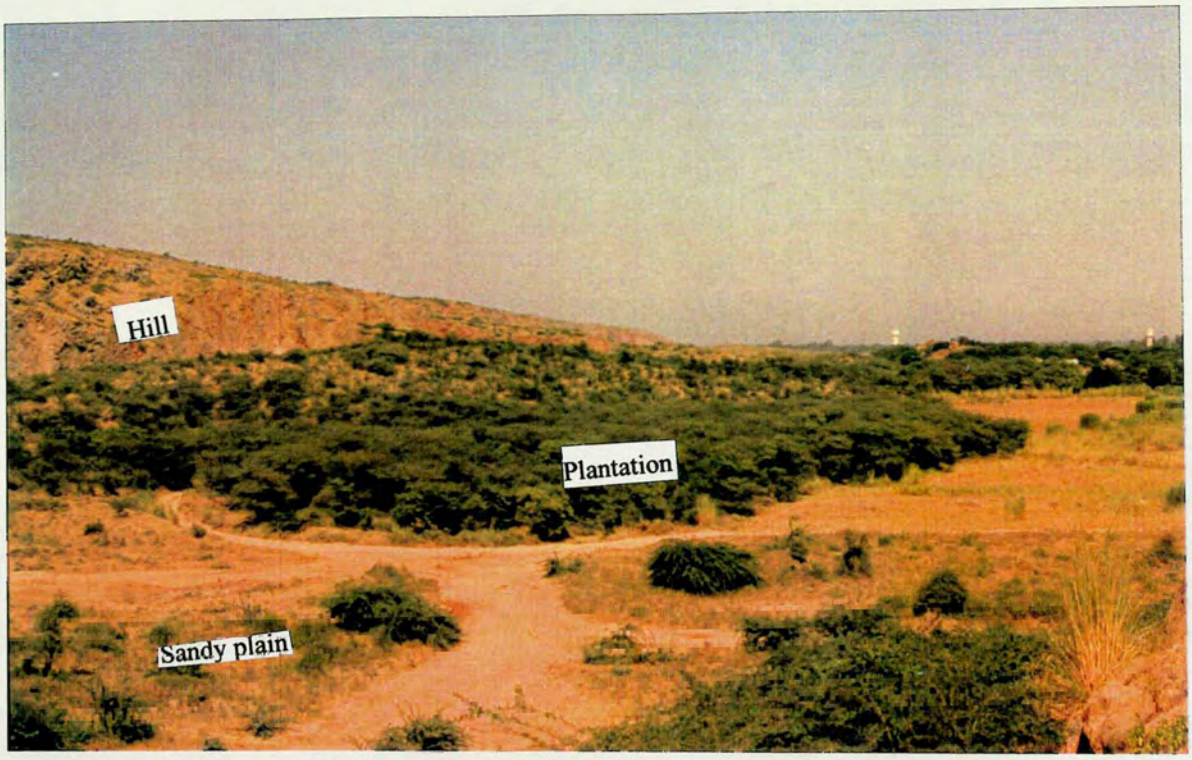
5.3.1 Geology

The research site is a small part of Aravalli mountain Super Series, the oldest lithounit in the world. Rocks of the site belong to the pre-cambrian Aravalli-Delhi system and their pediment extension in the south and south-east. The hill consists of Alwar series. The main rock units are quartzite, micaceous quartzite and gritty arkose. Features of relief are due to exposure of hard rock beds. The valleys among these outcrops are of two kinds - a narrow *chhind* formed by removal of easily eroded strata interbedded between more resistant beds and the broader and longer synclinal valleys excavated in the weaker supra Alwar rocks contained in a fold basin of the Alwar series. The prevalence of conspicuous steep slopes is due to high dip (inclination of rock strata). The sandy nature of pediment soils may be due to an

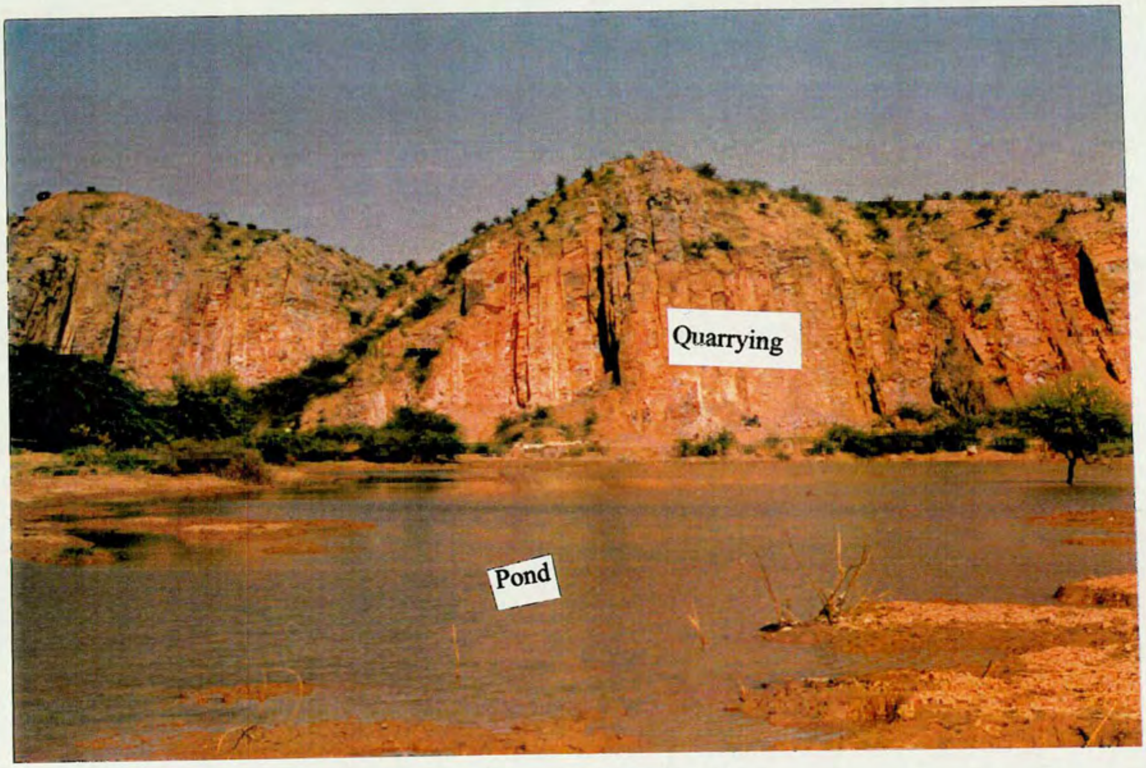
Fig. 5.2: Spatial features of the study site



Source: Field Survey

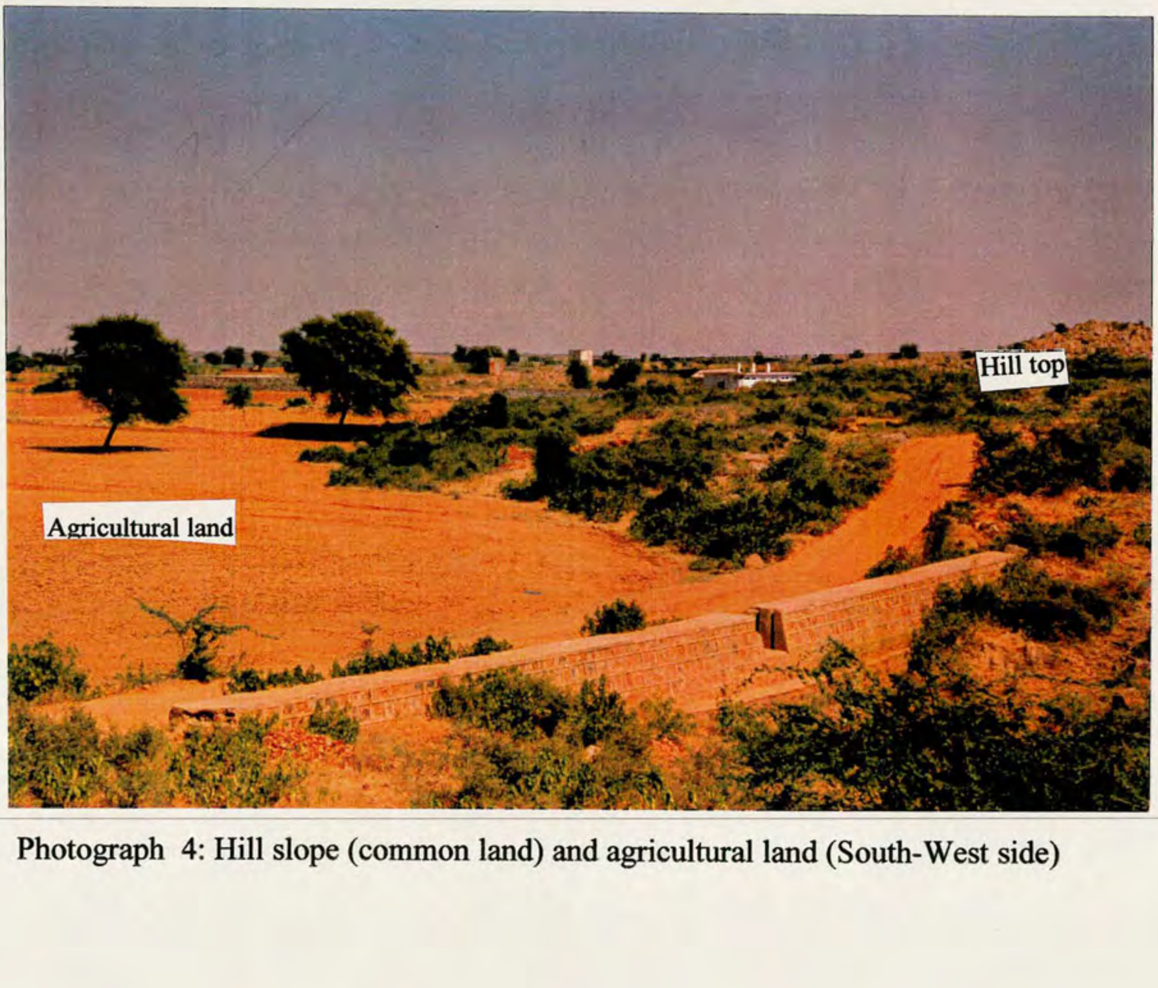


Photograph 1: Plantation of *Acacia tortilis* on sandy plain on common-forest land (North-East side)



Photograph 2: Steep rocks, quarrying activity and a water body on common-forest land (South-East side)

Photograph 3: Hill top, *nala* (stream) and soil erosion on common-forest land



Photograph 4: Hill slope (common land) and agricultural land (South-West side)

admixture of wind blown sand from the Rajasthan desert, a breakdown of the light textured plains and weathering of local rocks (Goel et al., 1990).

5.3.2 Drainage pattern

There is no natural drainage system in the area: a perennial or definite river system is lacking. Water flows in streams which follow the general slope of the area. Most streams have a well-defined water course and are directed eastward except a few small streams which drain out towards the West. The drainage pattern in the hilly area is controlled by structural joints and is of trellis[1] type. Soil deposits in the plains are dissected by moderately deep gullies and present a dendritic[2] pattern.

Heavy rain water causes serious erosion in the hills as well as in the plains. The streams in the Aravallis are characterised by flush and ephemeral flows with movement of sand and silt. Heavy rain creates gullies and nalas[3] in the sand dunes. The drainage water of almost all the streams is either absorbed by sand or floods the low lying countryside.

5.3.3 Climate

The climate of the site is subtropical, semi-arid, continental and monsoon type with prolonged hot periods from March to October. There are three seasons in a year: winter from November to February; summer from March to June; and rainy (Monsoon) from July to October. Frost is common in drier areas and hailstorms may also occur in April-May.

Rainfall

South-westerly monsoon winds are responsible for rainfall in the region. Nearly 80 percent of the total rainfall is received during the months of July, August and September (Fig 5.3). From October to mid April the weather remains dry except for a few light sporadic showers due to the westerly depressions. The weather from mid April to mid June is quite dry with high evaporative demand.

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[1] Several main streams flowing in sub-parallel valleys separated by anticlines.
[2] Large number of streams spread in different directions.
[3] Small streams

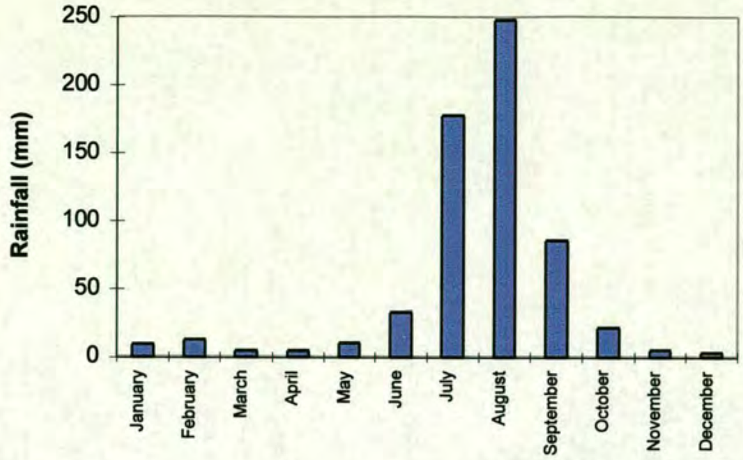

Fig. 5.3: Monthly rainfall at Sohna (1901-93)

The rainfall is highly variable and erratic in volume, place and time. (SFD, 1994). Therefore, its amount, distribution and intensity are highly important during the crop season. The average annual rainfall at Sohna is about 613 mm. Winter rains are more erratic. They are insufficient and, therefore, unsuitable for planting operations in this area, due to prolonged drought. Thus, planting operations are executed during July and all planning for the operations is basically tied to the monsoon.

Temperature

The monthly average maximum and minimum temperatures are given in Table 5.1. There is a prolonged hot period lasting from March to June. There is substantial variation in daily and annual temperature. Temperature can plummet to a freezing sub-zero during December and January in winter or rise well into the mid forties in summer months of May and June. Frost in winter causes damage to plants. Lack of soil in the hills and wide variation in the temperature brings in limitations in the choice of species suitable for the site. Hot winds from the adjoining desert of Rajasthan State cause further desiccation in the area, so that species have to be frost hardy as well as drought resistant.

Wind Velocity

Wind velocity is highest during April to July and remains low during the September to January period (Table 5.1). Hot winds and high velocity dust storms are quite common during the months of May and June and occasionally westerly wind velocities of more than 50 km per hour have been recorded (Goel et al., 1990).

Table 5.1:Average monthly temperature, wind velocity and relative humidity at Gurgaon (1972-1987)

Month	Average temperature (°C) Maximum	Minimum	Mean	Mean wind velocity (km/hr)	Relative humidity (%)
January	25.7	1.9	13.4	3.22	77
February	29.6	2.6	15.5	4.02	66
March	36.2	6.9	21.0	4.99	62
April	41.8	13.8	25.8	5.16	46
May	44.3	18.8	31.8	5.66	45
June	45.2	21.6	33.1	6.84	51
July	41.3	23.6	30.8	5.2	77
August	38.0	22.5	29.3	3.7	80
September	38.5	19.8	28.8	3.16	72
October	36.6	11.9	25.5	2.8	62
November	32.5	6.6	19.8	2.54	65
December	27.1	2.4	15.0	2.99	74

Source: Goel et al., 1990.

Relative humidity

There is marked variation in the values of relative humidity of different months (Table 5.1). The relative humidity during summer months is low and high during the monsoon period.

The following sections, deal with the classification of forest-common land into land suitability classes which would be considered homogenous in their properties for the purpose of mathematical modelling described in chapter six.

5.3 Survey methodology

For the purpose of mapping and classification of the forest-common land four site factors were considered in this study. These factors were topography, vegetation, soil and land use. All of them were found to be important elements in the management of the site in general. In order to study the identified site features in detail, a survey was conducted as described below.

Topographic survey

To delineate topographic units, a reconnaissance survey of the site was initially undertaken to gain an idea of the boundary and general features. Thereafter, a thorough survey of the area was conducted with the help of a chain and a compass. In the beginning, the external boundary of the area was surveyed and marked. Internal details were noted by laying east-west transacts at intervals of 200 m across the area. During this exercise details of altitude, slope, position of nalas (streams), presence of vegetation, location of quarries, etc., were recorded on survey sheets. These details were then plotted and a detailed topographic map was prepared on 1:10,000 scale. Topographic maps on 1:25,000 scale prepared by Survey of India (SOI, 1972), were used to demarcate contours.

Vegetation survey

During the topographic survey observations were recorded of the main vegetation types. Analysis of vegetation was carried out by selecting representative sample plots in each of the visually distinct vegetation areas. Two types of sample plots were chosen: areas with woody vegetation, predominantly of trees, were studied by sample plot of 30 m × 30 m size and areas with few or negligible number of trees were analysed by laying sample plot of 20 m × 20 m. The larger size of sample plots in the former situation was chosen because of the spread of tree canopies. A total of eleven sample plots were laid all over the site area for the vegetation analysis. The species of trees, shrubs and herbs were recorded (Appendix 5.1). The average crown diameter of tree species was calculated from two measurements of crown projection measured at right angles. The crown diameter was taken to get an idea about the abundance of different tree species. Based on the observed vegetation characteristics the site was subsequently divided into areas having distinct vegetation types. The different vegetation types were drawn on a map on 1:10,000 scale.

Soil survey

First of all, the surveyed topographic zones were inspected to detect differences in soil type. The help of local farmers, graziers and soil experts from the local research centre of Haryana Agricultural University was taken to discern differences in soil properties. Presence of vegetation and incidence of erosion were recorded. In places of apparently uniform soil but with differences in vegetation, erosion and other observable features, soil pits were dug out and studied for soil depth and profile. The above exercise provided a base to demarcate areas having more or less similar soil on external or visual observations. The next step was to take soil samples from each of the visually demarcated soil regions. In places where soil depth exceeded 30 cm, two samples were drawn one up to 30 cm depth and the other from 30 cm to 60 cm depth. The collected samples were analysed for nitrogen, potassium, phosphorus, organic matter, pH and electrical conductivity. Based on the above properties a soil map was prepared on a 1:10,000 scale.

Land use survey

Division of the site based on land use was carried out by actually identifying the current use activities on the site. Most of this work was completed during the topographic survey. Based on these, a land use map on 1:10,000 scale was prepared.

5.5 Land zones based on the site features

Information on the site features gathered during the survey was used for dividing the common-forest land into feature specific land areas. Properties of a particular site feature remained essentially similar within a land area. The land areas were called 'zones' corresponding to the four site features. The land zones based on topography, vegetation, soil and land use are described in the following sections 5.5.1 to 5.5.4.

5.5.1 Topographic zones

In general, the whole site terrain is undulating and dissected by seasonal rivulets. The terrain slopes in east and west directions. The westward slope is gentle to moderate and the hill merges into sandy agricultural land without any appreciable change in the slope angle. On the eastern side the slope is gentle to very steep and precipitous and the hillocks are rising from aeoline sand deposits formed due to wind deposition (Fig. 5.4). In places, quartzite formation forms the steep slopes and cliffs. Broadly, the site can be divided into two distinct parts referred to here as hill and undulating pediments.

The hill region constitutes about seventy five percent of the common-forest land. It consists of almost flat top with good soil development and moderate to steep hill slopes with little or no soil formation. The flat top contains approximately six percent of rocky outcrops and depressions of variable sizes. The pediments consists of soil deposits at the foothills with rock outcrops and aeolian deposits locally called *Bhur*[1] lands. The soil is fairly deep and the land is undulating with gentle slopes. These aeolian deposits are badly eroded and dissected to give a ravine look.

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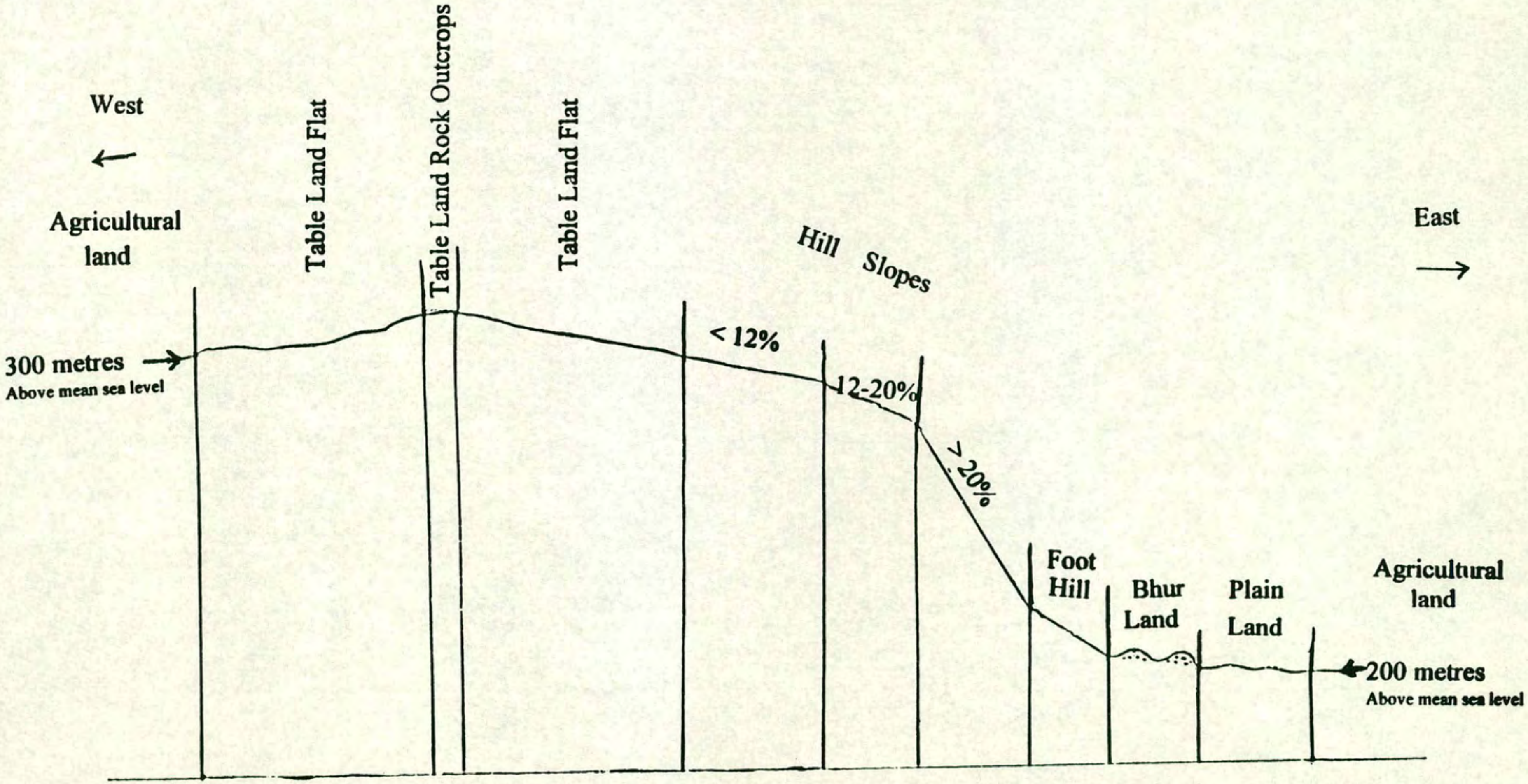
[1] The term *Bhur* denotes an elevated piece of land formed by accumulation of wind-blown sands, during the dry months (Wadia, 1975).

Fig. 5.4: Cross section of the study site along an east-west transect



On the basis of altitude, slope, soil deposit and surface features the common-forest land was divided into four topographic zones on the basis of similarities in topographic characteristics (Fig. 5.5). The zones and their characteristics are described below. Table 5.2 shows the area of each zone.

Table 5.2: Topographic zones and the areas of the site

	Area	
Topographic zone	Absolute (ha)	Percent
Hill Top	289	41.4
Lower Slopes	98	14.0
Higher Slopes	189	27.1
Sandy Plain	122	17.5

Hill Top

The altitude of this topographic zone varies from 275 to 306 metres above mean sea level. The slope is gentle (up to 6°). Soil formation is good; soil depth varies from 30 cm to 200 cm; and it is mixed with boulders. Natural depressions have deep soil and contain comparatively high moisture. The surface is almost flat with hard bed rock and depressions. In some places rocky outcrops are present which have steep slope and very little soil development. Their surface is marked by rocky boulders in various stages of disintegration. Water gets collected in the depressions during the rainy season. This region can support good vegetation except on the rocky outcrops.

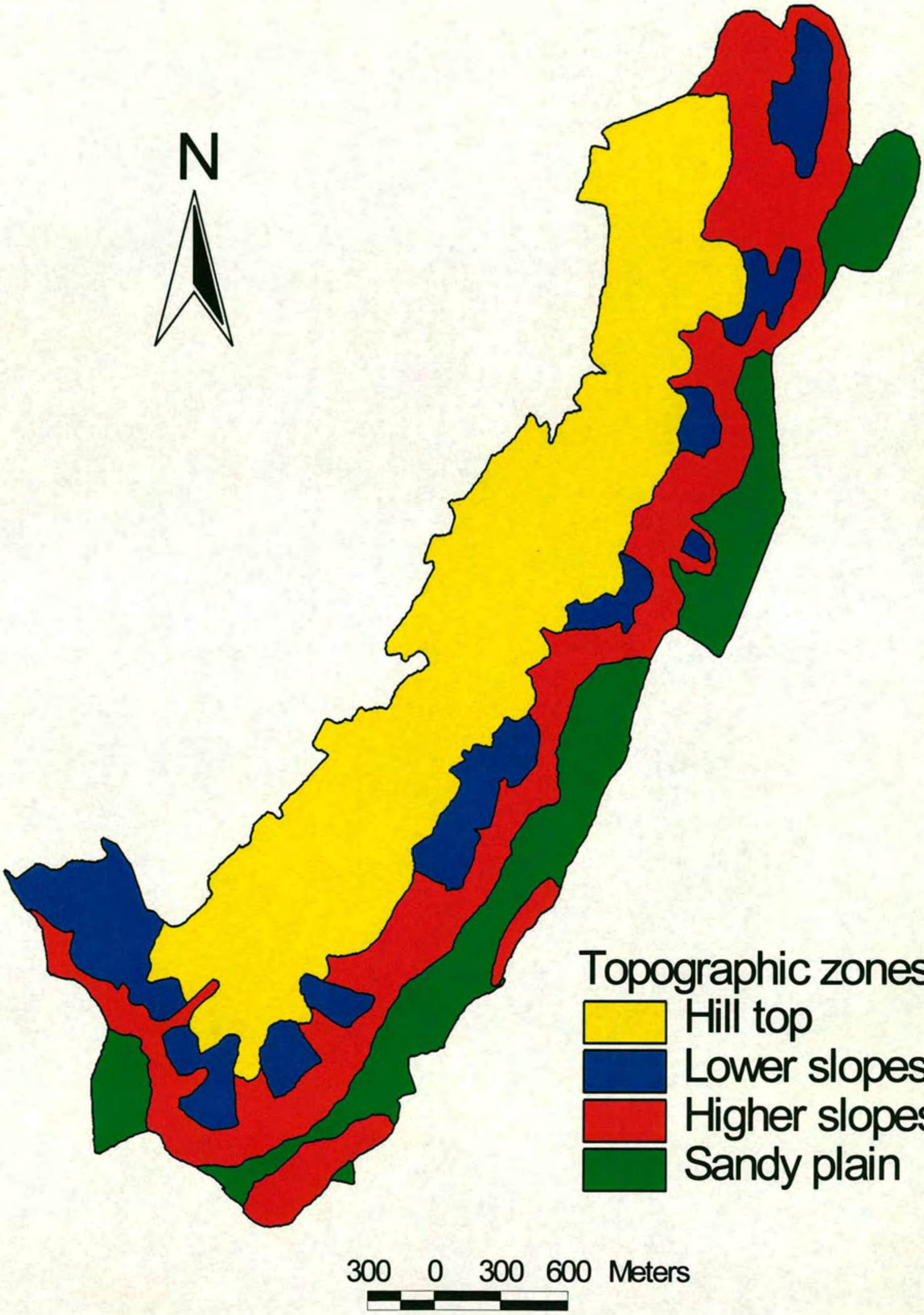
Lower slopes

The altitude of this zone ranges from 250 to 280 metres. Slope varies from 6° to 12° (at few places up to 20°). There is a fairly good amount of soil formation up to 60 cm deep. Rocky outcrops and stone boulders are found on the surface at many places. Rock in this region is more exposed in comparison to the hill top zone. There is some infiltration of rain water but most of it is washed away as surface run-off. These areas can support almost all the species of trees, bushes and grasses naturally found in the area.

Higher slopes

The altitude varies from 210 to 275 metres. The angle of the slope is more than 12° and in some areas the rocks are vertical. Soil formation is not good but in rock crevices deep soil with roots of trees and shrubs is quite common. The lower part of this zone is a mix of soil, rock boulders and debris rolled down from the higher altitudes. These areas are badly affected by water erosion and have very difficult terrain.

Fig. 5.5: Topographic zones of the common-forest land



Water erosion is accelerated by deforestation and grazing. There is hardly any infiltration of rain water. This area is less suitable for vegetation and moisture conservation but quarrying can be undertaken on these areas.

Sandy plain

The altitude varies from 195 to 210 metres. This zone comprises unstable and/or partially stable sand dunes with gentle to moderate slopes. The soil is sandy. The sand dunes are formed by high velocity wind which brings particles of silt and sand from other areas and deposits them near the hillside where wind velocity is reduced by the hill. These deposits are deep which take large forms and are mostly present on the eastern side of the site: they are badly eroded and dissected to give a ravines look. The main features of this zone are severe wind and water erosion, low fertility, low organic matter, undulating terrain, excessive drainage, very high infiltration rate, low water holding capacity and low cation exchange capacity of soil. Vegetation consists mainly of herbs and bushes with trees on some parts.

5.5.2 Vegetation zones

The natural flora of the area is classified as Northern Tropical Thorn Forests (Champion and Seth, 1968). These forests contain almost pure patches of *Acacia senegal* in association with *A. leucophloea*, *Salvodora oleoides*, *Zizyphus* and *Capparis* species. This type often merges with the degradation forms of Northern Tropical Dry Deciduous type like *Zizyphus* scrub. Presently, there appears to be no regular pattern of vegetation in the area. Most of the original vegetation has reduced to a shrubby form and stunted root stock under the pressure of excessive grazing and over-exploitation. Plantations of exotic species such as *Acacia tortilis* and *Prosopis juliflora* are spread over some parts of the research site.

Past vegetation trend: The site was very well covered with thick vegetation up to the early part of this century. There was no dearth of fuelwood, fodder and timber (SFD, 1994). Drought and famine in 1932 made people eat roots, leaves and bark of certain trees for their survival. This adversely affected the health of trees but the forest had the capacity to recover quickly. During World War II (1939-45), large scale felling of trees especially dhok (*Anogeissus pendula*) took place for making charcoal. The area still had a fairly good stocking of trees and shrubs. Village heads called 'Lamberdar' and elder people used to look after the forests on common lands and government used to take care of its forests. This system worked quite well.

Some of the subsequent events since 1950s led to almost total degradation of the site. Land consolidation process in 1962-63 encouraged people to fell trees on their holdings to earn extra money. This diverted the pressure on forest areas for fuelwood, timber and some fodder. In 1985, the government provided subsidies to farmers for purchase of cattle, goats, sheep, etc. This led to a rise in cattle and small ruminant population with inevitable pressure on forest lands for grazing. Of late, quarrying has become one of the major causes of degradation of the site. All these factors have resulted in a previously well wooded area being degraded almost into a wasteland site.

The most important grass for soil and water conservation found in the area is 'Munj' (*Saccharum munja*). This species is economically very important. Anjan (*Cenchrus ciliaris*) is the important fodder grass. Ber (*Zizyphus* spp.) is an important fodder shrub. The most widespread firewood species is *Prosopis juliflora* though the most preferred species are ronj (*Acacia leucophloea*) and dhok (*Anogeissus pendula*).

The entire site can be broadly divided into four vegetation zones (Table 5.3) on the basis of species composition and site features supporting growth of vegetation. These are shown in Figure 5.6 and their characteristics are described below.

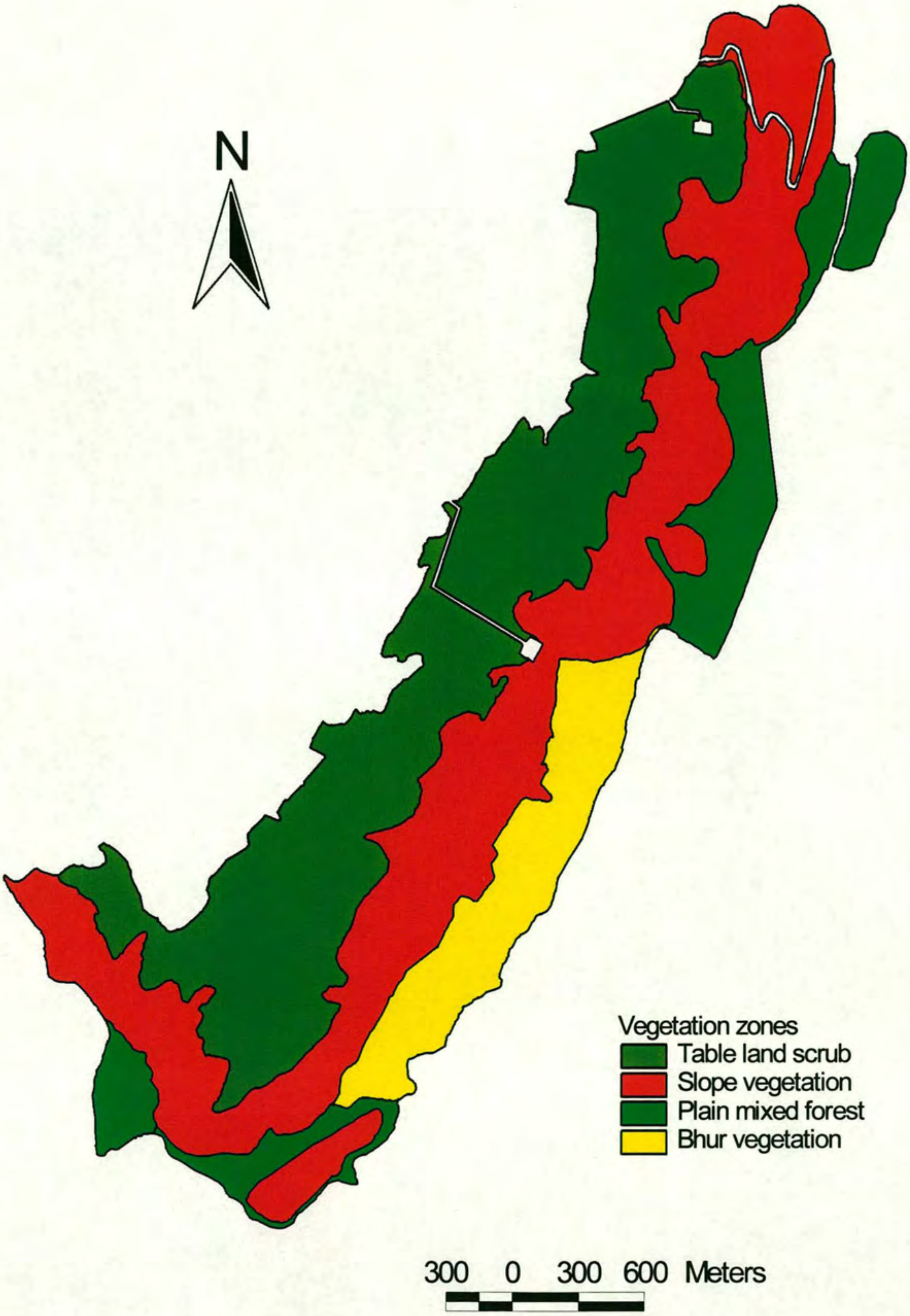
Table 5.3: Vegetation zones and their areas

	Area	
Vegetation zone	Absolute (ha)	Percent
Table land scrub	278	39.0
Slope vegetation	282	38.8
Bhur vegetation	67	10.2
Plain mixed forest	77	12.0

Table land scrub

The original vegetation from this region has almost vanished but still a substantial amount of root stock of many species is present. Due to good soil depth the root stock survives and vigorously pushes shoots up in the absence of biotic interference. The most prevalent species at the moment is mesquite constituting about 80 percent of the total vegetation. Other natural and promising species are: dhok, gangerin, ronj, dhak, papri, desi papri, amaltas, anjan tree, kachnar, hingot, kendu, gondi, and imli. All these species can be seen in patches or as single trees at places. These have been subjected to browsing, illicit cutting and mining affects. Medicinally important species are generally not felled. Main shrubs are bansa, balanite, and kair.

Fig. 5.6: Vegetation zones of the common-forest land



Important grasses are anjan, lapa and sarala. Grasses grow quite luxuriously and are the important source of fodder. Soil development and the gentle terrain are suitable for the growth of the vegetation.

Slope vegetation

Hill slopes are generally eroded. Vegetation on gentle slopes is denser than on steep slopes. On the very steep and precipitate slopes, only a few plants can be seen. The lower hill slopes bear good vegetation but this is influenced by biotic pressure. Species recorded on the slopes are: ronj, dhok, khairi, inderjau, dhak, and mesquite on lower slopes. On *nala* slopes particular species noticed were gingon, salai, inderjau, karaya and gum. Main shrub species are bansa, kair, gugal, lantana and jhar beri. Important herb species are balvala chirchita, jangli tulsi, anjan grass, barlu, daabsuli, sadahari, lapa, sarala and satti. Little or negligible soil development and difficult terrain are a deterrent to plant growth.

Bhur vegetation

Extensive silt and sand deposits due to wind erosion are present on the leeward side of rocks. Most of these deposits are now in a stable form but fresh deposits or disturbed dunes can also be seen. Vegetation mostly consists of shrubs and herbs. Species of this zone are bui, jhojhru, kheep, adha sheeshka doda, babul, jhar beri, Lapa grass, bhurat, sania, munj, ak, pawar, satti, ronj, hingot, kaur tumba, bansa, kharenti, jaichi, nagrmotha (near water bodies), barna and kair. Soil and the terrain of this part are not very good for planting useful species but the site can be manipulated for plant growth.

Plain mixed forest

These are undulating mainly sandy areas more or less stable with good natural vegetation. Of course, the vegetation is disturbed by felling and lopping. Tree species of this region are: khairi, janti, neem, kikar, papri, Israeli kikar, jal, amaltas, hingot, ronj, imli, karaya gum, uloo neem, dhak, kachnar, kakera, mesquite, sonjna, gular, pipal, siris, shisham, and *Kijelia pinnata.* The shrub species are bansa, kair, jhari beri, kakera, kendu, gangerin, ak, babul, adha sheesh ka doda, and desi papri. The herb species are bathua, bhurat, anjan, jhojhru, nagad bawri, kharenti and munj. Khajur and arind are found in a small part of the region where water spring exists. The soil and terrain of this region are quite good for plant growth.

5.5.3 Soil zones

The summer winds and dust storms cause widespread loess (aeoline) deposits on the eastern side of the hill. Soil formation on the hill tops is due to *in situ* weathering and erosion.

Soil depth and texture varies mainly according to the topographic conditions. On the hill slopes, soils are badly eroded, shallow and marked with conspicuous bare rocks. Deposits of deep soil occur between boulder outcrops or in depressions. A high degree of erosion and poor vegetation cover do not permit any improvement in soil conditions. Natural species struggle to survive by sending their roots through rock crevices. The table land on hill tops provides deeper soil conditions which are more favourable for tree growth. The aeolian deposits are largely stable, having a partial vegetation cover. Deep sandy, sandy loam and alluvial deposits are found on the foothills and plain land.

On the basis of soil texture, depth, pH, fertility status, electrical conductivity and ability to support vegetation, the site is divided into four soil zones (Table 5.4). Their location on the site can be seen in Fig. 5.7.

Table 5.4: Soil zones and their areas

	Area	
Soil zone	Absolute (ha)	Percent
Skeletal	123	17.6
Table deep	25	3.6
Medium loam	433	62.0
Sandy	117	16.8

Skeletal

There is no definite soil layer in this zone because of the hard rocks exposed to the surface. Soil formation can be seen between rock crevices and tiny depressions on rock surfaces. In this type of soil, the silt content is quite high, pH varies from 7.1 to 7.4 and electrical conductivity is 0.11 - 0.12 m.mho/cm. Fertility level is quite low with organic content of only 0.255%. Availability of phosphorus is 6.5 to 14 kg/acre and potash is 242 to 247.5 kg/acre. This soil can hardly support any tree and shrub species but grass can come up if there are good rains.

Fig. 5.7: Soil zones of the common-forest land

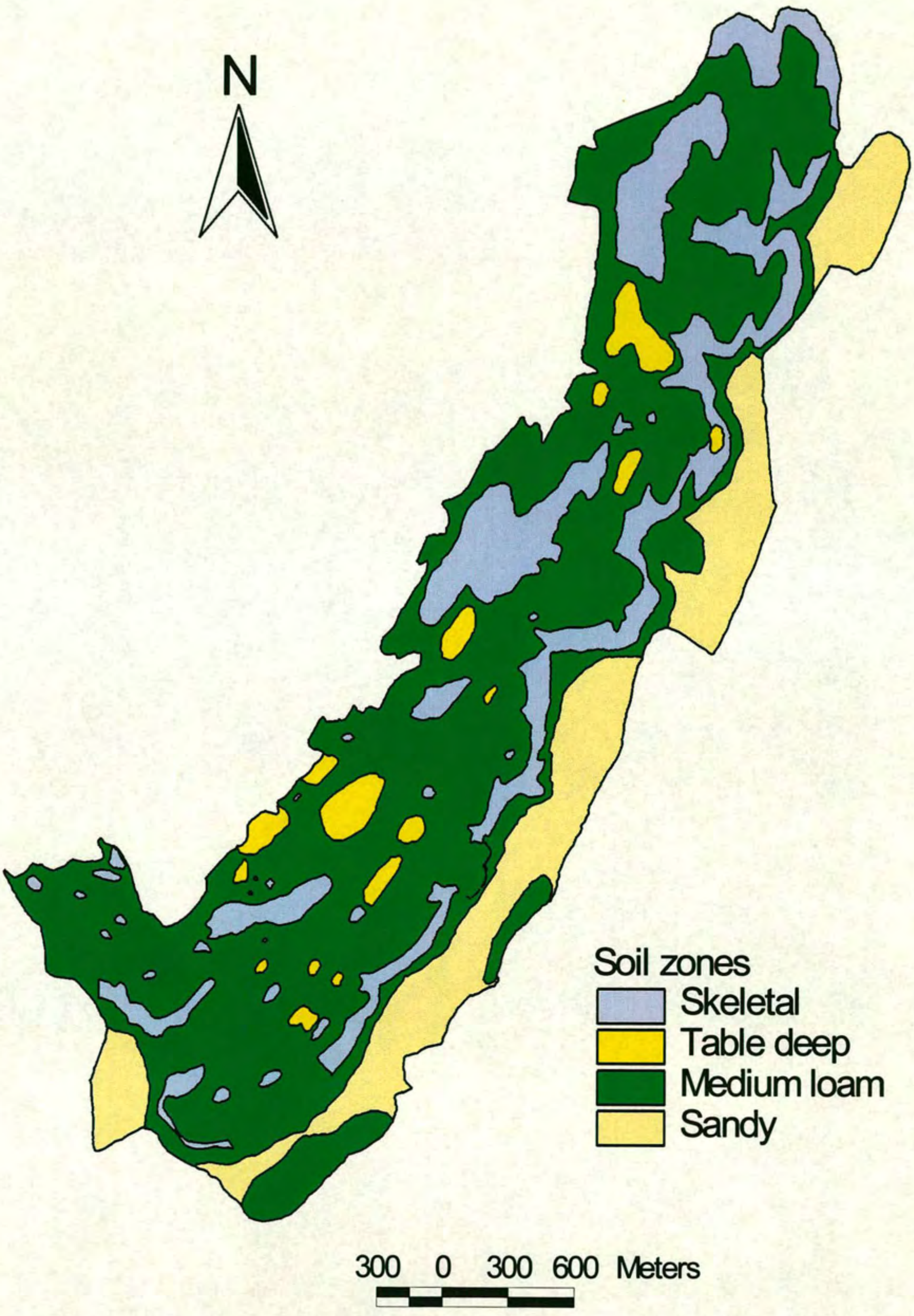


Table deep

Soil of this zone is mainly sandy loam and depth varies from 30 cm to over 200 cm. In some places the clay content is quite high. pH varies from 7.2 to 7.6. Organic carbon content varies from 0.21 to 0.33%. Availability of phosphorus varies from 14 to 16 kg/acre and that of potash from 209 to 220 kg/acre. Electrical conductivity of these soils is from 0.12 to 0.20 m.mho/cm. Erosion incidence is not prevalent. These soils are quite stable and provide very good conditions for plant growth.

Medium loam

Soil depth varies from few centimetres to 60 cm but in few small places soil may be 200 cm deep. Soil is sandy to sandy loam. Other characters are: pH - 7.1 to 7.6; organic matter - 0.37 to 0.45%; phosphorus - 6.5 to 18 kg/acre; potash - 192 to 303 - kg/acre; and electrical conductivity - 0.10 to 0.14 m.mhos/cm. This soil zone is capable of bearing good vegetation particularly grass and some particular tree species. It is the major source of grass for the villagers.

Sandy

This zone contains very deep sandy soil in which soil layers can not be distinguished. The pH of this soil is comparatively higher ranging from 7.9 to 8.7 but poor in organic carbon (0.21 to 0.29%). Availability of phosphorus and potash is 4 to 16 kg/acre and 209 to 407 kg/acre respectively. Its electrical conductivity varies from 0.13 to 0.16 m.mho/cm. These soils have very high infiltration rate and very little water holding capacity. In some pockets where water gets collected during the rainy period, clay content increases in the soil which makes the soil surface crack when it dries up. A good vegetation cover can be supported by this zone.

5.5.4 Land use zones

The area is put to multiple uses and most of it is affected by human activity. On the basis of current use the entire site area was allotted to eleven types of uses (Table 5.5). Most of them are very specific, but some uses such as grazing and plantation and natural vegetation overlap in their extent. For instance, cattle can be seen grazing in plantation and natural areas in addition to the assigned grazing area.

Table 5.5: Land use of the common-forest land

	Use	Area (in ha)	Percent of the total area
1	Grazing	472	67.0
2	Nursery	6	1.0
3	Plantation & natural vegetation	63	9.0
4	Water tank	6	1.0
5	Quarry	59	8.0
6	Road	2	0.3
7	Abandoned mines	13	1.8
8	Tourism	13	1.8
9	Office complex	7	1.0
10	Cremation	1	0.1
11	Unspecified use	63	9.0

Some of the uses are fixed as far as availability of land is concerned and they involve comparatively small areas. Therefore, for the purpose of the present research these uses have been grouped into three zones namely planting, quarrying and miscellaneous (Table 5.6). The geographical spread of the zonal areas is shown in Fig. 5.8.

Table 5.6: Land use zones and their areas

	Area	
Land use zone	Absolute (ha)	Percent
Planting	598	84.8
Quarrying	72	10.2
Miscellaneous	35	5.0

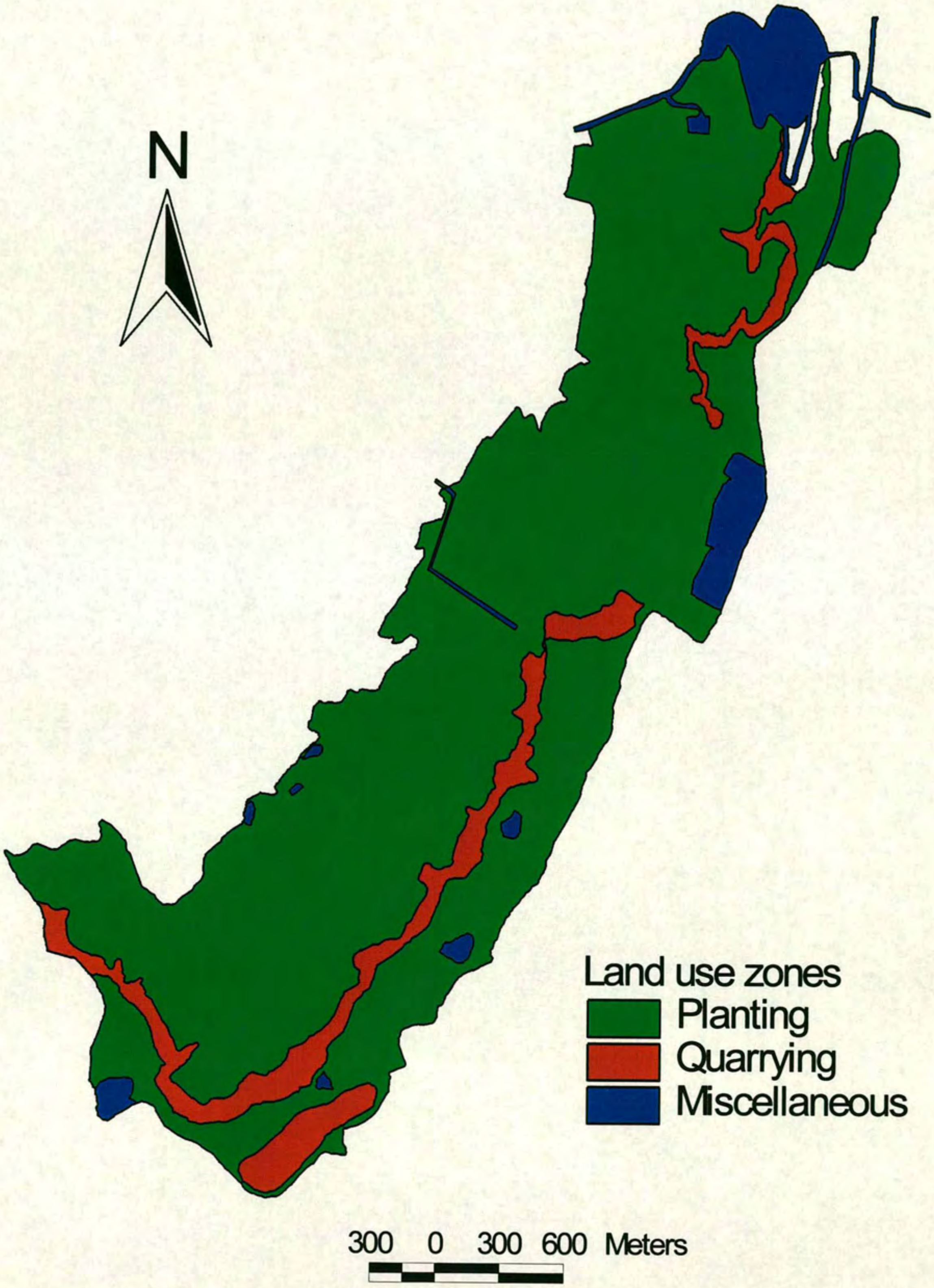
Planting

This land use zone constitutes about 83% of the total site area. People graze their cattle freely on all the site land except those areas which are restricted or unsuitable. When some part of the area is taken up for plantation, it is closed for grazing for a period of three years in the beginning to allow proper establishment of new plants. Afterwards, people can use it for grazing. Most of the area of this class is suitable for planting trees and grasses.

Quarrying zone

This land use class mainly comprises of the areas which are rocky with steep slopes. Rocks are broken by dynamite blast and then the broken stone pieces are loaded in trucks or transportation elsewhere. There is no scope for planting. Debris from the rocks roll down and gets collected at the bottom of the hill or some water stream.

Fig. 5.8: Land use zones of the common-forest land



Miscellaneous

As indicated, this land use class is used for various purposes, most of them are permanent uses. Within the boundary of tourism, nursery, antenna test site and office complex premises, there is a very good growth and cover of varied tree species because these areas are not disturbed by grazing or illicit cutting. Water bodies, in particular, help in moisture conservation by storing rain water.

5.6 Land suitability classification

The area of common-forest land was delineated into five suitability classes. The criteria for delineation were the factors supporting vegetation growth, ecological maintenance especially in terms of soil and moisture conservation and biodiversity conservation, land use and the potential for quarrying.

Emphasis was given to the site factors supporting vegetation growth because growing plant species on the common-forest land was a major activity covering a substantial area. The soil and moisture conservation were found to be important for the local environment and sustainability of agriculture. Land use was found to be important because certain types of uses on the site would remain unchanged, for whatever purpose the land might be suitable. Therefore, such areas were kept in a separate land class which is important in overall planning. Quarrying has been an economically and ecologically important activity in the area, so it has to be included for the land delineation purpose. The details of site delineation procedure are described in sections 5.6.1 and 5.6.2.

5.6.1 Use of GIS in land delineation

A Geographical Information System (GIS) is a computer-based information system designed to facilitate integration and analysis of geographically referenced data. Generally, it possesses the capacity to store, evaluate, combine and conditionally extract information from maps and associated attribute data. Essentially, GIS technology offers greater sophistication and accuracy in spatial data organisation and visual data interpretation (Mallawaarachchi et al., 1996). One of the most important applications of GIS is in the field of land use planning (Diamond and Write, 1988; Aronoff, 1989; Bracken et al., 1989; Tomlin and Johnston, 1990; Keller and Strapp, 1996).

Geographical information systems have generally been of use to land use planners in three major capacities (Tomlin and Johnston, 1990):

- the maintenance of general purpose data;
- the generation of special purpose information from such data; and
- the utilisation of such information in decision-support contexts.

The use of the GIS in decision-support has been mostly for land-use allocation, or the apportionment of land for specific types of development or utilisation.

It is possible to handle delineation of land into units by conventional inventory methods, if the delineation criteria is restricted to a limited number of characters such as soil or vegetation or topography. But when several criteria are used to delineate or classify land into homogeneous units, it becomes confusing and too complex to engage with large amounts of information.

In the present study, the common-forest land is to be delineated on the basis of many properties, i.e., topography, vegetation, soil and land use characters. It is necessary to reduce many properties and their associated variables in order to bring understanding on the basis of proximity or correlation of different variables. The most commonly used method of examining data measured on ratio scales for correlations is principal component analysis (Burrough, 1986; Corbett, 1996).

The principal component analysis is applied generally when large number of data sets with exact characteristics are present and there are many map layers, generally more than six layers (Wright, 1997). In the present study only four map layers, topography, vegetation, soil and land use are being used for classification, and the personal knowledge of the area plays an important role. Therefore, a simple GIS overlay, reclassification and generalisation (Tomlinson and Boyle, 1987) method was used in this study for classifying the forest-common land.

Reclassification is the regrouping or change in value of a set of existing attributes based on a set of rules that specify how to regroup or change the value, and generalisation involves dissolve and merge of polygons produced as a result of reclassification. Generalisation is often used to reduce the level of classification detail (Arnoff, 1989).

5.6.2 Delineation methodology

For the ourpose of delineation, topographic, vegetation, soil and land use zones identified, mapped and described in section 5.5, were used. The four zonal maps were first digitised using ARC/INFO software. Registration (TIC) points were used to transform from digitiser coordinates into simple latitude and longitude. Once each map had been registered to a common geographical reference system, the maps were combined through overlay. The ARC/INFO 'UNION' command was used to combine all of the spatial and attribute information from the input map layers, as shown in Figure 5.9.

Overlaying different maps produced a new set of polygons formed by the intersection of the boundaries in the original maps. A new database column was added to this new composite map layer. Land class codes for each polygon were computed[1] from the entries for soils, vegetation, land-use and topography, and stored in this column. The classification scheme adopted is included in Appendix 5.2. Once this column had been added, boundaries between similar polygons were dissolved and small insignificant areas, called 'silver polygons' (McDonnel and Kemp, 1995), were merged with adjacent large area polygons.

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[1] This was achieved using the Reselect, Calculate, Aselect and Nselect commands in the 'Tables' module of the ARC/INFO.

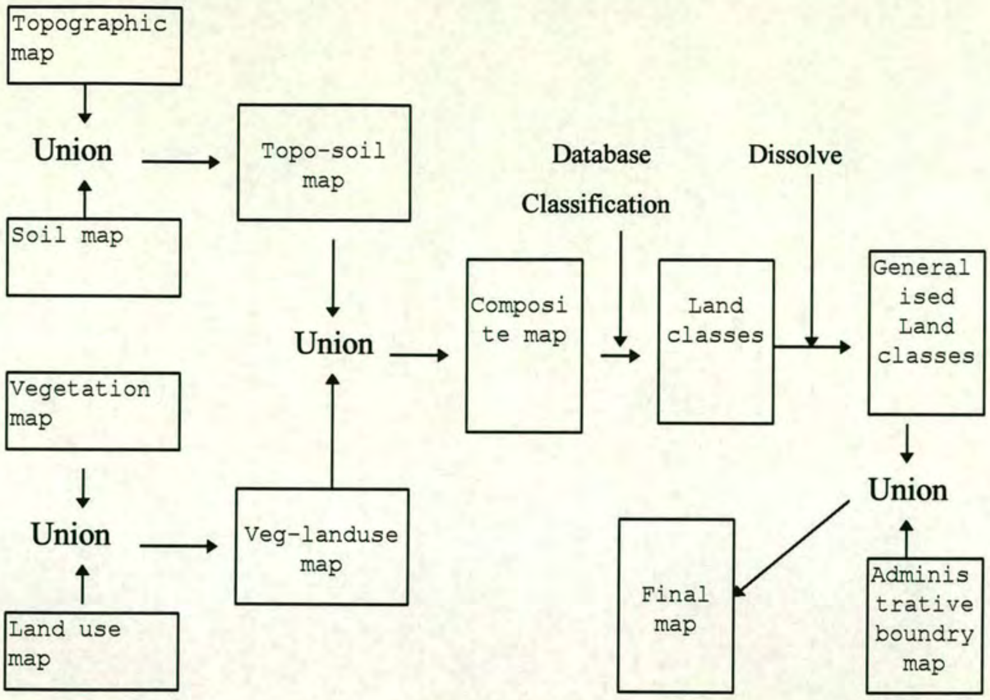


Fig. 5.9: Flow chart of the GIS operations used to create a map of land suitability classes

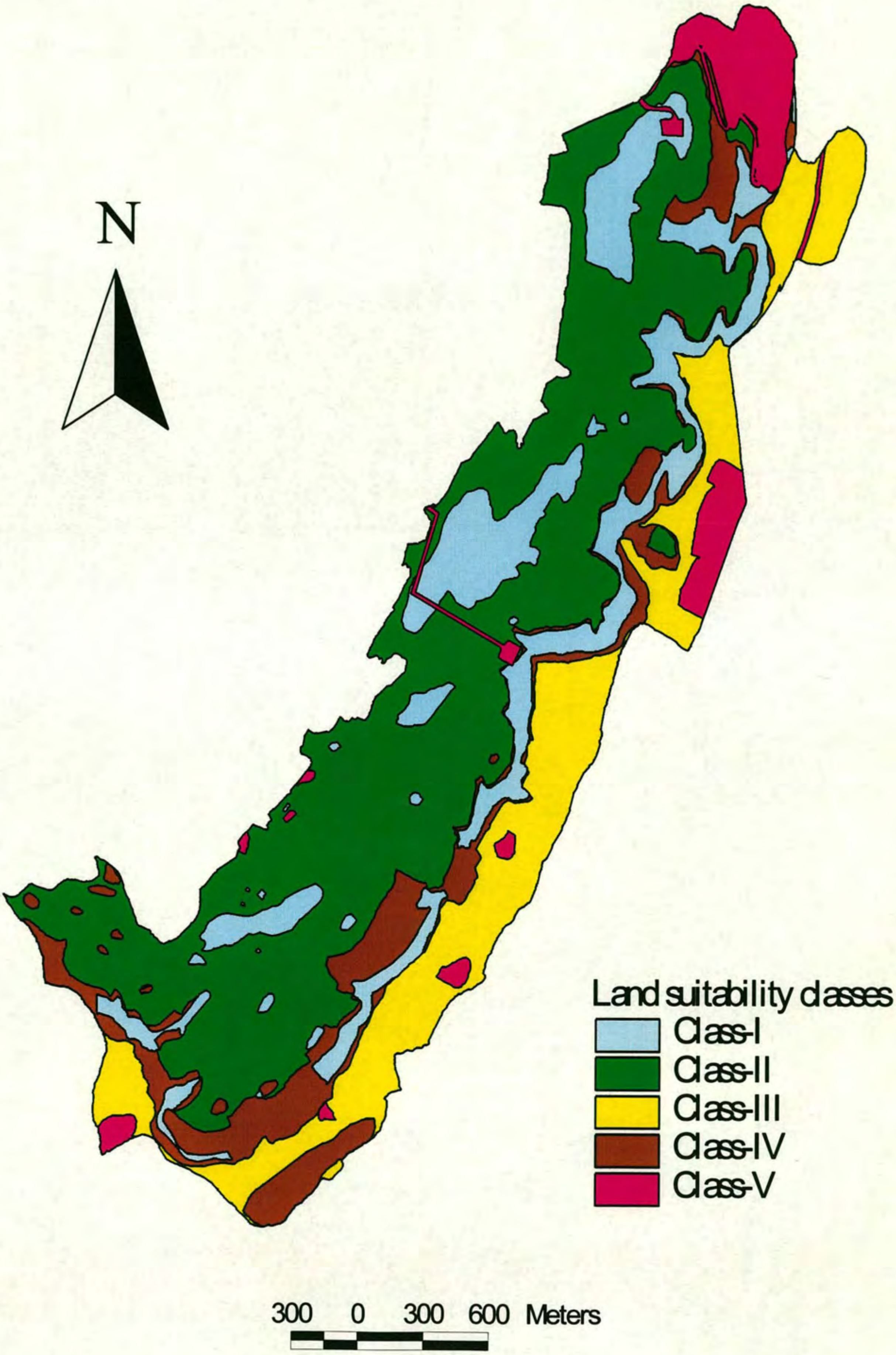
5.6.3 Land suitability classes

The area of common-forest land was classified into five groups (Table 5.7), called here land suitability classes, on the application of methodology described in section 5.6.1 and 5.6.2 above. Specific characteristics related to topography, vegetation, soil and land use are given in Appendix 5.2, and the geographical spread of different classes is shown in Fig. 5.10. Salient features with respect to criteria of delineation for each class are discussed below.

Land suitability class I

This class land is characterised by rocky and hard surfaces on the top of the hill and steep slopes. The area bears very little or no vegetation; and soil formation is negligible. It is suitable for quarrying and in fact all the abandoned as well as active quarries are present in this region. This land class is not suitable for planting.

Fig. 5.10: Suitability classes of the common-forest land



Land suitability class II

It has gentle to moderate slope. Soil formation is medium to deep. Some scrub vegetation can be seen with good rootstock in soil. Favourable soil conditions provides a scope for good vegetation growth. This part of the site is under no particular use except in some parts where plantation of mesquite (*Prosopis juliflora*) and other species has been taken up. At the time of the survey work, grazing was allowed on this class land without any restrictions.

Table 5.7: Land suitability classes of common-forest land

Land suitability class	Area Absolute (ha)	Percent
I	112	16.5
II	308	45.5
III	126	18.6
IV	83	12.3
V	48	7.1

Land suitability class III

This area is characterised by undulating sand dunes and plain area often dissected by water streams. The soil is sandy and very deep. Plantations of mesquite and *Acacia tortilis* have been taken up on a part of it, natural vegetation occurs on the relatively plain area and scrub, herbs and bushes occur on the sand dunes. At few places in depressed locations, water collects in the rainy season converting such areas into temporary water bodies. The area is mainly used for planting, grazing and collection of soil and forest products.

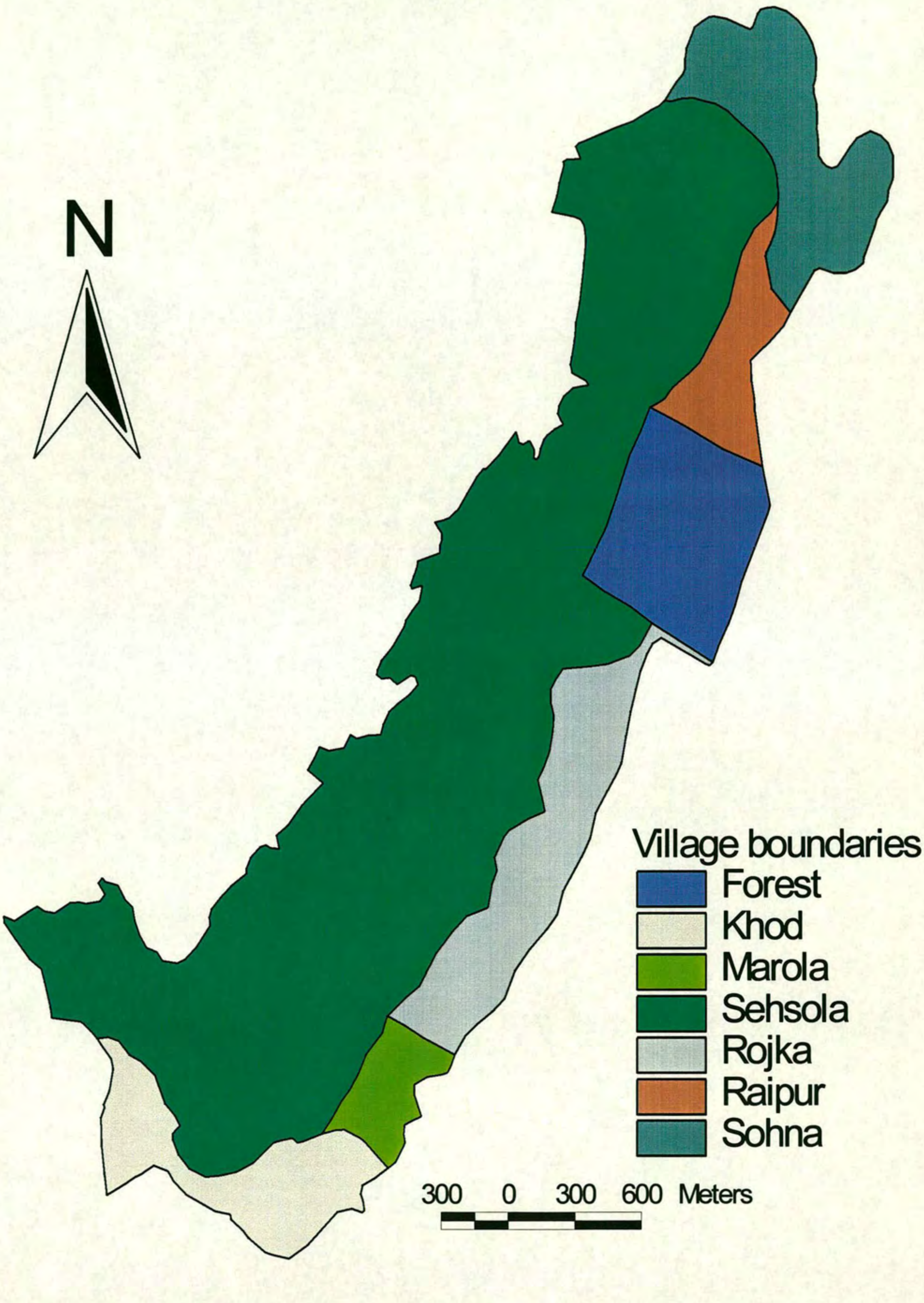
Land suitability class IV

It has moderate to steep slopes but with some soil development. Some tree species, shrubs and grasses can be seen growing on this area. Some parts are used for grass plantation and collection, grazing, stone collection, etc. There is little scope for tree planting on this area but this site is suitable for planting grass species.

Land suitability class V

This area is characterised by varied topography, vegetation, soil and land use conditions. The area is mainly used for specific purposes such as tourism, nursery, office complex, scientific installations, road, etc. The land under this area is not really available for activities other than the current use. Though the land is not

Fig 5.11: Village boundary map



available for developing a management plan, this land class is important as it provides employment to local people and some other benefits.

5.7 Village land suitability classes

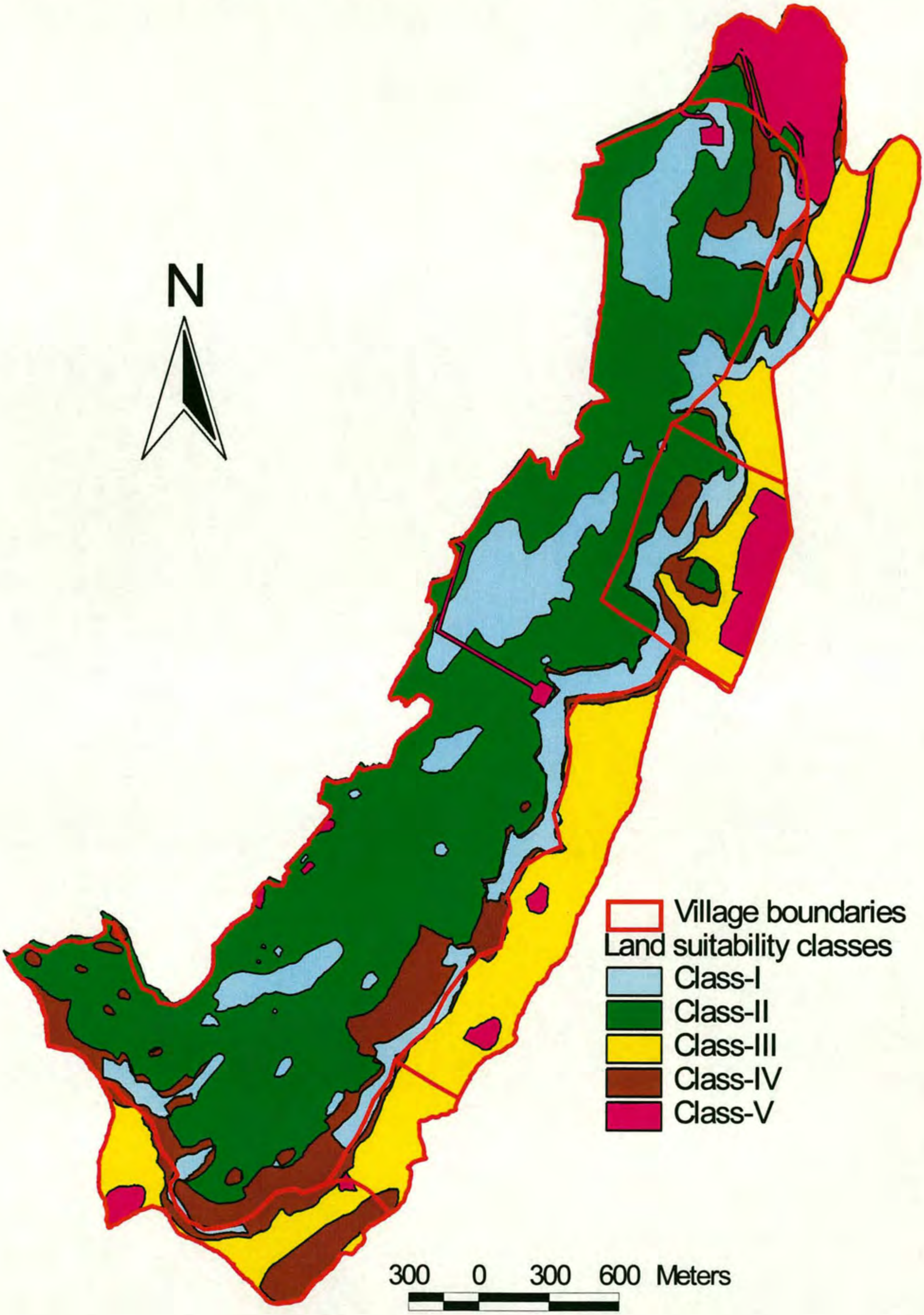
The common-forest land has been divided into five land suitability classes as described in section 5.6. The land is separately owned by six villages and the forest department. In order to develop a planning strategy for individual villages it is obviously necessary to determine the land suitability classes for each village. To find the extent of area under each of the land suitability classes, the village administrative boundary map (Fig. 5.11) was overlaid on the final map with the help of GIS ARC/INFO. A union map was produced (Fig. 5.12) from which the areas of each land suitability class were calculated for each village (Table 5.8).

Table 5.8: GIS results -village area (ha) under different land suitability classes

Village	Land class I	Land class II	Land class III	Land class IV	Land class V
Khod	0.8	-	18.4	15	2.4
Marola	0.7	-	12.7	21.4	0.1
Rojka	1.3	-	50.3	2.8	2.2
Raipur	7.2	5.8	9.2	2.4	-
Sohna	2.3	3.5	19.1	2.5	25.4
Sehsola	90.0	276.4	0.6	47.6	4.9
Forest	8.6	13.1	13.2	8.9	10.8

The bio-physical survey and GIS have helped in categorising the land resource into areas having homogenous characteristics. Such a classification of land would be helpful in developing suitable management strategies for an individual category of land. This is discussed in the following chapter.

Fig 5.12: Village suitability classes of the common-forest land



Part III

Analytical and planning framework

Chapter 6

Development of mathematical models for decision support to participatory management

Management planning of scarce natural resources essentially involves decisions about the allocation of the resources among competing uses so as to best achieve a set of objectives (Dent et al., 1986). The management process can usually be divided into six phases: (i) analysis of the system; (ii) construction of a mathematical model which reflects the important aspects of the system; (iii) validation of the model; (iv) manipulation of the model to produce a satisfactory, if not optimal, solution to the model; (v) implementation of the new plan; and (vi) the introduction of a strategy which monitors the performance of the system after implementation (Foulds, 1981). This study is concerned up to the fourth phase only. The other phases are important in participatory management but could not be a part of the research project.

6.1 Characteristics of the study site

The main resources in the study area are land, labour, livestock and capital. The three types of land are agricultural, common and forest. These lands are owned and managed differently. The agricultural land is owned and managed solely by local farmers. The common land is owned by Village Panchayat (VP) and is managed by the VP with the assistance of Forest Department (FD). The forest land is owned by the FD and is managed by the FD keeping in view the local environment and the demands and aspirations of the local people. For the purpose of this study, the land is divided into two broad categories. One category is for agricultural use and the other category combines common and forest lands (mentioned as 'common-forest' land).

Land use at the site is primarily determined by the actions of individual farmers, village groups and government departments in relation to prevailing economic and ecological forces. For instance, in recent years there has been a change in farm land cropping systems in favour of mustard and wheat from gram and barley crops. Quarrying has been undertaken on the common-forest land and industrial units have developed on some areas of agricultural land. On this site, objectives are complex and resources are limited. Moreover, there could be numerous alternative management options for any one type of land. Human and livestock pressure is high. People are comparatively backward and poor.

6.2 Need for a mathematical model

For suitable management of the site, the decision-maker(s), in this case, are the farmers, the VP and the FD. The environment, as indicated in section 6.1, in which the decision is embedded is so complex that an intuitive or easily derived solution is unlikely to provide a sound basis for decision-making. The essential aspect of this complexity is the multi-dimentional nature of the decisions to be taken. Decision-making is constrained by a wide variety of influences (for instance, the productive capacity of the land, the demand for particular products, climate, budget, etc). Any attempt to devise a framework for planning should consider these features and be capable of resolving the conflicts inherent therein (Mendoza et al., 1986; Romero and Rehman, 1984; Dent and McGregor, 1993; Dent and Jones, 1993).

Mathematical programming is concerned with the optimal allocation of scarce resources among competing ends (Dykstra, 1984). It involves the use of mathematical models to solve certain types of a problem. These models may be simple or complex. A mathematical model is developed to serve as an abstraction of the system under study. This model will include some means of evaluating solutions with respect to the optimality criteria (i.e., the objectives) and will ensure that the limitations on the availability of the resources are observed.

Mathematical programming models have been used where production activities are represented in terms of input-output relationships. An optimum value for the objective function is found by searching among the set of activities subject to various constraints imposed by resource availability or requirement or policy restrictions. The main advantage of this approach is to explore beyond the observed data. Activities can be differentiated subtly by altering input-output coefficients to reflect, for example, variation in management regimes or environmental conditions. This is particularly useful in the present context because of the continuous change in land use and management pattern. For the above reasons, mathematical programming was adopted to explore management options in the defined case study area.

6.3 Mathematical programming techniques

There are numerous mathematical programming techniques available to integrate complex information about natural resource management. Some of the relevant techniques are briefly discussed in the following sub-sections.

6.3.1 Single objective linear programming

Linear programming (LP) is one of the most important and widely used mathematical programming methods. LP has been applied to a wide range of planning problems in natural resource management including forestry (Bare, 1971; Leuscher et al, 1975; Johnson and Scheurmann, 1977; Bell, 1977; Kent, 1980; Johnson and Teddler, 1983), agricultural land use and agroforestry (Etherington and Mathews, 1983; Dykstra, 1984; Mendoza et al, 1986; Mendoza, 1987; Hanley and Lingard, 1987; Wojtkowski et al, 1988; Moxey et al., 1995). In some applications (Etherington and Mathews, 1983; Mendoza, 1987) a social welfare function has been included in the model.

For a problem set within a linear programming framework, the decision-maker wishes to maximise (usually profit) or minimise (usually costs) some function of the decision variables subject to a number of linear constraints. The function to be maximised or minimised is called the objective function. A general linear programming problem can be stated in algebraic terms relating to decision variables, constraints and technological coefficients:

Maximise (or Minimise) $Z = \sum C_j x_j$

Subject to

$$\sum a_{ij} x_j \gtreqless b_i \qquad i = 1,2,......., m$$

$$x_j \geq 0 \qquad j = 1,2,......, n$$

Where Z = denotes the objective function value

n = number of decision variables

m = number of constraints

x_j = decision variables or activities

C_j = objective function coefficient corresponding to x_j

a_{ij} = technological coefficient corresponding to variable x_j in constraint i (amount of resource required or production per unit of resource)

b_i = quantity of resource available for an activity in constraint i

Problems from a wide variety of human endeavour can be formulated and solved by means of linear programming. LP is recognised as a powerful and versatile computer-based aid because it can provide valuable insights into the nature of resource allocation decisions (Dent et al., 1986; Piech and Rehman, 1993). Nevertheless, the limitations and assumptions (i.e. linearity, divisibility and certainty) of LP may be seen as barriers to more effective representation of the land planning problem (Iverson and Alston, 1986). This approach, where a single objective is optimised, while treating others as restraints can produce disappointing solutions (Romero and Rehman, 1989). Optimisation of a single objective may have limited application to problems relating to small holder farming.

6.3.2 Multiple criteria decision making techniques

Multiple criteria decision making (MCDM) techniques encompasses a general class of mathematical programming techniques for solving problems in which several objectives are considered simultaneously (Mendoza et al., 1987). The general multiple objective programming problem involving *p* objectives ($p \geq 2$), n decision variables and m constraints can be expressed as:

$$\text{Max } Z(X) = [Z_k(X), \text{ for } k = 1, 2, ..., p],$$

$$\text{subject to } \; g_h(X) \; \substack{< \\ = \\ >} \; b_h, \quad \text{for } h = 1, 2,, ..., m$$

$$X \geq 0$$

where Z is a k-dimensional function, X is a vector consisting of decision variables $X_1, X_2, ..., X_n$, $g_h(X)$ represents the constraints associated with the problem and b_h is the right hand side values of the constraints.

The main MCDM techniques are summarised below.

Generating techniques

Generating techniques refer to those approaches whereby the analyst generates the entire set of nondominated solutions to a predefined problem in the absence of any goal preference information from the decision maker. Given this set of solutions, the decision maker applies some preference structure to arrive at the best compromise. The major problem with generating techniques is to decide which of the several objectives are fulfilled in different strategies when so many management alternatives are presented to the decision maker. The computational burden is high, and interpretation can become difficult with more than three objectives.

Multi-attribute utility function approach

The multi-attribute utility approach (MAUT) analyses the problem from a finite set of alternatives or systems assessed according to several criteria. MAUT is a theoretically sound approach based on the assumptions of perfect rationality underlying the classic paradigm of utility. Despite being theoretically sound and elegant, the MAUT is not very convenient to implement in practical terms mainly because of the rigid assumptions that it makes about the preferences of the decision maker (Rehman and Romero, 1993).

ELECTRE method

ELECTRE attempts to establish a partial ordering among the non-dominated alternatives by using an outranking relationship. In essence, ELECTRE is a technique for ordering a finite set of feasible systems from multiple viewpoints where outranking relations are established using the decision maker's preference. This technique is appealing mainly because of its simplicity and clarity (Rehman and Romero, 1993). Cohen and Marks (1975) have pointed out the failures of the ELECTRE method in providing opportunity cost information and measuring alternatives by comparative value. The technique is more suited to comparisons of discrete alternatives rather than to generating a range of alternatives.

Multiple objective programming

Multiple objective programming (MOP) seeks to find those solutions which are efficient in a Paretian sense. A given solution is Pareto-efficient and therefore, included in the efficient set, if another solution cannot improve upon it without degrading the performance of at least one objective in that efficient set. There are three techniques to generate the efficient set: the weighing method, the constraint method and the multi-criterion simplex method (Rehman and Romero, 1993). However, once the efficient set has been generated, the problem of helping the decision maker to choose the 'optimal' solution remains. Here the most widely used technique is Compromise Programming (CP) as proposed by Yu (1973) and Zeleny (1973). CP first establishes an ideal point, the co-ordinates of which are given by the optimum values of different objectives given the constraints of the problem. If finding an ideal point is infeasible, the efficient solution closest to it is defined as the best compromise solution. The problem with these techniques is that it is almost impossible task except for small problems to determine the complete efficient set. The computational burden remains a weak point when MOP is applied to large problems and while finding the compromise set there is considerable loss of information (Rehman and Romero, 1993). MOP techniques have been proposed for multiple-use forest planning (Steur and Schuler, 1978; Allen, 1986; Hof et al., 1986; Harrison and Rosenthal, 1986; Mendoza et al., 1987; Bare and Mendoza, 1988).

Goal programming

Goal programming (GP) is an important technique of multiple criteria optimisation. It is perhaps the oldest approach within the multicriteria decision making techniques (Romero, 1991) and has been widely used in agriculture and other natural resource planning problems (Field, 1973; Schuler and Meadows, 1975; Bell, 1976; Rustogi, 1976; Schuler et al, 1977; Field et al, 1980; Hotvedt et al, 1982; Arp and Lavigne, 1982; Mendoza et al, 1987; Sharma, 1990; Veloso et al., 1992; McGregor and Dent, 1993; Dent and McGregor, 1993; McGregor et al., 1994; Nkowani, 1996).

In GP, there is no requirement that objectives be defined in the same value terms. Multiple goals can be defined in different units of measurement such as number of cattle, pound sterling, rupees, dollars, cubic feet of timber, etc. The only requirement in GP is that the manager provides ordinal priorities, rankings to goals. Once goals have been defined and ranked according to priorities, a solution via GP can be obtained. The manager can then change the goal priorities, and by examining solutions can obtain an estimate of trade-offs between goals. GP is useful for identifying and resolving conflicts as well as for developing optimal management strategies.

Initially conceived as an extension of single objective linear programming, GP was developed by Charnes and Cooper (1961). It gained popularity in 1960s and 70s from the works of Ijiri (1965), Lee (1972) and Ignizio (1976). It is now an important area of multiple criteria optimisation, and distinguished from LP (Steuer, 1986) by:

1. The conceptualisation of objectives as goals.
2. The assignment of *priorities* and/or *weights* to the achievement of the goals.
3. The presence of deviational variables d_i^+ and d_i^- to measure *over-achievement* and *under-achievement* from target levels t_i.
4. The minimisation of weighted sums of deviational variables to find solutions that best satisfy goals.

Goal programming optimises several goals simultaneously. For that purpose, the deviations from the targets and actual achievement are minimised. The minimisation is accomplished by various methods, the most common methods are lexicographic goal programming (LGP) and weighted goal programming (WGP). LGP carries out the minimisation process by attaching pre-emptive or absolute weights to the sets of goals situated in different priorities. Higher priority goals are satisfied first and only then are lower priorities considered. WGP considers all goals simultaneously within a composite function composed of the sum of all deviations among the goals and the aspiration levels. The deviations are weighted according to the relative importance.

Mathematically, the goal programming problem is represented as:

$$\text{Minimise } \underline{z} = \sum d^- + \sum d^+$$

in order of assigned priority levels, and

$$\text{subject to } Ax + d^- - d^+ = b$$
$$\text{and } x,\ d^-,\ d^+ \geq 0$$

where b is a vector of constraints and ideal goals (right hand side values);

d^- and d^+ represent vectors of deviations from the proposed goals;

A is the matrix of coefficients; and

x is a vector unit representing alternatives (decision variables)

Goal programming assumes that a decision maker can define all the goals explicitly relevant to a planning situation and attach priorities to these goals.

Goal programming has the following advantages:

(i) It is a computationally efficient technique vis-à-vis other multi-criteria decision making techniques.

(ii) It can handle non-commensurable and conflicting goals, and trade-offs between them can be examined.

(iii) The technique is conceptually easy for the decision-maker to assimilate and trade-offs can be made in a logical way. A vast variety of information regarding trade-offs, sensitivity to changes and positive and negative slack variables is available which can be helpful to the decision-maker in making judgements.

(iv) The priority structure of the decision-maker can be incorporated into the model. This means that the goals can be ranked in order of priority and different weightings can be given to each goal.

(v) It provides a logical procedure for analysis, proceeding from goal specification to their achievement. This enables the decision-maker to understand the problem adequately and provides an opportunity to reassess goals in absolute terms and also relative to other goals. As a result, reassessment of earlier goals can be made realistically. This gives the desired dynamism to the analysis and the decision-maker can interact closely with the analyst.

(vi) Once goals and priorities have been specified, GP tries to achieve each goal level to the maximum possible extent so that the aggregate of the weighted deviations is minimised.

(vii) Post optimal and sensitivity analysis can be carried out to examine the effects of various changes in the variables on the management alternatives. Severe conflicts between certain goals that have an overriding influence on solutions are also identified through sensitivity analysis (Howard, 1991).

(viii) An otherwise infeasible problem can be reformulated to ensure its feasibility. This can be done by introducing deviation variables in the model.

(ix) A measure of risk can be incorporated in the programming routine (Berbel, 1993; Millan and Berbel, 1994).

(x) Qualitative information can be incorporated in the model (e.g., in goal weighting).

The disadvantages of GP are:

(i) A great amount of information is required from the decision maker about the targets, weights attached to each goal placed within a certain priority and pre-emptive ordering of preferences. When the decision-maker is not very confident of values of any of these parameters, difficulties may arise.

(ii) Sometimes GP may give inappropriate results. There is a possibility of identical solutions being generated by conventional LP and GP models for a given problem. However, equivalence of the solution is due mainly to poor problem formulation rather than potential usefulness of GP (Romero and Rehman, 1989).

(iii) Naive prioritisation can be a serious weakness when the size of the problem is small in relation to the number of priorities (Romero and Rehman, 1985).

(iv) Non-efficient 'optimal' solutions may be produced: this will happen when the target levels are fixed at a very pessimistic level (Zeleny and Cockrane, 1973;

Cohen, 1978; Dyer et al, 1979; Dykstra, 1984). A parametric analysis can be done to overcome this problem and ensure an increase in the level of some goals without reducing the achievement of others.

(v) The value judgements elicited are explicit and possibly incorrect because they are fixed by the decision-maker without a priori knowledge of likely trade-offs.

(vi) An infinite number of trade-offs between the goals at different priority levels is assumed. Trade-offs among goals are possible only when they are in the same priority. This possibility is not permitted across different priorities as they are assumed to be independent of each other in a pre-emptive fashion.

Many of the problems associated with GP can, however, be overcome or at least mitigated by proper and correct use of the technique (Romero and Rehman, 1989; Ignizio, 1994).

6.4 Mathematical technique for the present study site

Management planning of the resources in this study has to be seen in the light of multiple objectives. These objectives are ecological, social and economic in nature and can be partially or fully met by devising management strategies or alternatives for the various types of land. Management alternatives were developed through the application of LP and GP techniques. Procedures for constructing LP and GP models are reasonably well-established and once a base framework has been designed for the problem, it can be modified to fit different locations and conditions. These models can be constructed and run by using easily accessible software packages - in this case LINDO.

Planning in this study demands both the achievement of a range of goals and maximisation of income. In GP, it is possible to ensure high income by assigning an artificially high value to the income goal. Information relating to targets, weights and pre-emptive ordering of goals is not a major problem in this study. The difficulty rather is to identify a goal level for income. An arbitrary fixation of the goal may produce non-efficient solutions (Zeleney and Cochrane, 1973; Cohen, 1978; Dyer et al., 1979; Dyxtra, 1984). To avoid such a situation, a more satisfactory way of analysing the problem would be first to attempt achievement of goals (actual targets) other than income and thereafter maximise income as a simple LP problem by keeping these achievement of goal levels as constraints.

6.5 Strategy for model construction of the study site

Two types of mathematical models - one at village level and the other at community level - were developed (Figure 6.1). Villages are independent and have their own elected Panchayats. They are free to interact with other villages or cities.

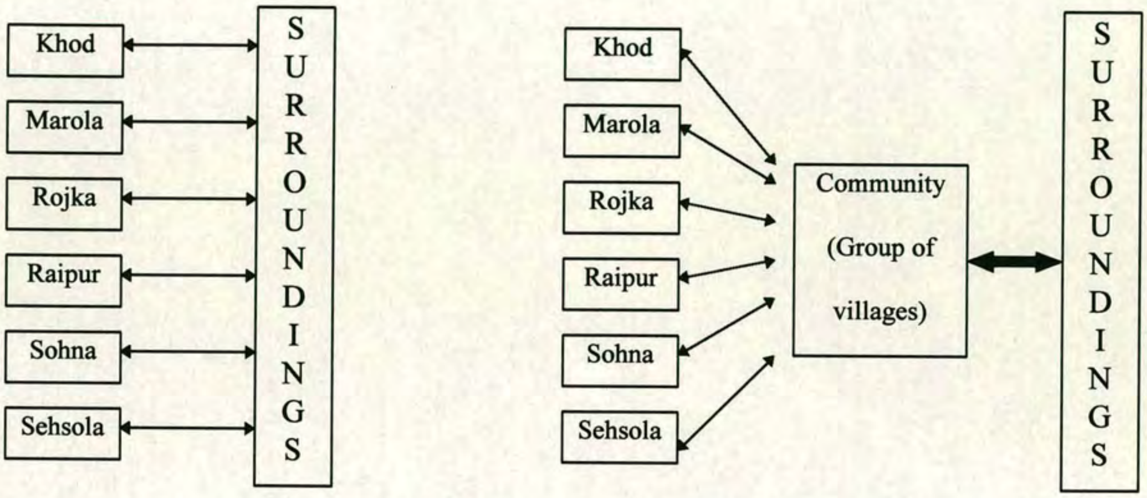


Fig. 6.1: Methodological approach to model formulation and decision-making

The villages of the case study site, though administratively distinct, interact with each other socio-politically and economically. Cattle and people move from one village to the other without any restriction. Afforestation and/or reforestation at one place affects other places over the area. The common lands of the different villages and the forest land are adjacent and, in fact, make one continuous stretch of land mass without any apparent demarcation. The whole stretch of land could in fact be considered as a unit of management instead of a number of small pieces of village land. Recent government policy about participatory forest management also is directed to some extent, towards community management.

Because of the above factors it was planned to construct separate models for each village and one composite model for all the six villages (referred here as the community model). It was significant to make the community model to investigate the effects of planning the group of villages as an interactive body. The proposed methodology helped in understanding the impact of socio-economic blocking of villages, i.e., community approach vis-à-vis individual villages on the local economy and people's welfare. In brief, the underlying idea was to try to identify a management alternative which was most appropriate and beneficial and which integrated different resources and efforts of villagers and government agencies for suitable and sustainable management of the resources.

6.6 Objectives

The aim of the mathematical modelling was to develop a participatory land use management planning scenario which balances ecological, social and economic interests of the site. The specific objectives were to:

- optimise the use of forest and common lands under a participatory management regime;

- integrate the use of agricultural land under private management regimes with the management of forest and common lands and other non-agricultural resources;

- develop a socially acceptable plan by accommodating the needs, views and perceptions of the various stakeholders;

- rehabilitate the site by providing a vegetation cover which in turn would help in conservation of soil and moisture and ensure sustainability (maintaining long term productivity without degradation of the natural resource base);

- achieve economic efficiency under a given scenario; and

- forecast quantitatively the patterns of agriculture and forestry land use and associated resource use under different scenarios.

6.7 Planning Horizon

The model is for one year time only and is based on the data gained during the period of field work. A year was divided into three periods (I, II and III) on the basis of prevailing periods of production and consumption activities. These periods correspond to three distinct seasons of the year.

Period I (Kharif season)

This period covers the time from 16th June to 15th October corresponding to the rainy season of the year. Agricultural crops grown during this period mainly depend on rains. Most of the plantation activities on the common-forest land take place during this period. It is one of the labour demanding periods for cropping and plantation work. This season is a good growth time for crops, grass and trees, fodder, food, vegetables and other minor forest products are in relative abundance.

Period II (Rabi season)

The time of year from 16th October to 15th April coincides with dry and colder conditions. Most crops during this period depend mostly on irrigation water, so the extent of certain crops is restricted because of limited irrigation facilities and quality water supplies. Plantation activity on the common and forest lands is negligible except for maintenance work. Grass fodder becomes scarce during this period so livestock depend either on green fodder from the agricultural fields or stored fodder from Period I. Quarrying activity increases at this time of year providing employment opportunities for men.

Period III (Summer season)

This period spanning from 16th April to 15th June, is the most difficult season because it is hot summer and extremely dry. There is almost no agricultural activity except for vegetable and sorghum growing on small areas of land. Little work is available on the common and forest lands. Availability of fodder depends mostly on sorghum cultivation, on the stored materials from an earlier period or on purchased fodder from the market. Employment is available in quarrying, services, industry, road construction and repair and for preparation of nursery plantations.

6.8 Socio-economic categories

Based on the socio-economic survey (described in Chapter 4), three socio-economic groups are considered in the model: large farmers, small farmers and landless people. These groups have different resources and also different demands. They also have different views and perceptions regarding the use and management of common and forest lands in particular. Each of these categories along with their resources and demands have been separately defined in the model formulation.

6.9 Village models

Various land uses and their activities coupled with the human and livestock resources and activities related with them (i.e., livestock products and their use) are the main constituent parts of the village level planning model. The direct activities (such as crop production and utilisation, and demand and supply of products) in the model are explicitly expressed by way of input-output relationships. Socio-cultural viewpoints and some of ecological objectives have been implicitly accommodated in the model through incorporation into the design of management options for the various land categories. For instance, an activity which ensures vegetation cover over the land area improves local environment as well as prevents soil erosion. Each village was initially modelled separately.

6.9.1 Model structure

The structure of the general LP model as applied to each village is shown in Table 6.1. Several assumptions made in the design of the model are stated below:

- Input and output prices are the ones prevailing in the market at the time of field data collection.

- The population of each socio-economic group in the villages is considered homogenous but the characteristics of populations of the different socio-economic groups differ from each other. Similarly, the area of each land class is uniform (as identified by survey and GIS) but the two land classes differ in their properties and productivity.

- Buying and selling of various products, whenever allowed depending upon the modelling situation, are without any bias among the people of different socio-economic categories, i.e., there is free flow of goods and services.

- Production technologies in agriculture and forestry are constant at the level assumed for the base year of data collection (although this assumption could be relaxed by changing the technical coefficients to reflect a change in the individual production processes). Moreover, the technology is assumed to be linear, implying that modelled production relationships are constant regardless of the scale of production.

- The size and shape of farms have not been considered, implying thereby, that farm structure has no effect on the pattern of land use and the productivity.

- Once the basic needs of people in respect of food energy, fuel energy, fodder and timber are satisfied (expressed as constraints), the next important criteria of planning is to maximise the economic gain in terms of cash generated (established from the socio-economic survey) from the resource. Villagers need cash to buy clothes, sugar, footwear, etc.

6.9.2 Model resources

The major resources considered in the model are land, labour and livestock. The agriculture, common and forest land classes determine the spatial framework of the model.

Land

Cropping activities on agricultural land were decided on the basis of the current land use pattern. For agricultural crops no distinction was made between good and poor land types because the area was small, detailed data on differential crop productivity were not available and no appreciable soil difference could be determined over the study area during the survey. Farmers, who, by experience or prudence generally have a detailed knowledge about the difference in the land quality of their fields, also did not suggest real differences during discussion. Practically, any crop can be grown on any farm without appreciably affecting the production.

The land of small and large farmers has been treated differently because the two categories of farmers have differential accessibility to farm machinery, inputs, etc. and their preferences for farm management vary depending on the different needs. They were similarly treated as two distinct categories in the socio-

Table 6.1: General structure of a village model

Activities / Constraints	(a) Production (agriculture, common & forest lands)	(b) Storage	(c) Sell	(d) Buy	(e) Use	(f) Labour	(g) Household food, fuel & timber demand [1]	(h) Livestock fodder demand	(l) Industry, tourism, sevices, etc.		
Production-Market-Use tie	$-a_{ij}$	+1	+1	-1	+1					≤	0
Storage transfer		$-a_{ij}$									
Use of land	+1									≤	L
Labour tie[1]	$+a_{ij}$					$-a_{ij}$			$+a_{ij}$	≤	0
Household food, fuel & timber ties [1]	$-a_{ij}$						$+a_{ij}$			≤	0
Fodder tie [1]	$-a_{ij}$							$+a_{ij}$		≤	0
OBJECTIVE FUNCTION											
Goal achievement											
- Food energy											
- Fuel energy											
- fodder											
- Employment											
- Timber											
Maximise											
- income											

[1] Food in Kcal; fuel in Mega Joules; Fodder in Kg DM; Timber in Ft^3; and employment in hours; L=Area of land

economic survey (Chapter 4) to evaluate their preferences about common-forest land.

The common-forest land was demarcated into various land capability classes with the help of GIS (Chapter 5) and each class has been treated differently in the model.

Labour

The labour resource was subdivided into adult males, adult females and children (12-18 years age group) available in various socio-economic categories of households. Different activities on the land, and concerning livestock, services, household works, etc., put varying demands on the labour resource within the three seasons. Some activities can be performed by any of the labour types, while others have specific demands for a certain kind of labour only; for instance, quarrying can be carried out only by men. Therefore, the three types of labour, viz., men, women and children have been treated separately in the model.

The availability of labour was calculated in terms of labour hours. A man is considered to work for eight hours a day. Women do household work and also contribute to the labour required in agriculture, animal care, planting, collection of firewood, fodder, etc. Therefore, in this model, time available to women for non-household activities is considered to be six hours per day. A child generally goes to school but can contribute up to three hours a day.

Labour pools: For the purpose of the model all the available labour in different socio-economic households has been pooled together. Since certain work requires only a specific type of labour, three kinds of labour pools have been recognised: general, men and women. A child pool is not separately recognised because whatever a child can perform, a man or woman can also do. Hence, children contribute to the general labour pool only while men and women contribute to the general pool as well as to their specific pool.

The labour pools are maintained at two levels in a season (Table 6.2). One is at the level of every socio-economic group, i.e., landless, small farmer and large farmer, and the other is a common pool in the season. All the households in a socio-economic group contribute to their own pool to meet the requirement of the group as well as to the common labour pool. The purpose of maintaining

Table 6.2: Labour interactions represented within a period

	Activity	Household equivalent (hours)			Labour transfer & quality substitution					Labour transfer within group			Hire labour within village		Hire labour outside village		
		Men	Women	Child	Men to Men	Men to pool	Women to Women	Women to pool	Child to pool	Men to group pool	Women to group pool	Child to group pool	Men	Women	Men	Women	
Labour																	
Pool Gen.	a					-1		-0.85	-0.5								=0
Men Gen.	b				-1								1				=0
Women Gen.	c						-1							1			=0
Men LL, SF or LF		-x			1	1											≤0
Women LL, SF or LF			-y				1	1									≤0
Child LL, SF or LF				-z					1								≤0
Pool SF or LF	e									-1	-0.85	-0.5					=0
Men SF or LF	f									1			-1		-1		≤0
Women SF or LF	g										1			-1		-1	≤0
Child SF or LF												1					≤0
Household size:																	
LL		1															$=L_1$
SF			1														$=L_2$
LF				1													$=L_3$

$L_{1\text{-}3}$ = Household size; x, y, z = labour hours available in a period; LL=Landless; SF=Small farmer; LF=Large farmer; Gen.=General separate common pool in each season is to meet the demand of labour for general purpose irrespective of socio-economic groups and in order to ensure the possibility of transfer of labour between groups.

The labour provided by men, women and child are not equivalent because of differences in their labour efficiency. To account for this, a man is assumed to be equivalent to one unit of labour. A women, doing men's work or if contributing to the general labour pool, is equivalent to 0.85 of a man and a child is equivalent to 0.5 (see Table 6.2).

Labour hire: In addition to its own supply a socio-economic group can hire labour either from another socio-economic group within the village or from outside the village. In the model, provision has been made to first utilise available labour from within a socio-economic group and then hire from other groups. Hiring from outside is resorted to only when there is labour shortage within the village itself. The average cost of hiring labour is five rupees per man-equivalent hour. Various kinds of labour interactions included into the model are shown in Table 6.2.

Labour requirement for various agricultural operations and work on other land, is averaged per season in a year for the entire rotation period. Demand for labour for livestock trading and rearing, social and religious functions, services, industry, tea stalls, shops, etc. has also been assessed and accounted for in the model as average requirement of labour hours.

Livestock

Livestock feed demand has been evaluated on the basis of a literature (Srivastava and Kaul, 1994), study on the site and from the knowledge of local farmers and other experts in the field. Fodder requirement, in dry matter equivalence, for different types of livestock is given in Table 6.4. The seasonal requirement of fodder for the different socio-economic groups was calculated (Annexure 6.4) and maintained separately in the model. Available fodder from agricultural farms and common-forest land was converted into dry matter equivalent. Livestock products - milk & dung - and their end uses in meeting up household energy need and supporting agricultural production are separately reflected (Table 6.4).

Table 6.3: Livestock and fodder interactions in the model

	Livestock (TBU)	Agricultural crop fodder	Consume crop fodder	Store crop fodder	Sell crop fodder	Fodder common-forest land	Consume common-forest fodder	Store common-forest fodder	Sell common-forest fodder	Buy fodder	Burn dung	Use dung in agriculture	Feed milk	Sell milk	
Fodder demand	D_f		-1_c				-1_f			-1					= 0
Crop fodder tie		$-s_a$	1	1	1										≤ 0
C-f fodder tie						$-s_c$	1	1	1						≤ 0
Milk tie	-m												1	1	≤ 0
Dung tie	-d										1	1			≤ 0
TBU	1														= N
				Supply to next period				Supply to next period			meet fuel demand	increased crop productivity	Meet food demand		

TBU=Tropical Bovine Unit; N is the number of Tropical Bovine Units; C-F=Common-forest land

Table 6.4: Per unit animal fodder requirement, milk & dung production (variuos sources)

Type of animal	Fodder requirement (Kg DM/day)	Milk production (Kg/day)	Wet Dung production (Kg/day)
Buffalo	20	6	15
Cow	15	4	9
Goat	2	1	1
Camel	20	-	9
Sheep	2	-	1.5

To keep the size of the model within manageable limits, different types of livestock were converted into a common Tropical Bovine Unit (TBU) according to the conversion factor as given in Table 6.5. Fodder requirement, milk production and dung production were adjusted accordingly. The various links involving livestock are shown in Table 6.3.

Table 6.5: Conversion of livestock into Tropical Bovine Unit (TBU)

Type of livestock	Conversion factor
Buffalo	0.9
Cow	0.75
Goat	0.25
Sheep	0.25
Camel	1.0

Source: SETA (1989).

6.9.3 Production and disposal (use) activities

On each land type, there is a possibility of having a number of production activities for each season. Each activity has its associated set of technical coefficients describing the range of production and input requirements. The identification of a pragmatic sub-set of activities to model was ultimately subjectively based on experience, common reasoning, and local realities. Production possibilities were represented within the model as a set of input-output coefficients that relate the quantity of input used to the quantity of output produced.

Activities on agricultural land

The crop species considered in the model are pearlmillet, guar and vegetables in period I, wheat, gram, mustard and vegetables in period II and vegetables and sorghum in period III. These crops are the most common in the area. Depending

Table 6.6: Agrcultural land use and production relationships

	Grow crop SF	Feed grain SF	Store grain SF	Transfer grain SF	Grow crop LF	Feed grain LF	Store grain LF	Transfer grain LF	Buy grain LL	Buy grain SF	Feed grain LL	Food demand LL	Food demand SF	Food demand L	
Food grain tie SF	$-s_1$	1	1	1						-1					= 0
Food grain tie LF					$-s_2$	1	1	1		1					= 0
Food Grain tie LL									-1		1				= 0
Food grain pool				-1				-1	1						≤0
Food demand LL											$-k_1$	d_l			= 0
Food demand SF		$-k_2$											d_s		= 0
Food demand LF						$-k_3$								d_f	= 0
			Supply to next period				Supply to next period								

LL = Landless; SF = Small Farmer; LF = Large Farmer; k = Conversion coefficient; s = Supply; d = Demand on the availability of irrigation facilities and the need to have a balanced production of various products some crops are bound by a land area constraint.

Crop production per unit area increases with the addition of dung to the field, therefore, crop production under two situations has been considered- with dung and without dung. Some farmers very occasionally add fertiliser to the wheat crop and rarely to mustard and bajra crops but there is no regular pattern as in the case of dung use. Neither the quantity nor the frequency of fertiliser addition to the crops, nor the effect on production are known. Hence, fertiliser was not considered in crop production activity.

Sowing, weeding, harvesting and pesticide requirements vary from crop to crop. These parameters were assessed separately for each crop and their monetary equivalents were included in the cost of production (Appendix 6.1).

Relationships involving crop growing, production and disposal of products are shown in Table 6.6. Crop grain and straw are either directly consumed or converted into different forms before consumption. These products can also be sold, bought or stored for later use according to the convenience and profitability of different socio-economic groups. The input-output coefficients of the crops are derived from various sources including observations during the field survey.

Grain, when consumed, contributes to the total energy requirement (estimated in Kcal) during a period and, when stored, it becomes a supply in the next period but at some reduced level due to losses in quantity and quality during storage. Guar grain is fed to the livestock where it contributes to the total requirement of dry matter. Straw mainly supplies the dry matter for livestock except for mustard straw which when burnt supplies fuel energy. Conversion coefficients in the model for the crop products into various forms, from grain to Kcal or from straw to dry matter, have been collected from various departments (Table 6.7).

Table 6.7: Nutritional values of crops and common-forest land products

Crop	Calorific value of grain (Kcal/kg)	Straw dry matter equivalence (DM/kg)
Pearlmillet	3000	0.75
Guar grain	-	3.0
Guar straw	-	0.85
Wheat	3300	0.85
Mustard oil	8000	-
Mustard feed	-	2.0
Gram	3100	0.9
Sorghum	-	0.5
Vegetables	2000	-
Fruit	1000	-
Grass	-	0.6

Source: Singh, 1994; HFD, 1994; AHD, 1994

The crop outputs (grain and straw) can either be stored, bought, sold or consumed by the small and large farmers. Landless people can only buy and consume in order to meet their food energy and fodder requirements for their stock. The food energy (in kcal) is met by food grains, vegetables and fruits. In the case of fodder ties the various fodder types are converted in kilograms of dry matter to meet livestock fodder demand.

Small and large farmers can transfer their grain and straw, firewood to a common pool in any one period from which it can be repurchased by any of the socio-economic groups in order to meet any shortfall in supply of that particular product. By way of appropriate pricing, products are bought and sold within the village itself as far as the products are available.

Trees in agricultural fields and household premises

Tree planting and naturally growing trees on field boundaries including trees growing on home premises is another important activity considered in the model because fuelwood, timber and shade are provided. In the absence of reliable data on timber, only the supply of fuelwood production (Sharma, 1993) has been included in the model. Planting and maintenance of such trees demand negligible resources. The labour requirement for planting and the outputs from trees over the rotation period have been averaged and only these values (Table 6.8) have been used in the model. Practically, no cost is involved in growing of trees on either agricultural land or household premises.

Table 6.8: Household and farm trees - fuelwood production and average labour requirement

Farmer type	Fuelwood production (Kg/year)			Labour requirement (Hours/year)		
	Period I	Period II	Period III	Period I	Period II	Period III
Small	800	1599	266	Men=38 Women=8	Men=38 Women=8	Men=19 Women=4
Large	1754	3507	585	Men=110 Women=22	Men=110 Women=22	Men=55 Women=11

Source: Field survey

Activities on common-forest land

Potential production activities on the common-forest land vary according to land capability classes. Determination of options was primarily guided by commonly observed land uses on different land classes, biophysical features, ecological requirement, needs and expectations of different socio-economic groups and the government agencies, availability of input-output data, etc. Emphasis was given to options that were, or potentially could be, profitable to a large number of farmers (in terms of providing employment opportunities, income generation and/or improvement of ecological conditions). Each management option uses a unique combination of inputs to produce outputs.

In fact, there are innumerable possibilities (management options) for each land class (some are shown in Annexure 6.2) but on the basis of common knowledge and experience, it is possible to discard many of the options to arrive at a potentially efficient set. In this study, only those potentially feasible options were considered which conformed to the overall objectives of participatory management planning and for which data were available. These are discussed below for each land capability class.

Land capability class I: Only one management option namely quarrying for stones was prescribed for this land class. No other activity is worth attempting because of unconducive features. Quarrying was found inevitable in the villages in view of the large scale employment provided particularly during the 'idle' period of the year. This activity, influenced by outside agencies, generates income to the VPs, and the government but at the same time it pollutes the environment and degrades the land resource. The level of the quarrying permitted in the model is as it existed at the time of data collection in terms of employment generation and extraction of stones. It is represented in the model as a distinct activity which includes costs, income and labour requirement (only men) in each season (Annexure 6.3).

Land capability class II: Three management options were selected and initially incorporated into the model: (i) planting trees (in 3 m × 3 m spacing) and grass species with a rotation period of 21 years (ii) allowing natural regeneration with controlled removal of forest products and iii) allowing natural regeneration with free removal and grazing. But in the final model only option (i) was kept for further analysis. This was mainly because, options (ii) and (iii) did not appear in the solutions of village models when run. Moreover, option (i) appeared to be a better choice keeping in view the overall objectives of planning: it provides a vegetation cover ensuring soil and moisture conservation and a rational, sustainable harvest of different products through the 'cut-and-carry' system.

The tree species permitted for planting under option (i) are those preferred by the local people and include *Cassia siamea, Acacia nilotica* and *Prosopis juliflora* for fuelwood, *Acacia leucophloea, Holoptilia integrifolia, Azadiracta indica, Albizzia lebbek*, and others for fodder, *Dalbergia sisso* and *Ailanthus excelsa* for timber and *Zizyphus* species for fruits. Grass species are *Cenchrus ciliaris, Cynodon dactylon, Stylosanthus* species and *Crotolaria* species.

Major products are fuelwood, fodder, timber and fruits. In addition to planting and final harvest, two thinnings are allowed in years 6 and 11. The first thinning reduces the number of fuelwood trees by 50% by felling alternative lines of trees, increasing the spacing to 3 m × 6 m while the second thinning reduces the number of fuelwood species to 25% of the original number, increasing the spacing to 6 m × 6 m. In this way, income from fuelwood fellings is generated in years 6, 11 and 21, whereas the growth of grass, herbs and shrubs will be enhanced throughout the rotation period by allowing sunlight to reach the ground. For the purpose of modelling, the inputs and outputs over the period of 21 years have been calculated and annual average figures have been included in the model (Appendix 6.3). The average figures were derived from the present net worths of yearly values discounted at the rate of ten percent.

Land capability class III: Only one option for use of the land class was incorporated into the model keeping the size of the model within acceptable limits. This management was similar to option (i) of land class II except in its species composition. Important species were *Acacia nilotica, Acacia tortilis, Cassia fistula, Bauhinia racemosa, Azadiracta indica, Acacia senegal, Salvadora* species, *Dalbergia sissoo, Ailanthus excelsa* and others for fuelwood, fodder and timber; and *Zizyphus numularia* for fruits. The main grass species were *Cenchrus ciliaris, Aristida adansionis, Heteropogon contortus* and *Stylosanthus* species. Planting, harvesting, rotation, etc. were similar to those described for land class II. Products, prices and labour requirement are given in Appendix 6.3.

Land capability class IV: The dominant option of this land class is large scale planting of various grass species with scattered tree planting of *Boswellia serrata, Acacia senegal* and other suitable indigenous species.

Land capability class V: This land class is given over for establishing tourist structures; office and other premises and water bodies. A part is under plantations of *Prosopis juliflora* and other species. Firewood and fodder are the two major products. Planting requires labour in different seasons of the year. Only figures concerned with planting trees and the output of fuelwood and fodder from the plantation of land class V are incorporated into the model. Labour requirement for tourism and other such activities is considered elsewhere under miscellaneous activities below.

The products from common and forest lands may be utilised by landless people, small farmer and large farmer households without any preferences to one particular group and likewise all these groups can contribute to labour requirement without any bias. The sale price of fuelwood, fodder, timber and fruits (Appendix 6.3) have been taken from a survey of prices during the field work.

Miscellaneous activities

Other activities which have been considered in the model are tourism, cottage industries, services, etc. Tourism, at present, is restricted to a small part of the site. It has been considered as an activity which demands labour and has associated benefits in the form of enhanced soil and moisture conservation due to increased vegetation cover, recreation and inflow of money from tourists. Cottage industries and services also demand labour. Demand of labour for all such miscellaneous activities was estimated (Table 6.9) on the basis of their scale of operation and the same was incorporated into the model.

Table 6.9: Miscellaneous labour requirement from individual villages (in hours)

Period	Khod	Marola	Rojka	Raipur	Sehsola	Sohna
I	7686	7442	24644	17568	50874	35014
II	11466	11102	36764	26208	75894	52234
III	3843	3721	12322	8784	25437	17507

Source: Field survey

6.9.4 Demand and supply of essential products

Household food energy

The most fundamental need of man is energy and the FAO has based its recommendations on calorie requirements on a reference man and woman (FAO, 1950, 1957a). In the model, only calories have been taken into consideration for human nutrition because once the calories are accounted for, then proteins, and other nutrients are also usually sufficient. Calorie requirement depends on physical activity, age, climate and other factors (Capping, 1976), therefore, in calculating the energy requirements average requirements of different groups were calculated separately (Table 6.10).

Table 6.10: Average food energy requirement (Kcal/day) per household in the study area

Household type	Period I	Period II	Period III
Landless	2050	2100	2000
Small farmer	2000	2050	1950
Large farmer	1800	1900	1850

Source: Singh, 1994.

Energy consumption per day for large and small farmers and landless people differs because of different activities. Landless people and some small farmers do more hard work like quarrying, grazing and other labour intensive activities. Large farmers and a small proportion of small farmers do less work in the fields or in the quarry and more of less energy intensive work.

The main sources of food energy are cereals, milk, vegetables, fruits and meat. Most of these products are produced locally either on the agricultural land or the common-forest land. Availability of energy per unit of different food stuffs was considered (Table 6.7). Energy from meat was excluded from the model because in practice only a small portion of total energy is supplied in this form.

Household Fuel energy

Fuel energy demand for the socio-economic groups in different seasons is calculated in Mega Joules (Appendix 6.4) and is met primarily from fuelwood, dung and mustard straw by standard conversion (Table 6.11). Utilisation of fuelwood, dung and straw have been reflected in the model along with the source of production. Some energy is also purchased from outside the village in the form of LPG, kerosene, electricity and fuelwood. Out of the many external sources of fuel energy only the cheapest source, i.e. fuelwood, has been represented in the model on the presumption that given the choice it will be selected provided there is no supply constraint. Dung may also be added to the agricultural fields. Fuelwood supply is from trees on agricultural, homestead, common and forest lands while straw comes from agricultural fields only.

Table 6.11: Conversion factors for different kinds of fuel sources

Type of fuel	MJ equivalent per kg
Fuelwood	12.34895
Crop straw	11.25575
Dung	8.75365
Kerosine oil	45.93474

Source: Sharma (1993).

Fodder

Fodder requirement of livestock is represented in kilograms of dry matter (Appendix 6.4).

Timber

Requirement of timber per household was taken at 3 ft^3 per annum irrespective of the category of household as per the information during field survey. Supply of timber from common and forest lands only was considered. The other source of timber from trees on household premises and agricultural farms could not be included in the absence of reliable data on timber productivity. Only a very small quantity of timber is normally produced from this source.

Table 6.12: General structure of a village goal programming model

Constraints \ Activities	(a) Production (agriculture, common & forest lands)	(b) Storage	(c) Sell	(d) Buy	(e) Use	(f) Labour	(g) Household food, fuel & timber demand	(h) Livestock fodder demand (Kg DM)	Miscellaneous activity	δ^+	δ^-		
Production-Market-Use tie	$-a_{ij}$	+1	+1	-1	+1							≤	0
Storage transfer		$-a_{ij}$											
Use of land	+1											≤	L
Labour tie[1]	$+a_{ij}$					$-a_{ij}$			$+a_{ij}$	-1	+1	≤	0
Household food, fuel & timber ties [1]	$-a_{ij}$						$+a_{ij}$				+1	≤	0
Fodder tie [1]	$-a_{ij}$							$+a_{ij}$			+1	≤	0

OBJECTIVE FUNCTION
Minimize
- Food energy underachievement
- Fuel energy underacievement
- fodder underachievement
- Employment under & over achievement
- Timber underachievement

[1] Food in Kcal; fuel in Mega Joules; fodder in Kg DM; Timber in Ft^3; and employment in Hours

6.10 A goal programming model for a village

Keeping the general structure of the model described in earlier sections unchanged, deviational variables were introduced in the model as separate slack activities to develop a goal programming model (Table 6.12). For food, fuel, fodder and timber only negative deviational variables were used because the aim was to minimise under-achievement of these goals. In the case of labour both negative and positive variables were introduced in order to minimise under-as well as over achievement. The objective function values of all variables except deviational variables were made to zero. Goals for food, fuel, fodder and timber were fixed at the actual demand level and for employment equal to the available labour.

6.11 Community model

To develop a mathematical model for the community, the six villages were considered simultaneously. Their resources were pooled together into a large model. The general structure of the model is shown in Table 6.13. The size of the model is almost six times the size of individual villages (3733 columns and 1885 rows).

The structure of the model was based on those for the individual villages described in section 6.9. Initially the model for the village Khod was constructed, then to it related parameters for Marola, Rojka, Raipur, Sohna and Sehsola were added as separate sets of activities and constraints with associated right hand side values as depicted in Table 6.13.

The villages are 'joined' by establishing sharing sinks called 'common pools'. Thus, five such common pools for food energy, fuel energy, fodder, labour and timber were incorporated into the model. Outputs of food, fuel, fodder, timber and labour could be transferred to the respective common pools and in case of demand, these products could be supplied to the villages from the pools. The common pools also received supply of the products from outside, as purchased material, to meet any shortfall in respect of any of the materials. The purchase price of materials and hiring cost of labour from outside the community were kept slightly higher to reflect transport costs and hence give preference to local materials and labour.

Table 6.13: General structure of the community model

CONSTRAINTS	ACTIVITIES						Transfer surplus to pool	Buy from pool	VILLAGES' RHS
	Khod								
		Marola							
			Rojka						
				Raipur					
					Sohna				
						Sehsola			
Food pool							$-a_{1.....6}$	$f_{1.....6}$	≤ 0
Fuel pool							$-b_{1.....6}$	$g_{1.....6}$	≤ 0
Fodder pool							$-c_{1.....6}$	$h_{1.....6}$	≤ 0
Timber pool							$-d_{1.....6}$	$I_{1.....6}$	≤ 0
Labour pool							$-e_{1.....6}$	$j_{1.....6}$	≤ 0
Objective function:									
Goal achievement									
- Food energy									
- Fuel energy									
- Fodder									
- Employment									
- Timber									
Maximise									
- income									

Note: $(a - e)_{1.....6}$ is supply from villages; $(f - j)_{1.....6}$ is supply to villages.

The model structure and pricing arrangements of various products were such that individual socio-economic household groups preferentially used their own resources to meet their demands before resorting to common pools for supply or withdrawal. Thus, the surplus of one village could be used to meet the shortfall in another village while any remaining surplus is sold out with the community.

6.12 A goal programming model for the community

Keeping the general structure of the community model described in section 6.11 unchanged, deviational variables were introduced to develop a goal programming model for the community of six villages (Table 6.14). Only negative deviational variables for food, fuel, fodder and timber were used because the objective was to minimise under achievement only. In the case of labour both negative and positive variables were introduced in order to minimise under-as well as over achievement. Target values for various goals were kept equal to the actual demand levels. The values of the activities in the objective function were brought to zero except for the deviational variables.

6.13 Approach to the analysis of the models

Following the methodology for the development of models in the previous chapter, change in land use on agricultural and common-forest lands are observed along with the achievement of the objectives under two scenarios as depicted in Figure 6.1.

The village models were run separately first as goal programming models and then as linear programming models. The outcomes of the solutions of the runs were compared with the respective village demands and preferences. Similarly, the community level model was run and the outcome was compared with total demand and preferences of all the villages. The procedure followed is described below.

Table 6.14: General structure of a community goal programming model

	A C T I V I T I E S						Transfer surplus to pool	Buy from pool	δ^+	δ^-	
CONSTRAINTS	Khod										VILLAGES' RHS
		Marola									
			Rojka								
				Raipur							
					Sohna						
						Sehsola					
Food pool							$-a_{1.....6}$	$f_{1.....6}$		+1	≤ 0
Fuel pool							$-b_{1.....6}$	$g_{1.....6}$		+1	≤ 0
Fodder pool							$-c_{1.....6}$	$h_{1.....6}$		+1	≤ 0
Timber pool							$-d_{1.....6}$	$I_{1.....6}$		+1	≤ 0
Labour pool							$-e_{1.....6}$	$j_{1.....6}$	-1	+1	≤ 0
Objective function: Goal achievement - Food energy - Fuel energy - Fodder - Employment - Timber											

Note: $(a - e)_{1.....6}$ is supply from villages; $(f - j)_{1.....6}$ is supply to villages.

6.13.1 Analysis of goal programming models

The models were analysed for the achievement of the targets by minimising deviations from the desired goal levels (see Appendix 6.1 for food, fuel, fodder, employment and timber targets). The aim of applying pre-emptive goal programming was to determine plans which would satisfy people's demands while reflecting their preferences as identified through the socio-economic survey. Minimisation of under-achievement of goals was emphasised rather than to minimise over-achievement except for the employment goal (Table 6.15).

Until the decision-maker is actually interested in the minimisation of both deviational variables, that is, when exact achievement of goals is desired, two sided goals[1] should not be included. This kind of modelling is not only conceptually wrong but can also lead to a sub-optimal solution (Romero, 1991). In the case of food, fuel, fodder and timber goals, the objective was to try to fulfil the demand: the excess production would be sold for income. Hence, only under-achievement was minimised for those goals. In the case of employment, both under-achievement and over-achievement are undesirable. Under-achievement means unemployment; and over-achievement means hiring labour from outside. The objective was to reduce both unemployment and hiring of labour.

Table 6.15: Goal types and goal attributes at village level

Goal type	Objective (minimise)	Deviational variable	Target level (Values given in Appendix 6.4)
Food (Kcal)	Under	s_1^-	$X_{1\ (1......9)}$
Fuel (MJ)	Under	s_1^-	$X_{2\ (1......9)}$
Fodder (Kg DM)	Under	s_1	$X_{3\ (1......9)}$
Employment (Hours)	Over & under	s_1^- & s_1^+	$X_{4\ (1......9)}$
Timber (ft^3)	under	s_1^-	X_5

[1] A goal with both under- and over-achievement deviational variables.

The main purpose of minimisation of the over-achievement of the employment goal was to look for self sufficiency at the village or community level.

Application of pre-emptive goal programming requires the decision maker to rank goals from the most important (goal 1) to the least important (goal n). The goal priorities used in this study are shown in Table 6.16 for any one village. The objective function coefficient as presented by Winston (1995) for the variable representing goal *i* will be P_i. We assume that

$$P_1 >>> P_2 >>> P_3 >>> \ldots >>> P_n$$

Thus, the weight of goal 1 is more than the weight of goal 2, the weight of goal 2 is more than the weight of goal 3, and so on. The definition of the P_1, P_2, ..., P_n ensures that the procedure first tries to satisfy the most important goal (goal 1). Then, among all points that satisfy goal 1, the procedure tries to come as close as possible to satisfying goal 2, and so forth. This is continued until the only way it is possible to come closer to satisfying a particular goal is to increase the deviation from a higher-priority goal.

The target levels of goals were kept equal to the actual demand of various products as determined from field survey. The goal levels were not set at an artificially higher level as is generally the case in pre-emptive goal programming (Sharma, 1990; Piech and Rehman, 1993; McGregor and Dent, 1993; Nkowani, 1996), because in this study the objectives of management planning were to fulfil people's demands and then to maximise income.

Table 6.16: Priority structure of the goals used in solving the models

Goal description	Goal priority levels for run		
	A	B	C
Food	1	3	3
Fuel	2	4	4
Fodder	3	1	2
Employment	4	2	1
Timber	5	5	5

LINDO (Linear Interactive and Discrete Optimizer), Release 5.0 (Schrage, 1991) computer package was used to solve pre-emptive goal programming as well as the linear programming models. Use of LINDO to solve the goal programming problem is shown in Appendix 6.5. The procedure suggested by Winston (1995) was slightly modified, i.e., while solving the goal programming model for a lower priority, the value obtained for higher priority goals were incorporated as inequalities '≤' rather than rigid equalities '='. Doing so provided flexibility to the model for achieving the next priority goal or the maximisation of income without violating the goal achievement level as determined by the pre-emptive goal programming procedure.

6.13.2 Analysis of linear programming models

The achievement values of the goals from the pre-emptive goal programming runs were incorporated as constraints in the LP model. Using LINDO, the LP was then solved to maximise the objective function of income.

Some inadequacies were observed in the formulation of models. These are discussed in the next chapter along with the presentation of results.

Chapter 7

Application of the mathematical models to village and community planning: results and discussion

In this chapter, the results of the programming models developed in the previous chapter at the village and community levels are presented and discussed. It begins with brief discussion about model validation in section 7.1 followed by results of model runs. Section 7.2 presents and discusses the results of village models while section 7.3 deals with the impact of community management on land use and achievement of goals. In the last section, important issues related to the models are discussed.

7.1 Model validation

According to Gass (1983), model validation refers to activities to establish how closely the model mirrors the perceived reality of the model user/developer team. This definition is too broad to be useful. A model cannot represent all of the perceived reality, so attention should be narrowed down to that part of the reality which the model is intended to represent (McCarl, 1984). In view of the specific nature of participatory management, model validation in this study refers to activities designed to determine the usefulness of the model, i.e., whether it is appropriate for its intended use(s); and whether the model could contribute to decision-support.

The validation procedure involves comparing the performance of the model either against recorded data for the system or against a subjective judgement of what the output should be, given a broad understanding of the system or type of system which the model represents (Dent and Blackie, 1979). Most often, simple comparisons are made and measures of deviations are calculated (Hazell and Norton, 1986). For carrying out the comparisons, one simple and pragmatic strategy, as suggested by McCarl and Apland (1986), is to restrict the values of all activities (using constraints or bounds) to a set of values observed in the real world, then run the model to check whether the model solution is comparable with the real world. If the solution is not reasonable, it is necessary to find out why and correct the problem.

Many of the difficulties in validating a model arise from the data it is being validated against (Hazell and Norton, 1986). Sometimes the full data are not available, particularly in developing countries (Lingard et al.; 1983); and sometimes the data are not reliable or mutually consistent. In such a situation, it is better to validate the model on the basis of partial data sets (McCarl, 1984; Hazell and Norton, 1986; Pannell, 1997).

Along with or without comparing the results with recorded data, a model is also validated by assumption (McCarl, 1984). Virtually, all models go through a validation by assumption stage, which involves a judgement of validation through expert opinion, antecedent, theory, data or logical structure.

In the present study, validation of the programming models developed in chapter six relies mainly on the logical structure of the model built on the basis of data collected during field survey. Efforts were made to make the model, as far as possible, representative of the various resources and activities existing in the field. Wherever, recorded data were available, these were compared with the model results; in other situations, the usefulness of the model was assessed in relation to its intended objectives. The following sections 7.1.1 and 7.1.2 discuss validation procedures adopted in this study.

7.1.1 Data validation

The data used in model construction were based on observed values and estimations. The number of coefficients in the matrix is large due to the many types of land, resources and activities related to them. Ideally, each of the coefficient values in the matrix should be validated individually; but in reality, this was not entirely possible since the number of coefficients were simply too large and in many cases additional recorded data were not available.

Most of the data related with activities on common-forest land were collected from the records of the Forest Department; and the same were used as such in the model. Data about quarrying were based on work study at the site and for miscellaneous activities were collected based on local observations and expert opinion.

Specific agricultural production data for these villages were not available, so, such data were based on farmers' estimates; generally, such estimates seemed reasonable. Prevailing buying and selling prices recorded during market survey were used.

Similarly, specific data were not available in respect of demand for various products. Studies were carried out by the author to estimate the average demand of food, fuel, fodder and timber per household.

Most of the data were judged to be reasonably reliable as they were based on records, opinion, experience and/or work study of the participants.

7.1.2 Validation by results

Validation of the village models was carried out by comparing the recorded (also referred as observed) land use on agricultural and common-forest lands with the land use provided by the model solutions. In the case of the common-forest land, observed data during the field survey were used to test the validity of all the six village models. But, in the case of agricultural land use, rigorous validation of all village models could not be undertaken because records for only two villages, namely Khod and Sehsola, were available. In these villages too, the reliability of the data could not be ascertained as they were furnished by the office of Natural Resource Data Management Systems (NRDMS), Gurgaon from unpublished records. However, in the absence of other published records the NRDMS data were used in this study for validation purposes. This might not be a stringent test, but it, at least, gives the trend of land use.

Initially, the recorded values of land use were entered into the model as constraints; and then model solutions were obtained. The recorded and the simulated values of land use, as in the model solutions, for villages are presented in Tables 7.1 to 7.6. The difference between the recorded and the simulated values were calculated in terms of percent deviation.

Table 7.1: Comparison of recorded and simulated land use pattern in village Marola

	Recorded* (ha)	Simulated (ha)	Deviation (%)
Common-forest land			
Class-I (Kharif)	0.7	0.7	0
Class-I (Rabi)	0.7	0.7	0
Class-I (Summer)	0.7	0.7	0
Class-II	-	-	-
Class-III	2.0	2.0	0
Class-IV	2.0	2.0	0
Class-V	0.1	0.1	0

Source: * Field survey

The simulated and the recorded values in respect of common-forest land are similar in Marola, Rojka, Khod, Sehsola and Raipur villages (Tables 7.1, 7.2, 7.3, 7.4 and 7.5). In case of Sohna (Table 7.6), except for class-I land, the recorded and the observed values are same. Class-I land is very small (0.1 ha). One of the reason for the exclusion of class-I land from the model solution in Sohna is the shortage of male labour, explained in the later sections. From the sameness of the recorded and the simulated values, it can be concluded that the village models appear reasonable as far as the common-forest land is concerned.

Table 7.2: Comparison of recorded and simulated land use pattern in village Rojka

	Recorded* (ha)	Simulated (ha)	Deviation (%)
Common-forest land			
Class-I (Kharif)	1.3	1.3	0
Class-I (Rabi)	1.3	1.3	0
Class-I (Summer)	1.3	1.3	0
Class-II	-	-	-
Class-III	25.0	25.0	0
Class-IV	0.1	0.1	0
Class-V	2.2	2.2	0

Source: * Field survey

For carrying out comparisons between the recorded and the simulated values of agricultural land use in Khod and Sehsola villages, the area under different crops in respect of small and large farmers in the model solutions were added together because the recorded data were not categorised according to the farmer types. The recorded and the simulated values differ from each other (Tables 7.3 and

7.4). Some difference is caused by non-inclusion of crops included in the category 'other' into the model formulation because of unavailability of respective input-output data. Deviation is very high in respect of the area under vegetables in Kharif and Rabi seasons and also in case of guar and mustard crops in both the villages. A higher proportion of area under vegetables and guar, and decreased area under mustard in the model solutions in comparison to recorded area for these crops might be due to huge demand for food grains and fodder in these villages. Vegetables contribute to food energy and guar is a fodder crop.

Table 7.3: Comparison of recorded and simulated land use pattern in village Khod

	Recorded (ha)	Simulated (ha)	Deviation (%)
Agricultural land use*			
Kharif			
- Pearlmillet	20.0	17.3	13.5
- Guar	2.0	2.7	37.0
- Vegetables	5.0	8.0	60.0
- Others	1.0	-	-
Rabi			
- Wheat	33.0	34.0	3.0
- Mustard	4.0	1.5	62.5
- Gram	1.0	1.5	50.0
- Vegetables	7.0	10.0	42.8
- Others	2.0	-	-
Summer			
- Vegetables	4.0	4.0	0
- Sorghum	3.0	3.0	0
Common-forest land**			
Class-I (Kharif)	0.8	0.8	0
Class-I (Rabi)	0.8	0.8	0
Class-I (Summer)	0.8	0.8	0
Class-II	-	-	-
Class-III	3.0	3.0	0
Class-IV	3.0	3.0	0
Class-V	1.0	1.0	0

Source: * NRDMS (1994); **Field survey

The proportion of the agricultural land under the two major crops, pearlmillet and wheat, is substantial in Khod village model; and the difference between the recorded and the model values is small. The model can, therefore, be assumed as representing the broad pattern of agricultural land use.

Table 7.4: Comparison of recorded and simulated land use pattern in village Sehsola

	Recorded (ha)	Simulated (ha)	Deviation (%)
Agricultural land use*			
Kharif			
- Pearlmillet	194.0	143.0	26.2
- Guar	21.0	-	100.0
- Vegetables	4.0	100.0	+100.0
- Others	24.0	-	-
Rabi			
- Wheat	146.0	150.0	2.7
- Mustard	209.0	138.3	33.8
- Gram	104.0	150.7	44.9
- Vegetables	39.0	100.0	+100.0
- Others	41.0	-	-
Summer			
- Vegetables	100.0	100.0	0
- Sorghum	60.0	60.0	0
Common-forest land**			
Class-I (Kharif)	30.0	30.0	0
Class-I (Rabi)	30.0	30.0	0
Class-I (Summer)	30.0	30.0	0
Class-II	80.0	80.0	0
Class-III	-	-	-
Class-IV	30.0	30.0	0
Class-V	4.0	4.0	0

Source: * NRDMS (1994); ** Field survey

Like the Khod village model, the recorded and the observed values of agricultural land use differ in case of Sehsola village model as well (Table 7.4). Here too, the major deviations are due to land area under vegetables, guar and mustard, and also due to gram and 'other' crops. However, the deviations of major crops, i.e., pearlmillet and wheat are within reasonable limits. Part of the differences may be explained by lack of differentiation between large and small farmers.

Table 7.5: Comparison of recorded and simulated land use pattern in village Raipur

	Recorded* (ha)	Simulated (ha)	Deviation (%)
Common-forest land			
Class-I (Kharif)	2.0	2.0	0
Class-I (Rabi)	2.0	2.0	0
Class-I (Summer)	2.0	2.0	0
Class-II	2.0	2.0	0
Class-III	5.0	5.0	0
Class-IV	0.2	0.2	0
Class-V	-	-	-

Source: * Field survey

Table 7.6: Comparison of recorded and simulated land use pattern in village Sohna

	Recorded* (ha)	Simulated (ha)	Deviation (%)
Common-forest land			
Class-I (Kharif)	0.1	0	100
Class-I (Rabi)	0.1	0	100
Class-I (Summer)	0.1	0	100
Class-II	3.5	3.5	0
Class-III	10.0	10.0	0
Class-IV	0.5	0.5	0
Class-V	-	-	-

Source: * Field survey

Keeping in view the use of factual data from the field survey, the similarity between the observed and the model solutions of the common-forest land, and the partial verification of agricultural land use, the model can be judged as valid or nearly valid. Small differences in the recorded and the observed values can be ignored in this study as the model is built upon a logical framework; and the aim of the programming is to develop a planning scenario which is efficient and suitable to the site. Management planning similar to the past, in the study region, is not the priority because it has been proved inefficient and unsuitable (HFD, 1994). The real test of the model is whether all the individual elements combine to give acceptable predictions of land use patterns (Moxey et al., 1995).

7.2 Results of village models

The results of the analysis of the village models are presented and discussed in this section. The results include the levels of real activities that come into the plan, the amount of resources used and their marginal value products; and the maximum achievable goal levels and income level for each village.

7.2.1 Land use pattern

The results of the model runs are discussed for the agricultural and the common-forest lands separately.

Agricultural land

The land use pattern on small and large farms in different seasons (also called periods at certain places in the thesis) is presented in Table 7.7. It is seen that almost all the available land in Khod, Marola, Rojka, Raipur and Sehsola villages came into the plan for growing different seasonal crops. In Sohna, land allocated for cultivation of sorghum (a fodder crop) in the summer season only is fully utilised while in Kharif and Rabi seasons, a high proportion of agricultural land remains unutilised. The possible reason for under-utilisation is the shortage of labour, both men and women, within the village.

Table 7.7: Simulated agricultural land use of the village models (ha)

	Khod	Marola	Rojka	Raipur	Sohna	Sehsola
Kharif						
Small farmer						
- Pearlmillet	8.4	9.5	80	6.5	-	54.3
- Guar	19.3	20	13.5	50	178.5	400
- Vegetables	-	-	13	-	-	-
% utilisation	100	100	100	100	27.5	100
Large farmer						
- Pearlmillet	8	9.5	80	6.7	-	54.3
- Guar	20	20	16.7	49.8	264.7	400
- Vegetables	-	-	9.8	-	-	-
% utilisation	100	100	100	100	40.7	100
Rabi						
Small farmer						
- Wheat	14	20	40	30	128.8	75
- Mustard	14	9.5	46.5	26.5	-	379.2
- Gram	-	-	-	-	-	-
- Vegetables	-	-	20	-	-	-
% utilisation	100	100	100	100	19.8	100
Large farmer						
- Wheat	14	14	40	30	348.2	75
- Mustard	14	15.5	46.5	26.5	-	379.2
- Gram	-	-	-	-	-	-
- Vegetables	-	-	20	-	-	-
% utilisation	100	100	100	100	53.5	100
Summer						
Small farmer						
- Vegetables	5	7	20	25	44.8	50
- Sorghum	5	7	10	20	100	30
% utilisation	100	100	100	100	48.2	100
Large farmer						
- Vegetables	5	7	20	25	73.1	50
- Sorghum	5	7	10	20	100	30
% utilisation	100	100	100	100	57.7	100

The cropping pattern of the small and large farmer groups are quite similar. The main crops which came into plan are pearlmillet and guar in Kharif; wheat and mustard in Rabi; and sorghum and vegetables in summer. Cultivation of vegetables does not come into the plan in Kharif and Rabi except in Rojka where a small area is allocated to the vegetable crop.

The model solutions allocate higher land area to guar crop in comparison to pearlmillet in the Kharif season except in case of Rojka. Though, guar is a valuable crop, the percentage of area devoted to it does not match the existing cropping pattern by the farmers in the field. In reality, area of land for pearlmillet is much higher than for guar (NRDMS, 1994). According to observations during field survey, areas of wheat and mustard are more or less similar to the observed pattern in the field but the exclusion of gram crop completely from the solutions is unusual. In fact, some farmers do cultivate gram as it is an important source of protein and is used by the local people for a variety of purposes.

Demand of agricultural land is very high because of the need to produce fodder and food items. Land is a scarce resource in Khod, Marola, Rojka, Raipur and Sehsola. The marginal value product of agricultural land (Appendix 7.1) indicates that the income of these villages could be appreciably increased by bringing additional land under cultivation particularly in the Kharif season.

Common-forest land

The area of land capability classes which came into the management plan under the assigned management options are shown in Table 7.8. Class-I land for quarrying is fully used in Khod, Marola and Rojka as these villages have surplus labour because of a relatively small area of agricultural and common-forest lands. In case of Sohna class-I land does not come into plan and in Sehsola, there is partial utilisation of this class land. The non-utilisation of class-I land in Sohna and under-utilisation in Sehsola is because of the male labour constraint in these villages. Much of the male labour here is used for other activities, such as cropping, miscellaneous activities and planting on class-II, III and V lands.

Table 7.8: Simulated common-forest land use in villages (ha)

	Class-I Kharif	Class-I Rabi	Class-I Summer	Class II	Class III	Class IV	Class V
Khod							
- area	1	1	1	-	18.4	15	1
- % utilisation	100	100	100	-	100	100	100
Marola							
- area	1	1	1	-	12.7	21.4	0.1
- % utilisation	100	100	100	-	100	100	100
Rojka							
- area	2	2	2	-	55.3	3.2	2.6
- % utilisation	100	100	100	-	100	100	100
Raipur							
- area	7.15	7.15	4.8	6.3	9.7	2.8	-
- % utilisation	100	100	67.1	100	100	100	-
Sohna							
- area	0	0	0	3.5	0.7	2.9	-
- % utilisation	0	0	0	100	3.3	100	-
Sehsola							
- area	10.4	16.6	40.6	319.4	4	69.6	-
- % utilisation	8.5	13.6	33.3	100	100	100	-

Economically, quarrying is not the preferred choice as male labour is used preferentially for other activities. Such a model solution is important in participatory management as quarrying is not the people's preferred choice for work because of relatively difficult conditions and it is also harmful for the local ecology.

Available areas of class-II and IV lands are completely consumed; class-III land except in case of Sohna is also fully utilised (Table 7.8). The under-utilisation of class-III land in Sohna (3.3%) is because of paucity of both male and female labour. Class-V land, for miscellaneous activities, is completely exhausted as it uses labour from the general pool.

Land of class-II, IV and V is in scarcity in all the villages. This is also the case with land class-III, except in Sohna. Class-I land is also scarce in Khod, Marola and Rojka in all seasons; and in the case of Raipur in Kharif and Rabi seasons only. The high marginal value products of these lands (Appendix 7.2) indicates that income of the villages can appreciably be enhanced by making additional areas of these land types available to the villages.

7.2.2 Achievement of targets

Fulfilment of demands in respect of food energy, fuel energy, fodder, employment generation and timber were calculated as a percentage satisfaction by comparing the requirement levels with production levels in the model solutions (Table 7.9). Figures 7.1 to 7.6 depicts the comparative satisfaction levels with change of goal priorities.

Table 7.9: Satisfaction level of demands of the villagers (%)

Item	Season	Khod	Marola	Rojka	Raipur	Sohna	Sehsola
Food energy	Kharif	100	100	100	100	100	100
	Rabi	100	100	100	100	100	100
	Summer	100	100	100	100	100	100
Fuel energy	Kharif	100	100	100	100	100	100
	Rabi	100	100	100	100	100	100
	Summer	100	100	100	100	100	100
Fodder	Kharif	100	68.4	100	100	100	100
	Rabi	96.6	33.4	100	77.7	52.2	56.0
	Summer	89.0	21.4	100	100	99.0	50.4
Employ ment (General)	Kharif	68.8	69.8	82.6	80.8	99.1	100
	Rabi	61.0	61.6	66.1	76.3	99.1	93.2
	Summer	52.2	60.9	51.6	96.8	98.9	80.5
Timber	Annual	100	100	100	100	23.0	100

Food demand

Demand for food energy is fully met in all the seasons. There is surplus production of wheat, milk and vegetables in all the villages; pearlmillet in Rojka and Sehsola; and fruits in Raipur and Sehsola. Surplus is sold on the open market. Landless people meet their requirement of food energy either from purchases from large or small farmers, or from fruits found in common-forest land. In the model results, none of the small or large farmers consume fruits. All milk produced is sold. Neither the landless, small nor large farmer consume any of their milk: full dietary calorie requirement is met from crop products. This does not match the real situation in the field where at least a part of milk is consumed. This difference could possibly relate to the fact that no minimum level of dietary protein is specified in the model in the belief that if energy requirements are met then protein needs will be fulfilled (Capping, 1976).

Fuel demand

Fuel energy requirement is completely satisfied from different fuel sources. There is surplus production of fuelwood in Khod, Raipur and Sehsola; dung in Khod, Marola, Raipur, Sohna and Sehsola; and mustard straw in all the villages. Among the different socio-economic groups, landless and small farmers tend to use most of the fuelwood production from the common-forest land while the large farmers tend to rely on their own productions.

Fodder

The target for fodder production is not achieved (Table 7.9). The problem of fodder shortage is more acute in the Rabi and Summer seasons, mainly because supply from the common-forest land reduces drastically. During these seasons the only sources of fodder are crop residues or stored fodder. To meet the demand, the local people have to import or use stored fodder from other seasons.

Fodder supply is dependent on the area of land available to the villagers. If the ratio of livestock to land is high then there is obviously more likelihood of fodder shortage. For instance, Khod and Marola villages have almost same land area but the livestock populations are much different. The dependence of landless people on common-forest land clearly is higher than small or large farmers.

Employment

One of the key goals in participatory management in the study area, is the maintenance of regional employment. In the present study, the target of employment generation is nearly achieved in Sohna but in other villages it is not fully achieved (Table 7.9). The higher surplus of labour in Khod, Marola and Rojka in comparison to Raipur and Sehsola can be attributed to low availability of work in these villages due to the low land to people ratios on both agricultural and common-forest lands.

Requirement for labour is generally higher in Kharif season than in Rabi and Summer. In Raipur, there is a higher employment opportunity in Summer than in other seasons because of availability of better irrigation facilities and a large area under class-I common-forest land.

From the Tables 7.7 and 7.8, it is seen that a large part of both agriculture and class-I common-forest lands remains unutilised in Sohna; and of class-I land in Raipur and Sehsola. This is due to the scarcity of male labour. Use of class-I land, i.e., quarrying, requires only male labour which constitutes about sixty percent of the total labour force in the villages (Table 7.10). Further, the men are preferably used in cropping and other activities on class-II or class-III land, and only the surplus is available for quarrying.

Large farmers, in all the villages, hire mostly male labour from the landless people in Kharif and Rabi seasons. In the case of Marola, Raipur and Sohna, they hire male labour in Summer as well. Small farmers, in Kharif and Rabi, hire landless male labour in Raipur and Sohna villages only.

Table 7.10: Proportion of male, female and child labour available in the villages (%)

Type	Khod	Marola	Rojka	Raipur	Sohna	Sehsola
Men	60.8	59.2	62.1	59.1	60.0	60.3
Women	32.3	33.8	34.5	37.3	36.5	35.9
Child	6.9	7.0	3.4	3.6	3.5	3.8
Total	100	100	100	100	100	100

Timber goal

The target for timber is fully achieved in all the villages except Sohna (Table 7.9). The supplies come mainly from class-II and class-III common-forest land. In the case of Sohna, class-III land hardly comes into the plan.

7.2.3 Effect of priority structure on goal achievement

As seen in section 7.2.2, goals for fodder, employment and timber in some villages remained under-achieved while there was surplus production of food and fuel energy. In order to improve the situation of fodder and timber scarcity, and of under-employment, the models were run by changing goal priorities as explained in section 6.13.1. The results of three model Runs A, B and C (explained in Table 6.16) are depicted in figures 7.1 to 7.6 for each village.

Demand for food energy is fully met under different priority runs in all the villages. Similarly, fuel energy is sufficiently produced except in Run-C of Raipur (Figure 7.4).

The level of fodder production remains the same in Runs A and B; the supply does not improve by change in the priority of fodder goal. This might be due to the fact that the level of activities does not vary much between Runs A and B. In Run A, the level of fodder production (number 3 priority goal) remains equal to that of Run B because food (number 1 priority goal) and fuel (number 2 priority goal) are in surplus production. In such a situation, once minimum food and fuel levels are achieved, the model tries to achieve the next priority goal.

Fig. 7.1: Effect of change in priority levels on the achievement of goals in village Khod

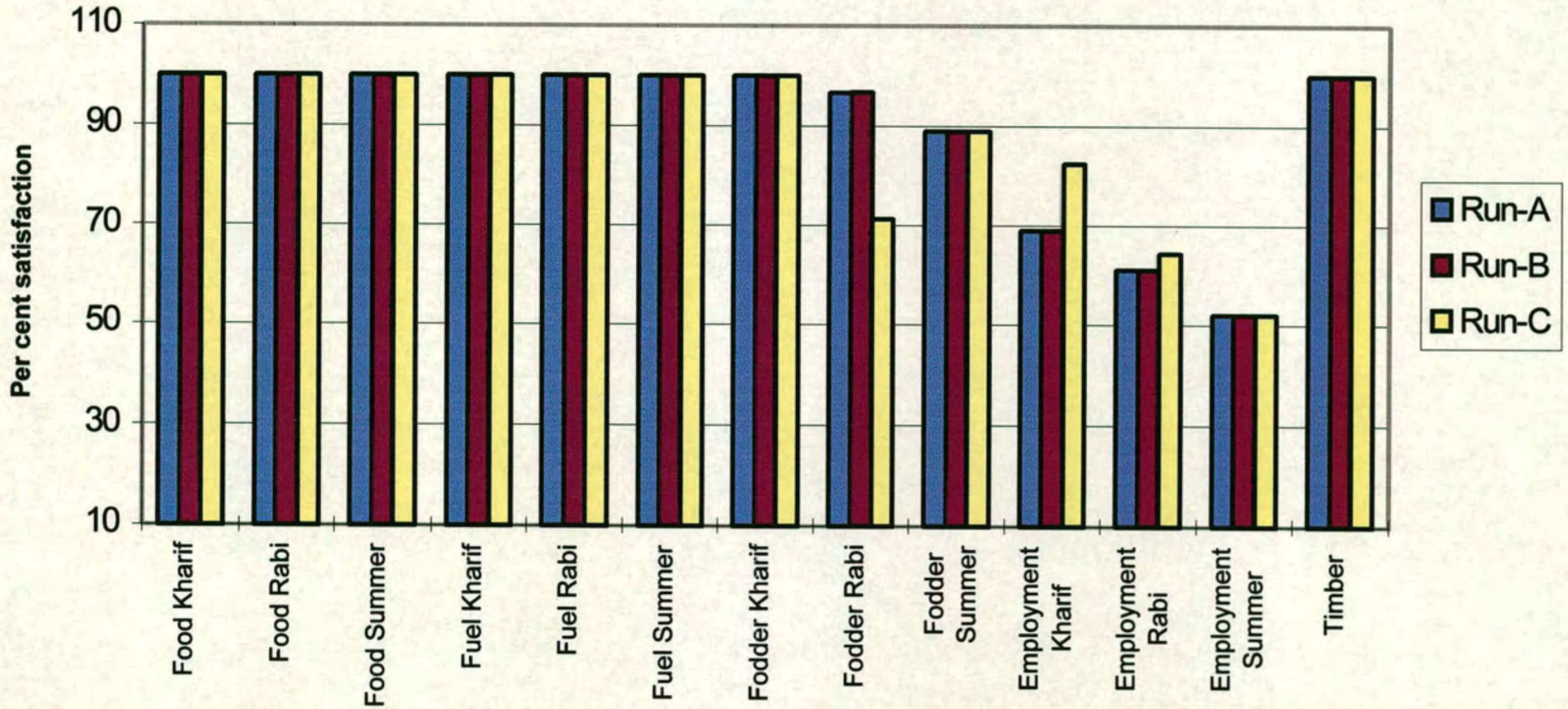


Fig. 7.2: Effect of change in priority levels on the achievement of goals in village Marola

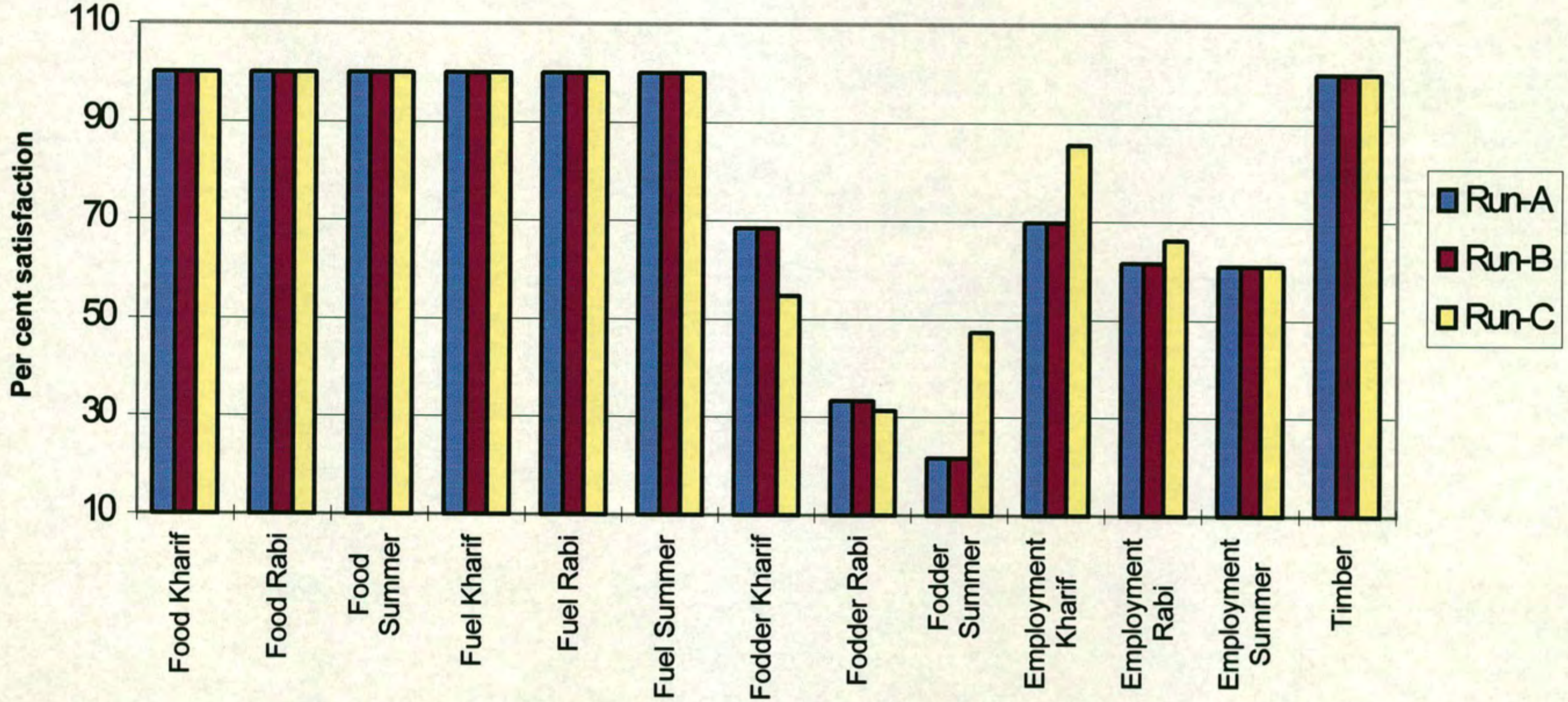


Fig. 7.3: Effect of change in priority levels on the achievement of goals in village Rojka

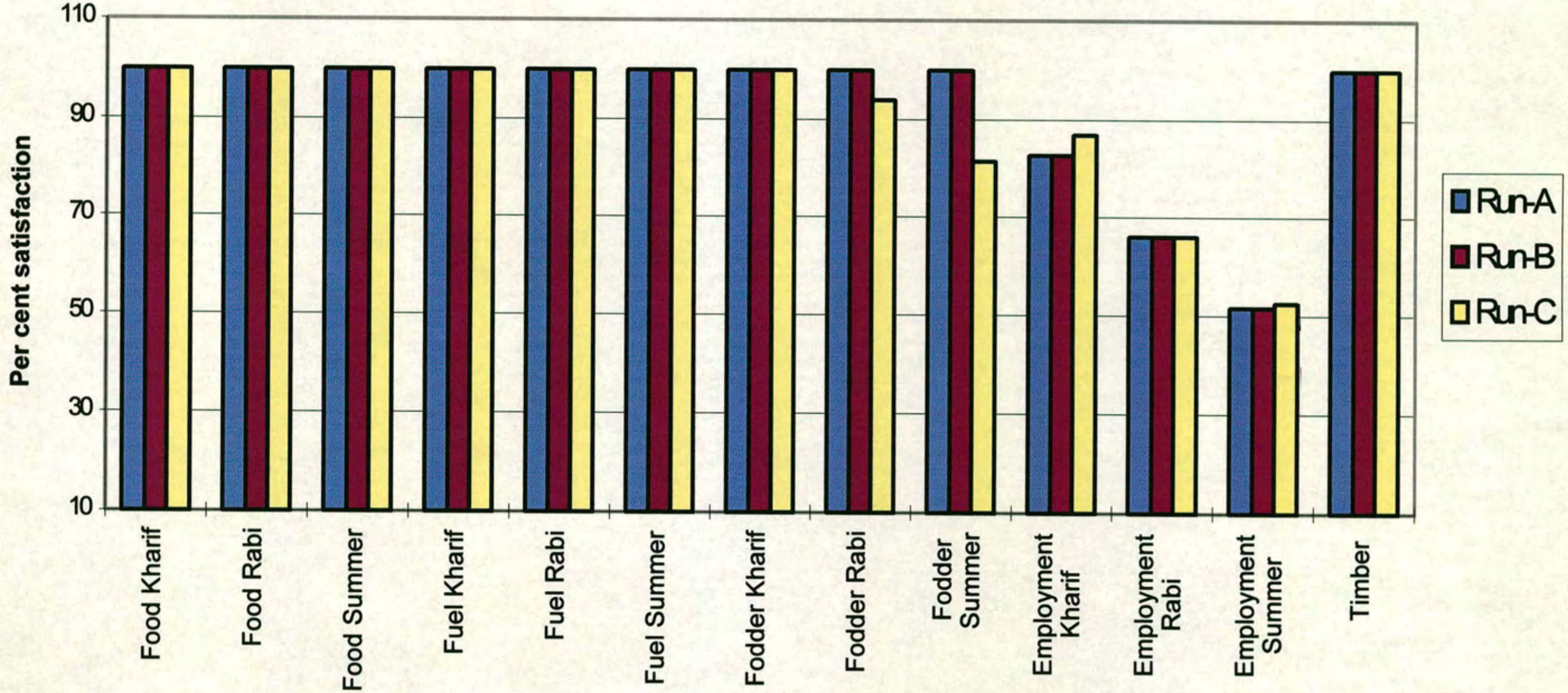


Fig. 7.4: Effect of change in priority levels on the achievement of goals in village Raipur

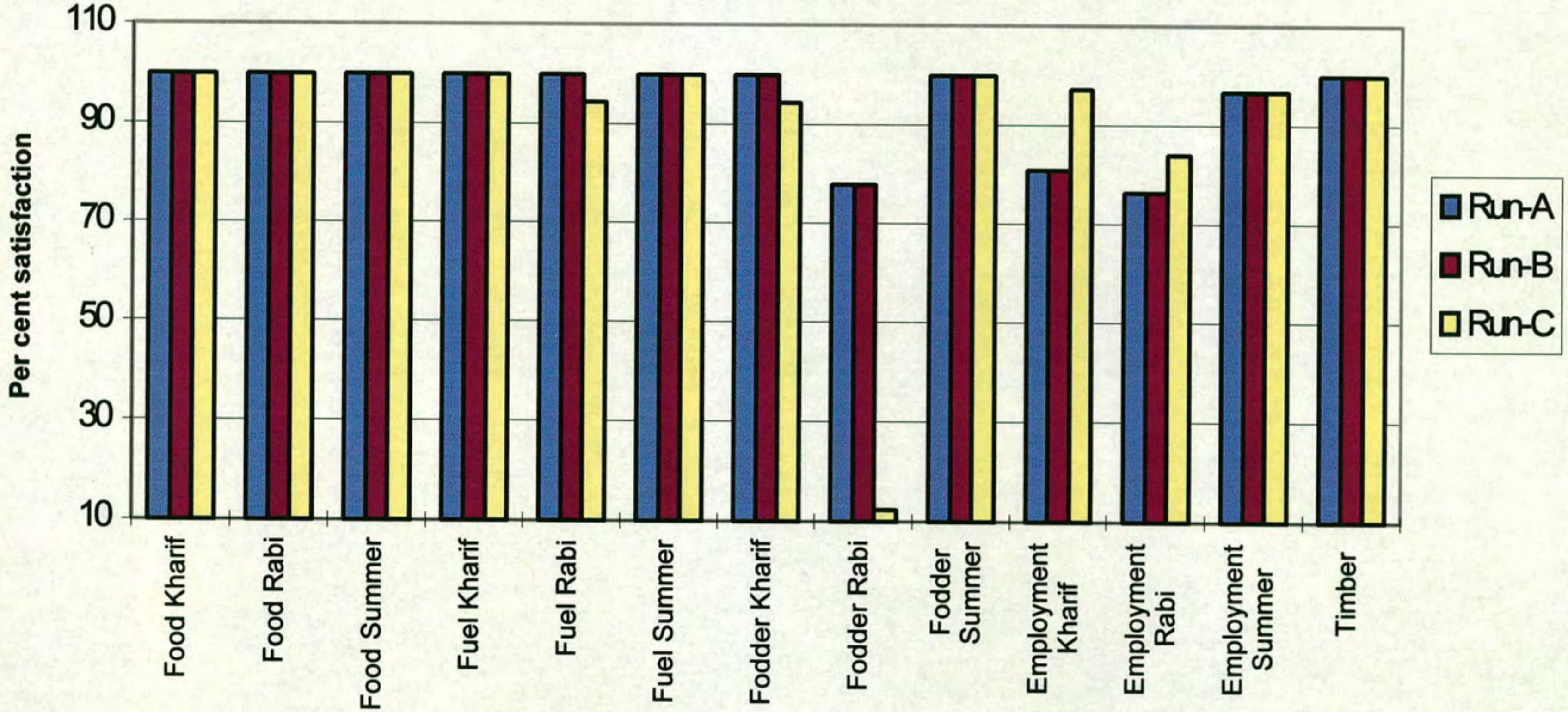


Fig. 7.5: Effect of change in priority levels on the achievement of goals in village Sohna

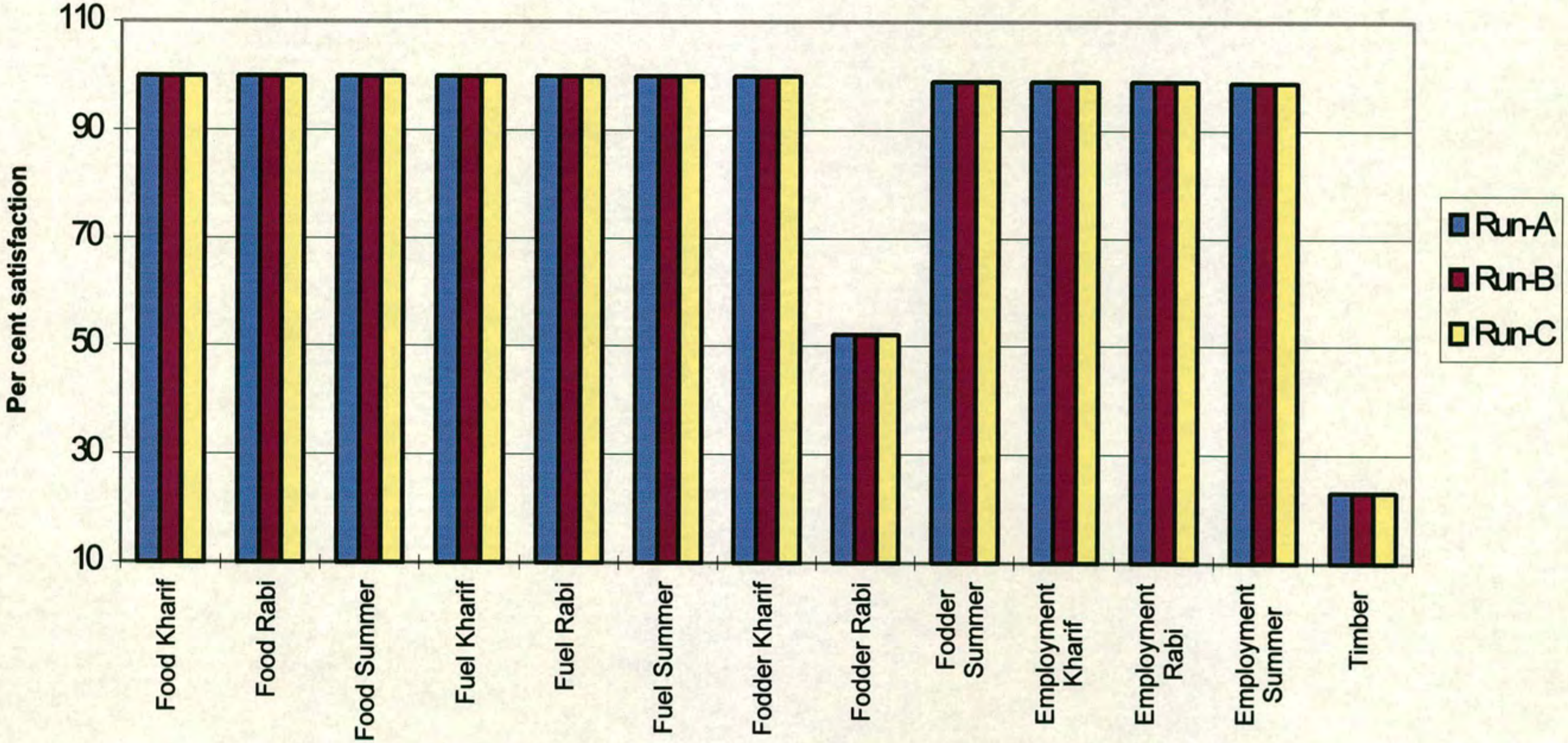
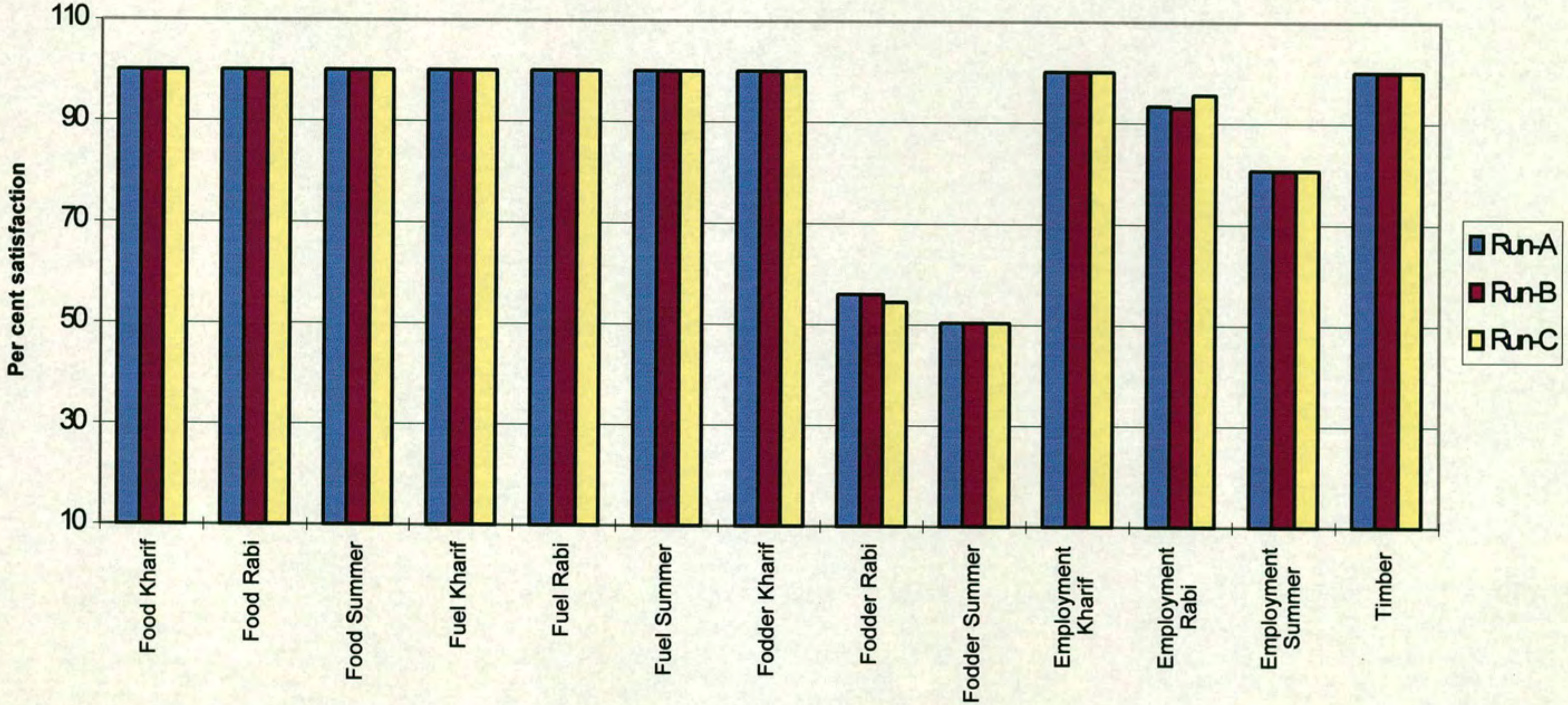


Fig. 7.6: Effect of change in priority levels on the achievement of goals in village Sehsola



On the other hand, the supply of fodder was invariably reduced in Run-C when the employment goal was given priority over fodder production in all the villages. The impact of Run-C, i.e., employment made the top priority goal, varies from village to village. In Khod, the effect is only in the Rabi season (Figure 7.1). In the case of Marola, the supply of fodder is affected in all the seasons; but interestingly, there is a substantial improvement in fodder supply in the Summer season (Figure 7.2). The supply of fodder is reduced in Rojka in the Rabi and Summer seasons (Figure 7.3), but the reduction is more in Summer. A similar situation is found in Raipur except there is drastic reduction in fodder supply in the Rabi season (Figure 7.4). This is probably because of exclusion of guar, a fodder crop, from the solution in Run-C. There is no impact of Run-C in the case of Sohna (Figure 7.5); and a minor impact in Rabi in Sehsola (Figure 7.6).

There is no impact on labour employment in Runs A and B; but a perceptible change takes place in Run-C in most of the villages. The change, mostly towards enhanced employment opportunities, is more pronounced in Kharif and Rabi seasons. This happens because of bringing in labour intensive activities into the plan. Marginal value products of labour (Appendix 7.4) indicates a shortage of male and female labour in Sohna in different seasons. In case of Sehsola, male labour is in short supply in all the seasons but female labour is scarce only in Kharif.

Looking at the individual villages, there is no effect of model runs in Sohna in any of the seasons (Figure 7.5) because there is scarcity of labour, both of men and women, in this village. Also, not much impact is observed in Sehsola except marginal improvement in Rabi season (Figure 7.6). A more pronounced effect of Run-C is visible in Khod (Figure 7.1), Marola (Figure 7.2) and Raipur (Figure 7.4) in Kharif and Rabi seasons. In Rojka, there is only a marginal improvement in Kharif and Summer seasons (Figure 7.3).

There is no effect on timber supply in any of the model runs.

7.2.4 Income

Though income generation was not considered a goal to be achieved, it is nevertheless, an important yardstick to the decision-making process. Increase in income was one of the most important preferences for management (see chapter four). The figures in Table 7.11 represent the net income generated by different runs of the village models.

There is no difference in income in Runs A and B; but the income increases appreciably in Run-C in all villages except Sohna where there is no change in income. This is again because of labour shortage.

Table 7.11: Income generation from the solution of models (Rupees)

	Run-A	Run-B	Run-C
Villages			
Khod	605049	605049	901035
Marola	-624620	-624620	-292746
Rojka	3429647	3429647	3648731
Raipur	1690331	1690331	2717933
Sohna	5371595	5371595	5371595
Sehsola	2436009	2436009	4041655

The change in income of the villages depends on the availability of employment opportunities and shortage of fodder. Enhanced employment increases income; reduced purchase of fodder, saves money which means an increase in income.

In Sohna, there is no change in income as the fodder and employment situation does not vary with the change of goal priorities. In other villages the increase in income (Run-C) is mainly because of improvement in employment. The contribution due to fodder, however, is negative as fodder shortage increases in Run-C. But the contribution due to income more than compensates the loss of income due to fodder purchase. It is seen that Marola has a negative income. The cost for the purchase of fodder exceeds the gain due to increased employment.

7.3 Impact of community management

The effect of community management on land use and on the achievement of goals was assessed at the village level. Land use on agricultural and common-forest lands (Appendix 7.3) were directly compared with land use results from village models in each season. In the case of goals and income, the achievement values of goals for all villages were summed and these values were related to the corresponding values in the solution of the community model.

7.3.1 Effect on land use

Overall, there is better utilisation of the land resource, quantitatively as well as qualitatively in the community model. Quantitatively, because, by and large, the total land area under agricultural crops increases except in the case of large farmers in the Summer season (Table 7.12). The increase in area is largely related to Sohna where a part of the previously unutilised agricultural land comes into the plan (see Appendix 7.3).

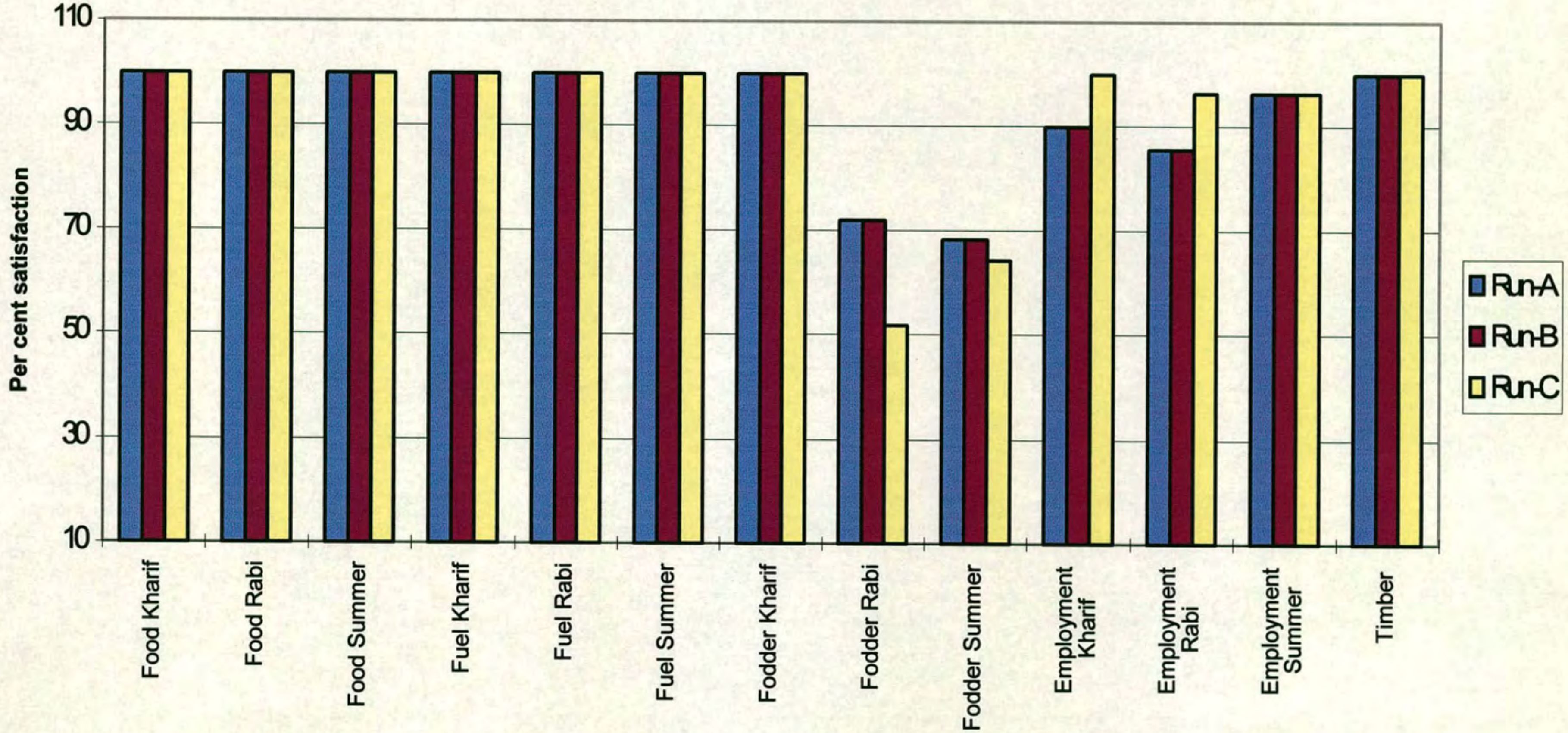
Table 7.12: Percent utilisation of agricultural and common-forest lands under village and community management

	Village management (%)	Community management (%)
Agricultural land		
Kharif		
- Small farmer	64.4	66.9
- Large farmer	70.9	86.0
Rabi		
- Small farmer	67.6	80.5
- Large farmer	73.5	62.7
Summer		
- Small farmer	52.0	71.0
- Large farmer	60.6	43.2
Common-forest land		
Class-I		
- Kharif	15.9	0.7
- Rabi	20.5	0.7
- Summer	36.4	49.0
Class-II	100.0	100.0
Class-III	83.1	100.0
Class-IV	100.0	100.0
Class-V	100.0	100.0

There is an important increase in area under the guar and mustard crops (Table 7.13). Such a increase may be liked by the participant's because both these crops can be grown in relatively water-scarce conditions. It may be recalled that water availability is a serious constraint to agriculture in the region. In addition, guar being a leguminous crop, helps in improvement of soil conditions.

In the case of common-forest land, that part of class-III land in Sohna remaining unused in village management comes under utilisation in community management (Appendix 7.3). Increased use of class-III contributes to fodder as

Figure 7.7: Effect of change in priority levels on the achievement of goals at community level



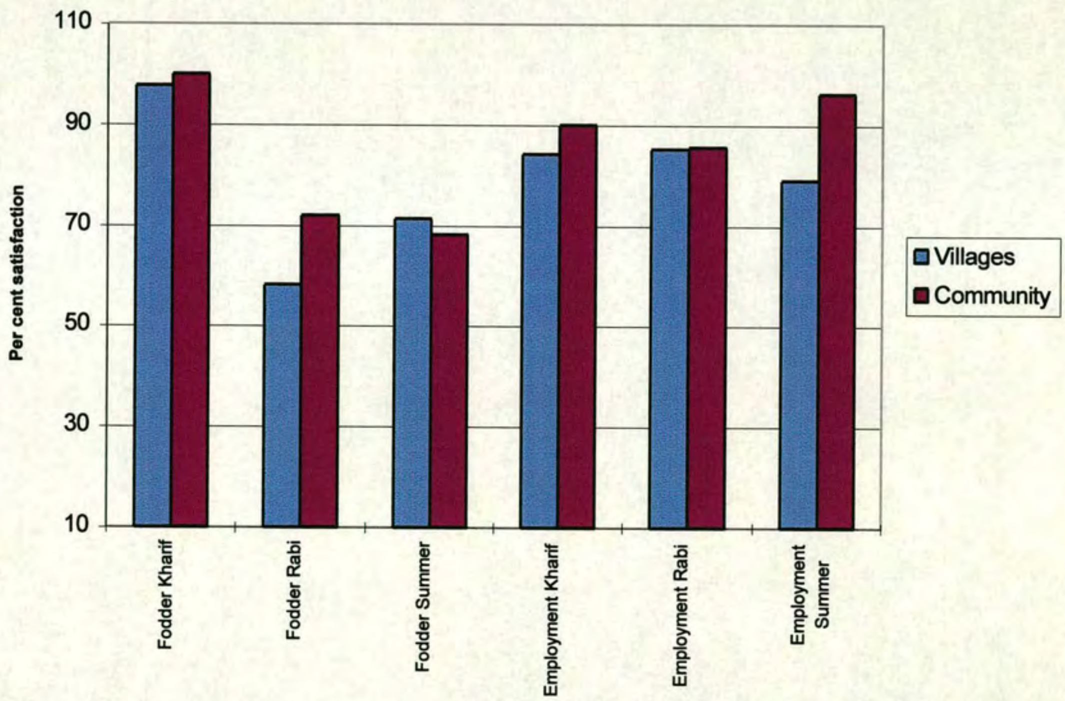
well as improves the ecology of the site by creating vegetation cover. A large reduction of the quarrying area in Kharif and Rabi seasons in community

Table 7.13: Total crop land under guar and mustard crops under village and community management

Crop type	Village management (%)	Community management (%)
Guar		
- Small farmer	51.4	60.0
- Large farmer	58.2	78.1
Mustard		
- Small farmer	35.9	44.5
- Large farmer	36.4	39.8

management (Appendix 7.3), helps in amelioration of local environment due to decreased level of air pollution.

Figure 7.8: Achievement of fodder and employment goals in village and community models (Run-A)



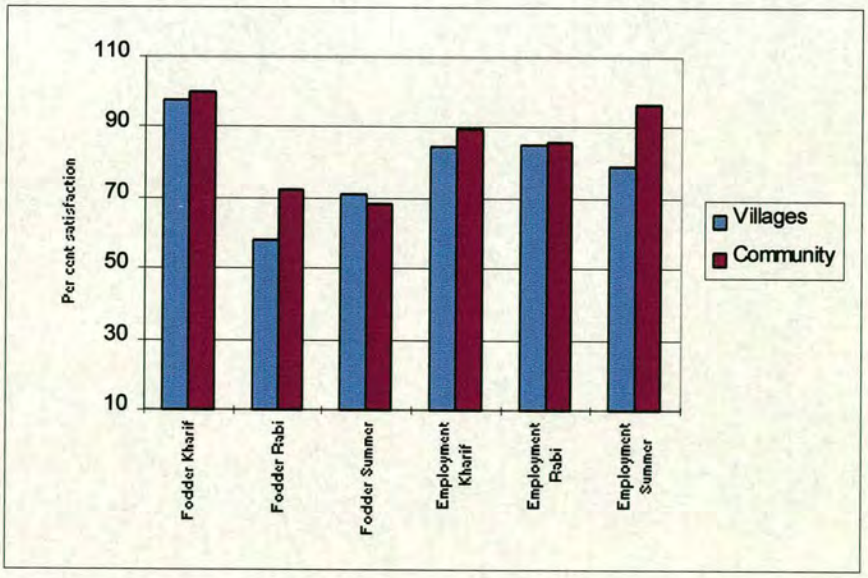
7.3.2 Effect on the achievement of goals

The effect of different model Runs (A, B and C; see section 6.14) in community management on the achievement of various community level goals are depicted in Figure 7.7. The difference in fodder supply and employment due to village and community managements are shown in Figures 7.8 to 7.10.

There is an increase in the satisfaction level of products and services; although the degree of satisfaction is affected by a change of goal priorities. Food energy, fuel energy and timber goals are fully satisfied in the community model (Figure 7.7). The supply of fodder in the Kharif season increases under community management; and is sufficient to meet the demand. In the Rabi season too, the fodder supply increases but is still short of demand. Overall, the supply of fodder in community management is greater than single village management. While increase in fodder availability in Kharif and Rabi is welcome, the decrease in summer is certainly not desirable from the people's point of view. The production of fodder also goes down when employment is assigned top priority (Figure 7.7).

The employment goal is better achieved under community management (Figures 7.8, 7.9 and 7.10) largely due to the transfer of surplus labour from Khod, Marola and Rojka to Raipur, Sehsola and Sohna villages.

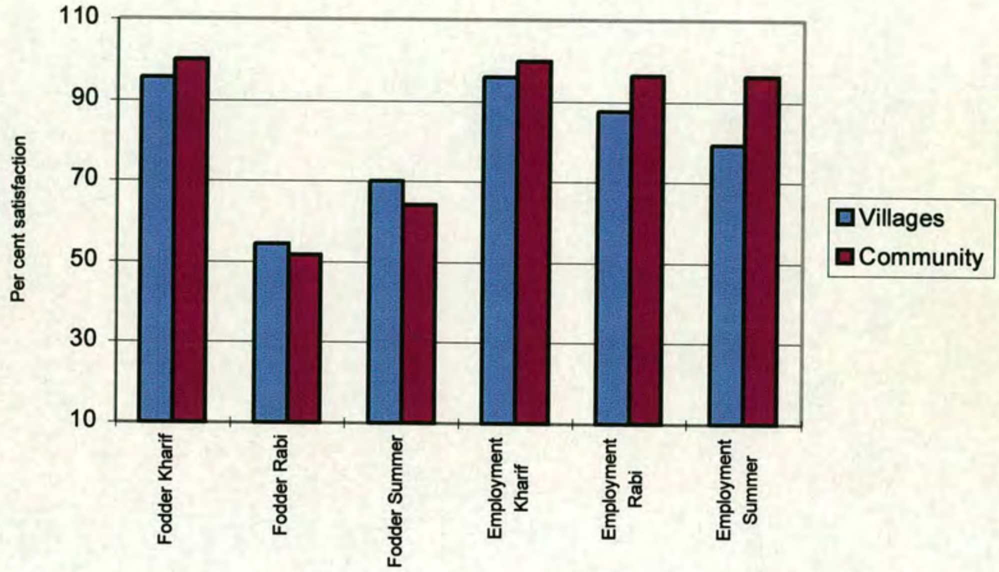
Figure 7.9: Achievement of fodder and employment goals in village and community models (Run-B)



Improvement in employment is highest in the Summer season which is a desirable feature contributed by the community management. There is near total employment for both men and women in Kharif and Rabi seasons under community management. Marginal value products of men and women is much higher in community management than in village management (Appendix 7.4).

Total income figures are Rs. 16388203 and Rs. 18640454 for village and community management respectively. There is a net increase of 13.7 percent in income of the villages due to community management.

Figure 7.10: achievement of fodder and employment goals in village and community models (Run-C)



7.4 Discussion

Most of the issues related to resource planning and decision-making have been discussed while presenting the results of village and community models. Running various models suggests that meeting food, fuel and timber goals need not be much of a problem. In fact, surplus production of these products indicates an opportunity to meet higher levels of these goals due to increases in population.

At the same time it is clear that the need for fodder cannot be met using the current management strategies at the current level of livestock population, regardless of the level of fodder goal priority. There certainly is a possibility of increasing income by producing more food grains on agricultural land and in turn of using this income to buy fodder from outside. The shortage of fodder can always be met from imports; but this availability of fodder from surrounding areas may not be comfortable. This issue needs to be considered among the participants. One strategy would be to reduce the size of the livestock population to a reasonable level.

Full employment can not be achieved. The model solutions indicate that employment opportunities can be increased by a change in goal priorities. In this way, full employment can be achieved for men folk in the villages. The pertinent issue here is majority of labour finds work in agriculture or forestry related activities which in turn are dependent on various climatic and other factors. Improvement in employment is accompanied by reduction in fodder supply. Thus, it gives rise to a conflicting situation. Another such situation arises between maximisation of income and fodder production.

The level of income is affected by a change in goal priorities. A change in priorities between food and fodder goals as number 1 or 2 or vice versa (Run-A & Run-B, Table 7.6) did not affect the income. There was, however, a substantial increase in income when employment was given priority over food and fodder (Run-C, Table 7.6). In the latter situation, increased income was accompanied by an increased fodder gap while in the former, the fodder production is higher but the income is lower in comparison to Run-C.

The solutions to different model runs can help the decision-maker(s) resolve conflicts. For instance, conflict between fodder production and income maximisation can be achieved by comparing the gain in income with the cost of purchasing fodder, assuming there is no restriction on import of fodder. For Run-C of the community model to maximise employment, the gain of income is Rs.9390379 in comparison to Rs.7624000 to be spent towards purchase of fodder. Thus, it would be advisable to adopt a management plan produced in Run-C of the model as it results in net higher income while maintaining fodder supply. Likewise, the decision-maker can attempt to resolve some of the other conflicting goals by converting possible objectives into monetary terms and then judge the suitability of different scenarios.

Two types of models - village and community - were developed and their results were examined in comparative terms. In fact, the villages are independent from each other; and they are under no obligation to behave as components of a community management strategy. But some advantages of community management over single village management are obvious in terms of better utilisation of land, higher achievement of goals and enhancement of income. The biggest advantage of community management lies in planning for the management of common and forest lands.

Some of the villages have small areas of common and forest lands. It may not be a sensible and practical exercise to plan for such small pieces of land individually in terms of time and technical resources. Also, various objectives, particularly environmental, can be better achieved by taking a broad and holistic view of a land mass which is bio-physically contiguous but socio-economically demarcated (as in the present study). It is important that the comparative advantages of different management strategies are presented to the participants and discussed to offer them alternative management for overall welfare. The approach of this study is an appropriate illustration of participatory management.

Efforts were made to make the models, as far as possible, representative of the various resources and activities prevailing in the field. This was not always achieved. Some of the inadequacies in the model formulation and the results are as follows.

- The area of the agricultural farms was not considered in the model. It was assumed that the area of a farm, small or big, would not affect the productivity per unit land. This does not actually match the normal situation in the field. In some situations, small sized farms are intensively managed, especially, if they belonged to small farmers. During the survey work, however, it was observed that the productivity per unit area was lower on small area farms than the big farms when trees were growing on field boundaries. Another observation during field survey was that a certain part of a big farm would remain neglected, particularly, if it belonged to a large farmer. There is therefore a lack of precise information on inputs and outputs related to farm size.

- The total demand of fodder was calculated by considering standard requirement of fodder for a tropical bovine unit. In reality, not all the livestock are able to get the supply of fodder as required. It was observed during the survey that some of the livestock, particularly belonging to the poorer households were underfed. This means that actual consumption of fodder is less than that calculated on the basis of standard requirement. In that sense, the fodder target was slightly exaggerated and also the actual expenditure on buying fodder to meet the shortfall would be less than that made out by the model solution.

• The division of households into landless people, small farmers and large farmers was rigidly followed. In real life, the households do not strictly adhere according to this categorisation. Some of the landless people are involved in sharecropping which has not been accounted for in the model; but, in fact, they could be well treated as small farmers. Further, it is a common phenomenon that a substantial number of people from landless people and small farmers migrate elsewhere for employment; and in turn they add to their income. The contribution to income from such employment was difficult to assess. As such, income figures provided by the models are understated.

• The model was set up for a period of one year only, with fixed resources and well-defined limited activities. The reality is that the whole economy is in a dynamic state. The resources except land are never fixed. The number and type of livestock vary from time to time; there is inflow and outflow of people, i.e., temporary migration. Even the character and quantum of the land resource are changing, particularly in recent years. For instance, an industrial township is being established in Rojka on a part of agriculture and common lands and a residential township in planned by some outside agencies in Sehsola which is likely to be occupied by the people from other areas. These activities have their impact on the local economy but have not been considered in the model formulation.

• The validity of the model plan can be questioned because cutting and carrying the fodder is preferred over normal grazing. People of all the socio-economic categories graze their cattle mostly on common and forest lands. There is no alternative provision for grazing in the plan. People might find it hard to accept a plan without the provision of grazing. They may not like stopping an activity in which they have been involved for centuries in the past. Also, restriction on grazing means, people will have to resort to stall feeding which in turn would put additional burden on labour for collection of fodder. This is very pertinent issue in participatory management and should be given due thought. Reduction of grazing, however, permits better control over activities which are potentially damaging to conservation and sustainability.

• One of the important objectives of the management was to maintain the ecological balance of the area. It was assumed in the management plan that restriction on grazing and adoption of specific management options would result in a vegetation cover over the area of forest and common lands. An increase in vegetation cover would, in turn, improve the ecology and biodiversity of the area. This conclusion was partly based on knowledge and experience and partly on assumed increase in vegetation cover and species diversity as a result of successful implementation of the management plan. But judging improvement in ecological conditions without basing it on actual measurement is a questionable conclusion.

• The model does not take into account increase in population. The population of the study villages is in fact increasing at a rate higher than in the rest of Haryana State. There will certainly be a higher demand for all kinds of products in future. Further planning will need to take this into account.

• From the point of view of participatory management, another serious lacuna of the planning process described in this study, is the lack of interactive process. For making management planning truly participatory and adaptable, the results of the models should have been discussed with the participants; and necessary modifications made in the models on the basis of the outcome of the discussions of various participants. Actually, this is a continuing process, and the model would keep on developing in stages. This activity was not possible within the scope of this thesis.

• The yield estimates used in this model are average figures achievable in a reasonably good year. In a practical situation, the yield of different crops does not remain same every year because of the variation in climatic and other factors. In some years, the yield is good, in others, it is relatively poor. Variations of the basic LP method, e.g. MOTAD (Hazell, 1971), would have permitted a limited examination of yield uncertainty but no suitable data were available. Even reliable subjective assessments of yield variation proved impossible to obtain in this study. In any case, with a true participatory approach, it would be more effective to re-run the multiple objective models several times with alternative yield assumptions providing easily appreciated results data to the farmers for discussion. Such 'sensitivity' runs were not completed here because an interactive debate between planners and the farmers could not be arranged. This would not be a problem if the work was carried out in the location.

It is seen from the foregoing discussion in section 6. And the results in this Chapter that there were a number of deficiencies in the model formulation and the planning process. However, inspite of the inconsistencies, the models have served useful purpose in integrating bio-physical and socio-economic parameters in order to meet various objectives of resource management. The models provide alternative planning strategies to the participants to decide upon the most suitable management plan: i.e. provide decision-support. They also help the decision-maker(s) in resolving conflicts. In the planning methodology, it is possible to remove the inconsistencies by incorporating various relevant parameters following further study. Due to limited resources and time constraint, it was not possible in this thesis.

Chapter 8

Conclusions

Participatory planning in this study has been shown as a practical approach for the management of natural resources, particularly in a subsistence economy. The study demonstrates that planning for the management of natural resources can be systematically developed by taking into consideration subjective and objective knowledge of the various resource systems, i.e., social, physical, biological and economic. It also illustrates how, with the assistance of various scientific tools, such as survey, GIS and mathematical programming, bio-physical and socio-economic components can be integrated to address various, often conflicting, objectives of the participants in resource management.

Previous chapters have considered socio-economic evaluation of a selected site, the assessment of physical and biological site factors, and the development and application of mathematical programming models including the presentation of results. This chapter is a brief summary of the potentialities and limitations of participatory natural resource planning relevant to this study site; and some suggestions for future research.

Potentialities

(1) Participatory management of natural resources involves a number of stakeholders such as farmers, landless people, professionals, government agencies, etc. All of these stakeholders, as participants, contribute to planning and decision-making. They have different objectives according to their individual needs and preferences. The objectives are often conflicting. This study shows that it is possible to determine the objectives of the participants through a socio-economic survey. Although the objectives might be conflicting, in fact, in a subsistence economy, they are relatively simple: related mostly with the basic needs of the majority of population, maintenance of the local ecological balance and enhancement of income.

(2) Various management objectives can be reasonably represented in a computer model vis-à-vis the resource availability. Priorities of different socio-economic groups of the population and other relevant agencies can be incorporated in the model. It is also possible to link the management of common property resources (common and forest lands) with privately owned resources (agricultural land) of the people in a complementary manner. Goals which are not possible to achieve under given resource availability, can be identified and highlighted to the agencies responsible for management.

(3) If different issues, objectives and resources, are properly represented into the programming model, management options for the common and forest lands can be explored and presented to participating agencies such as the Village Panchayats (VP) and the Forest Department (FD). There is an opportunity to achieve the desired results by modifying the parameters of model, if the VP and/or the FD feel the need for it.

(4) Through the outcome of the planning process, the importance of appropriate management of common and forest lands can be demonstrated; and why it is important to exert strong management control and restrictions, and to involve the people in planning.

(5) Classification of land resources into areas of homogenous characteristics helps in designing suitable management strategies for individual areas. GIS can help in classifying the land into such areas. It is possible to integrate various site features such as topography, vegetation, soil and land use, and apply subjective knowledge of the site within GIS methodology.

Limitations

(1) Participatory multiobjective management on a holistic basis required large amount of detailed information for various activities and constraints. The detailed published information on all aspects of activities was not available. Due to the lack of sufficient data, complete validation of the model was difficult and the choice of management options for various land classes was restricted to only few. Specifically yield variation data were not available.

(2) An important limitation of the study was the rigid assumptions regarding socio-economic categories of people, fixed resources and well-defined activities and demands. In real life, rigidity gets diluted according to the prevailing environment. In this study, rigidity was, however, maintained in the models.

(3) Improvement and preservation of the fragile ecology was a major and priority objective of this study. While doing so, a ban on grazing was imposed through adoption of particular management options. Such a step may prove a disincentive in people's participation. Further interaction with the local people would have been desirable.

(4) A truly participatory planning approach is an interactive process between the modeller(s) and the participants. The outcome of the models should have been discussed with the VP and the FD: it could not be done due to limitations of time and resources available for this study.

(5) Assessment of the improvement in ecology and environment was completely subjective. It could not be possible to assess improvement by field measurements due to limitations of time and resources.

Suggestions for further research

(1) For practical utility of the planning methodology described in this study, there is a need further to explore all the possible management options based on different levels of inputs on the common and forest lands as well as on the agricultural land. More data, collected on the basis of field experimentation and work studies, may have made the model more robust. For example, plantation of species in different combinations on class-II and III lands, various agroforestry designs and application of varying silvicultural techniques would have given a wide range of potential options to choose from.

(2) The planning process should be dynamic. There is need to take into account change in resources and demands, particularly the likely increase in human and livestock populations, which means higher levels of demands of various products.

(3) For practical purposes, this type of work should be broad-based involving different experts working as a multi-disciplinary team. The team may be as broad-based as possible, but it should, at least, include a forester, an agronomist, a soil

scientist, a sociologist, an economist, a farmer and a modeller. It would help in better assessment of resources and activites, and in the formulation of a model. Clearly, too, it would permit a fuller participative process to take place, in place of the rather restricted opportunities within the present study.

(4) It is important to involve people from different socio-economic groups, particularly those who depend most on the resources, and who are generally indifferent or neglected in decision-making. For example, landless people and the marginal farmers who do not have any other means of livelihood are generally neglected by in the decision-making process. If they are involved, they would take interest to improve a resource which they depend on.

(5) Finally, to make the planning process truly participatory, a continuous interaction among the participants and the modeller(s) is essential. The old adage 'out the sight, out mind', is pertinent to participatory management. Occasional contact or discussion of the results in the end is not be sufficient to keep up people's enthusiasm. Interaction with them at each step in the planning process on a continual basis would not only help in formulating a realistic plan but also make them feel responsible. When various issues related with planning are discussed with people, they feel involved and tend to behave more responsibly and seriously.

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Appendix 2.1
Forest types in India

Forest type	Area in sq. km	Percentage
1.Tropical Wet Evergreen forest	51,249	8.0
2. Tropical Semi-Evergreen	26,749	4.1
3. Tropical Moist Deciduous	236,749	37.0
4. Lottoral and Swamp	4,046	0.6
5. Tropical Dry Deciduous	186,620	28.6
6. Tropical Thorn	16,491	2.6
7. Tropical Dry Evergreen	1,404	0.2
8. Sub-Tropical Broad Leaved hill	2,781	0.4
9. Sub Tropical Pine	42,377	6.6
10. Sub Tropical Dry Evergreen	12,538	2.5
11. Montane Wet Temperate	23,365	3.6
12. Himalayan Moist Temperate	22,012	3.4
13. Himalayan Dry Temperate	312	-
14. Sub-Alpine and Alpine	18,628	2.9

Appendix 2.2

Estimates of wastelands in India (million ha)

Staes/UTs	Non-Forest Degraded area	Forest Degraded area	Total
Andhra Pradesh	7.682	3.734	11.416
Assam	0.935	0.795	1.730
Bihar	3.896	1.562	5.458
Gujarat	7.153	0.683	7.836
Haryana	2.404	0.074	2.478
Himachal Pradesh	1.424	0.534	1.958
Jammu and Kashmir	0.531	1.034	1.565
Karnataka	7.122	2.043	9.165
Kerala	1.053	0.226	1.279
Madya Pradaesh	12.947	7.195	20.142
Maharastra	11.560	2.841	14.401
Manipur	0.014	1.424	1.438
Meghalya	0.815	1.103	1.918
Nagaland	0.508	0.878	1.386
Orissa	3.157	3.227	6.384
Punjab	1.151	0.079	1.230
Rajasthan	18.001	1.933	19.934
Sikkim	0.131	0.150	0.281
Tamil Nadu	3.392	1.009	4.401
Tripura	0.108	0.865	0.973
UttarPradesh	6.635	1.426	8.061
West Bengal	2.177	0.359	2.536
UTs	0.889	2.715	3.604
Total	93.691	35.889	129.800

Appendix 4.1
Infrastructure and other information about the study villages

Housing: Every household in the villages has got a house of its own.

Health care: Sohna has got a primary health centre, dispensary, family planning centre and homeopathic practioners. Rojka has got a Public Health Centre.

Educational institutions: There is one primary school in each of Khod, Rojka, and Raipur villages. Sehsola and Sohna villages have five and three primary schools respectively. Other educational institutions include one middle school at Sehsola, two high school, one college and a Technical Training Centre at Sohna.

Transport: Each village is connected by a metalled road and bus service. Besides, bus service other modes of transport are auto rickshaw; cycles, taxis, carts and trucks. Some people have jeeps, motorcycles, cycles, tractor and camel carts for moving and transport of goods.

Electricity: All the villages are fully electrified. Electricity is mainly used for household lighting, for running tube wells, flour mills, oil extraction units, etc.

Water supply: Water supply from overhead water tank is provided to each village by the public health department.

Other services: A large part of land at Rojka has been acquired by the government to develop an industrial town. Some industries have already been established. Other facilities are: one post office, Mewat Sevika, Anganwari (women's group - Mahila Mandal) and Gram Panchayat, veternary hospital, artificial insemination centre for animals, post office, bank branches, telephone exchange, etc. Large number of shops and cottage units exist at Sohna aand Rojka.

Local Markets: Local markets are held twice at Sohna and thrice at Tauru in a month. In these markets goods of local consumption are traded. People from villages come to sell as well as to buy. Cattle fairs are also held once or twice a year. These fairs attract people from far and wide. Recently, trading of certain animals such as camels is in decline because of their reduced role in the modern economy due to mechanised agriculture and modes of transport.

Appendix 4.2
Workers in the study villages (according to 1991 Census of India)

Type	Khod	Marola	Rojka	Raipur	Sohna	Sehsola	Total
I. Cultivator	43	39	94	63	23	390	652 (29.12%)
II. Agricultural labourer	8	12	2	20	172	81	295 (13.18%)
III Livestock, forestry and allied activities	2	-	3	2	-	-	7 (0.31%)
IV Mining and quarrying	-	-	-	-	-	104	104 (4.65%)
V Manufacturing, processing, etc	44	35	66	36	90	50	321 (14.34%)
VI Constructions	-	2	9	30	21	37	99 (4.42%)
VII Trade & Commerce	-	7	12	16	43	22	100 (4.47%)
VIII Transport, Communications	4	7	29	21	14	90	165 (7.37%)
IX Other services	3	2	155	23	75	238	496 (22.15%)
Total main workers (I to IX)	104	104	370	211	438	1011	2239 (25.36%)
Marginal Worker	34	3	209	4	65	342	657 (7.44%)
Non-worker	275	337	805	638	1215	2662	5932 (67.20%)

Appendix 4.3
Quarrying process and its economic and employment potential in the villages*

Mines Department: This department is to oversee the operation of quarries, welfare of labourers and collection of royalty for the stones extracted from the quarries. The labourers are provided with shoes, medicines and a helmet.

Stone extraction: Labourers prepare stone in the quarries. They may be hired by some contractor or work on their own. Either way prepared stones are loaded into trucks and are carried to crushers. Loading is manual and unloading is mechanical. Each truck load makes about 225 cu. ft. of stone. Two persons prepare upto six truck loads of stone per day. They charge Rs. 65 per truck load. Four persons can load 8 trucks per day at the rate of Rs. 25 per truck. The crusher owner pays Rs. 350 per truck load. Each crusher employs on an average about 20 persons per day which include mechanics, assistants and labourers.

Total number of truck loads per day removed from the site	680
Number of operative days in a year	313
Number of trucks engaged	170
Number of mechanic shops	10
Number of crushers for handling the load	34

Employment potential of quarrying in the area: Various components of quarrying have taken into consideration to derive the employment potential of this activity in the study villages. They are given in the table below.

Type of Employee	Number (per day)	Share of money (Rupees)
1. Employees of the Mining Department	27	
2. Labourer for stone preparation	340	44,200
3. Stone Loaders	340	17,000
4. Drivers	175	10,500
5. Truck and tractor assistants	175	7,000
6. Mechanic shops	30	3,000
7. Blast material handling	5	500
8. Crushing labourers	680	34,000
9. Owners of trucks & tractors, contractors, etc.	175	132,600

In addition to the above mentioned direct employment, there are people depended on the downstream activities. Crushed stones are purchased by builders. road makers, individuals, etc. They in turn employ people to use the crushed stones. Other people associated are bankers, middlemen, and other relevant government departments. The government gets Rs. 85 per truck load as royalty out of which Rs. 8.50 goes to the Village Panchayats. Thus, total revenue to the government could be to the tune of Rs.57,000 and to the VPs Rs.5,700 per day.

*Based on work study on the site and information gathered from various sources

Appendix 4.4
Questionnaire for the villagers
(Household Questionnaire)

Village: [ ]

1. Particulars of the respondent household

a.) Head of the family (name):

b) Gender: [ ]
Code: Male=1, Female=2

c.) Caste: [ ]
Code: General Caste=1, Scheduled Caste=2

d.) Religion: [ ]
Code : Hindu=1, Muslim=2, Others=3

e.) Family size :
(a) Major= (b) Minor= (c) Total=
Age: Major (>18years)=1, Minor (<18years)=2

f.) Occupation: [ ]
(Occupation: Govt. service =1, Private job=2, Self employed=3, Daily labour=4, Self farm and household work=5, No work=6)

g.) Education level: [ ]
Education level : Primary=1, Secondary=2, Graduate=3, Post-graduate and above=4, Illiterate=5

2. Agricultural details

a.) Agriculture land

Area (in ha)	Tenure	Security	Irrigation status (per cent area under irrigation)

Codes Tenure : Owned=1, Leased=2, Sharecropper=3, Encroached=4, Other=5
Security: <5 yrs=1, 5-10 yrs=2, 10-20 yrs=3, Indefinite=4

b) Landholder category: [ ]
Codes: Large farmer=1, Small farmer=2, Marginal farmer=3, Landless=4

c) Trees on farm

Species	Pattern	Purpose	Production
1			
2			
3			
4			
5			

Codes Pattern: Field boundary=1, Intercropping=2, Block=3, Scattered=4
Purpose: For cash=1, firewood=2, fodder=3, small timber=4, Shade=5, Other=5
Production : 1=Timber, 2=Small timber, 3=Firewood, 4=Fodder, 5=Other

d.) Cropping pattern

Rabi*

1.
2.
3.
4.
5.
6.

Kharif**

1.
2.
3.
4.
5.
6.

(* R = Rabi (Nov-Dec. to March-April), ** K = Kharif (June-July to Sept.-Oct. - The two cropping seasons)

e.) Constraints in tree planting on agriculture land: [ ]

Code: Shortage of land=1, Land tenure=2, Unavailability of seedlings=3, Interference to agricultural crops=4, Interference with agricultural operations=5, Not profitable=6, Other=7, specify

3. Livestock details

(a) Livestock population and feeding

	Population				
Type	Male	Female	Calf	Mode of Feeding'	Grazing place
1	2	3	4	5	6
Cow					
Buffalo					
Camel					
Goat					
Sheep					
Pig					

Codes: Mode of feeding : Stall feeding=1, Grazing=2, Both=3.
Grazing Place: Common and Forest land=1, Agricultural fields=2, Other areas=3

b.) Source of fodder

Source	Percentage of total fodder
Agricultural farm	
Common and Forest lands	
Purchased	

c.) Tree fodder

Species	Use	Preference order
Ronj		
Kikar		
Uloo neem		
Papri		
Neem		
Beri		
Lasura		
Dhak		
Dhok		

Code: Use - Yes=1, No=2
Preference scale: 1-9, 1=most preferred, ..., 9=least preferred.

4. Household fuel energy

(a) Fuel use

Type	Source	Percent of total fuel requirement
Fuelwood		
Crop residues		
Dung cake		
LPG		
Electricity		
Other		

Codes, Source: Agriculture fields=1, Common and Forest lands=2, Other source=3, specify
Requirement (need of the family per year): Fuelwood, crop residues, dung cake, LPG and Electricity.

b.) Tree species for fuelwood

Species	Use	Preference order
Mesquite		
Khairi		
Kikar		
Ronj		
Dhak		
Dhok		
Israeli kikar		

Code: Use - Yes=1, No=2

5. Supply of timber

Species	Use	Source	Preference order
Kikar			
Papri			
Ronj			
Neem			
Shisham			
Uloo neem			
Siris			

Codes Use- Yes=1, No=2

Source- Farm land=1, Common & forest lands=2, Ohters=3, Purchased=4

6. Non-timber Forest Products

Type of product	Source	Use
Thatch		
Seeds & fruits		
Soil		
Gum		
Tree leaves		
Stones		
Medicines		
Grasses		
Twigs		

Source: Farm fields=1, Common and forest lands=2, Purchased =3

Use: Costruction=1, Household consumption=2, Cash income=3, Other=4, specify

7. Social Insight

a.) Is the village society stratified into different groups? [ ]

Code: Yes=1, No=2, Don't know=3

b.) If yes, then what is the basis of stratification : [ ]

Code: Caste=1, Landholding=2, Total income=3, Servoice=4, Religion=5, Political affiliation=6, Other=7, specify

c.) Does the stratification effect the collective action by the villagers? [ ]

Code: Yes=1, No=2, Don't know=3

d.) According to you what is the position of Scheduled Castes in the society? [ ]

Code: Better off=1, At par=2, Worse off=3, Don't know/can't say=4 (in comparision with other groups)

e.) What are the socio-economic problems in the village?

1.
2.
3.
4.

f.) Do you feel any conflict in decision making by Panchayat and/or village forest committee? [ ]
Code: Yes =1, No =2, Don't know/can't say=3

g.) On what occasions people from different strata tend to work together? [ ]
Code : On religious festivals=1, During elections=2, On village fare=3, During crisis from outside=4, Others such as common purpose, spiritual good cause, multiple factors, etc.=5, It never happens=6, Don't know/can't say=7

8. Forest Management

a.)(i) Please rank the following agencies in terms of their effectiveness in forest management-

1. FD
2. NGO
3. Village forest committee
4. FD+VFC
5. FD+VFC+NGO
6. VFC+NGO
7. Can't say

(ii) Which system is better for the management of forest and common lands? [ ]
Code: Traditional management by FD =1, JFM =2, Don't know/can't say=3

b) Would you like to participate in the management of forest and common land? yes=1, no=2 [ ]

(i) If yes, for what [ ]
Code : To meet basic needs for : fuelwood/fruits/small timber & poles/timber/fodder/fruits=1, For additional source of income=2, Checking environmental degradation : watershed reclamation/soil-moisture conservation/river bank protection, etc.=3, Tree planting is linked with religious sentiments=4, Have surplus time so want to devote for constructive work=5, For prestige, ego satisfaction and to lead the people=6, Other=7, specify

(ii) If no, please give reasons [ ]
Code: no time=1, no stamina=2, no interest=3, Other=4, specify.

(iii) If not, what might encourage you to actively participate? [ ]
Code: Cash=1, Benefit in kind=2, Leadership=3, Ego satisfaction and greater say in decision making=4, Other=5, specify

c) What difficulties do you perceive in JFM planning and implementation?
1
2
3
4
.

d) According to you what should be the objective of management of the forest and common lands [ ]
Code: For commercial production=1, For ecological maintenance and for environmental preservation=2, To produce items required by the local people=3, Mining development=4, Pasture and grazing=5, Agriculture=6, Other=7, specify

e) What is the best forest protection method? [ ]
Code: Employ protection guard=1, Villagers=2, FD=3, Other=4, specify

f) Which species do you prefer for planting on the site?
i.
ii.
iii.
iv.
.

g) Would you like to become a member of Village Forest Committee? yes=1, no=2
[ ]

9. Benefit Distribution

a.) How should benefits accruing from the forest land be distributed? [ ]

Code: Should go to the government=1, Should be given to the Panchayat for the development of village=2, To be used further for forestry development=3, To be distributed equally among people=4, Produce to be distributed according to the family size=5, To be given to the poor people who are needy=6, Other=7, specify

b.) How should benefits accruing from the common land be distributed? [ ]

Code: Should go to the government=1, Should be given to the Panchayat for the development of village=2, To be used further for afforestation=3, To be distributed equally among people=4, Produce to be distributed according to the family size=5, To be given to the poor people who are needy=6, Other=7, specify

10. Perception about others

a) What do you think about forest staff?

i. Are they capable of managing the forests own their own? [ ]

Code: Yes=1, No=2, Don't know/can'tsay=3

ii. Are they sincere in performing their duties? [ ]

Code: Yes=1, No=2, Don't know/can'tsay=3

b) What do you think about Panchayat and VFC? Do they work well? [ ]

Code: Yes=1, No=2, Don't know/can'tsay=3

c) Whom do you prefer FD or Panchyat-VFC for forest management? [ ]

Code: FD=1, P-VFC=2, Both=3, None=4, Don't know/can't say=5

d) Whom do you prefer FD or Panchyat-VFC for the management of common lands?
[ ]

Code: FD=1, P-VFC=2, Both=3, None=4, Don't know/can't say=5

Appendix 4.5

Questionnaire for the government staff

(Personnel questionnaire)

1. Name of personnel:

2. Name of the department:

3. Main activities of the department:

4. Involvement in forestry: [ ]
Code: High (forestry main activity)=1, Not much (forestry secondary activity)=2, No involvement=3

5. Are you aware of JFM? [ ]
Code; yes=1, No=2

6. Is JFM strategy truly required for the management of forest land? [ ]
Code: Yes=1, No=2

7. If not, then what is a better alternative, could you suggest please?

8. Social Insight

a.) Is the village society divided/stratified into different groups? [ ]
Code: Yes=1, No=2

b.) If yes (1), then what is the basis of stratification : [ ]
Code: Caste=1, Landholding=2, Total income=3, Servoice=4, Religion=5, Political affiliation=6, Other=0, specify

c.) Does the stratification effect the collective action by the villagers? [ ]
Code: Yes=1, No=2, Don,t know=3

d) According to you what is the position of Scheduled Castes in the society? [ ]
Code: Better off=1, At par=2, Worse off=3 (incomparison to other people)

e) What are the socio-economic problems in the village?
1.
2.
3.
4.

f) Do you feel any conflict in decision making by Panchayat and/or village forest committee? Yes =1, No =2, Don,t know=3 [ ]

If yes, then what causes the conflict?

Who helps in conflict resolution?

What is the best way according to you to resolve conflicts?

g) On what occasions people from different strata tend to work together? [ ]

Code : On religious festivals=1, During elections=2, On village fare=3, Other=4, specify

9. Forest Management

a.)(i) Please rank the following agencies in terms of their effectiveness in forest management-

1. FD
2. NGO
3. Village Forest Committee
4. FD+VFC
5. FD+VFC+NGO
6. VFC+NGO
7. Can't say

(ii) Which system is better for the management of forest lands? [ ]

Code: Traditional management by FD =1, JFM =2.

b) Would you like to participate in the management of common &forest land? yes / no

(i) If yes, for what [ ]

Code : Basic needs for : furelwood, staple food & fruits/small timber & poles/timber/fodder=1, Additional source of income : selling trees as cash crops/wage income=2, Checking environmental degradation : watershed reclamation/soil-moisture conservation/river bank protection/other=3, Tree planting is linked with religious sentiments=4, Have surplus time so want to devote for constructive work=5, For prestige, ego satisfaction and to lead the people=6, Other=7, specify

(ii) If no, please give reasons [ ]

Code: no time=1, no stamina=2, no interest=3, other=0, specify.

(iii) If not, What might encourage you to actively participate in JFM? [ ]

Code: Cash=1, Benefit in kind=2, Leadership=3, Ego satisfaction and greater say in decision making=4, Other=5, specify

c) What difficulties do you perceive in JFM planning and implementation?

1.
2.
3.
4.

d) What should be the top priority for the management of forest lands? [ ]

Code: For commercial production=1, For ecological maintenance and for environmental preservation=2, For production of products required by local people=3, Mining development=4, Pasture and grazing=5, Agriculture=6, Other=7,specify

e) What is the best forest protection method? [ ]

Code: Employ protection guard=1, Voluntary protection duty by villagers in rotation=2, Left to FD for protection=3, Other=4, specify

f) Which species do you prefer for planting on the site?
i.
ii.
iii.
iv.

g) Would you like to become a member of Village Forest Committee? yes / no

10. Benefit Distribution

a.) How benefits accruing from the forest lands be distributed? [ ]

Code: Should go to the government=1, Should be given to the Panchayat for the development of village=2, To be used further for forestry development=3, To be distributed equally among people=4, Produce to be distributed according to the family size=5, To be given to the poor people who are needy=6, Other=7, specify

b) How benefits accruing from the common lands be distributed? [ ]

Code: Should go to the government=1, Should be given to the Panchayat for the development of village=2, To be used further for forestry development=3, To be distributed equally among people=4, Produce to be distributed according to the family size=5, To be given to the poor people who are needy=6, Other=7, specify

11. Perception about others

a) What do you think about forest staff?
i. Are they sincere in performing their duties?

ii. Are they capable of managing the forests own their own?

b) What do you think about Panchayat and VFC? Are they working well?

c) Whom do you prefer FD or P-VFC for forest management?

d) Whom do you prefer FD or P-VFC for the management of common lands?

Appendix 4.6
Species desired by the villagers for plantation

Name of the species	Households Number	Households Percent
Acacia leucophloea	82	63.6
Azadiracta indica	79	61.2
Butea monosperma	51	39.5
Acacia nilotica	48	37.2
Prosopis juliflora	39	30.2
Zizyphus mauritiana	39	30.2
Anogeissus pendula	26	20.2
Dalbergia sissoo	24	18.6
Mangifera indica	21	16.3
Acacia senegal	17	13.2
Holoptilia integrifolia	16	12.4
Imli	13	10.1
Sarifa	10	7.8
Emblica officinalis	10	7.8
Albizzia lebbek	7	5.4
Acacia tortilis	7	5.4
Boehinia variegata	7	5.4
Nimbu	6	4.7
Cordia dichotoma	6	4.7
Pithocolobium dulce	5	3.9
Ailanthus excelsa	5	3.9
Mulberry	5	3.9
Cassia fistula	4	3.1
Gulmohar	4	3.1
Cassia siamea	3	2.3
Balanitus aegyptiaca	3	2.3
Bamboos	3	2.3
Jatropha species	3	2.3
Ficus glomerauta	2	1.6
Salvodora persica	2	1.6
Phasendu	2	1.6
Anthocephalos cadamba	2	1.6
Eucalyptus	2	1.6
Sal	2	1.6
Fruit trees	14	10.9
Local/suitable species	7	5.4
Any speccies	6	4.7
No mesquite	6	4.7
Shade trees	4	3.1
Commercial species	2	1.6
Mixed plantations	2	1.6
Grasses	2	1.6

Appendix 5.1
List of plant species observed during survey

Common Name	Scientific name
Aadha sheeshka	*Xanthium strumarium*
Amaltas	*Cassia fistula*
Ak	*Calotropis procera*
Anjan grass	*Cenchrus ciliaris*
Anjan tree	*Hardwichea binata*
Arind	*Ricinus communis*
Babul	*Acacia jacuamontii*
Balwala chirchita	*Achyranthus aspera*
Bansa	*Adhatoda vesica*
Barlu	*Dicanthium annulatum*
Barna	*Artemisia scoparia*
Bathua	*Chenopodium album*
Bhurat	*Cenchrus biflorus*
Bui	*Aerva tomentosa*
Daabsuli	*Heteropogon contortus*
Desi papri	*Ephresia lewis*
Dhak	*Butea monosperma*
Dhok	*Anogeissus pendula*
Gangeran	*Grevia villosa*
Gingon	*Lanea grandis*
Gondi	*Cordia rothii*
Gugal	*Commiphera wightii*
Gular	*Ficus glomeruta*
Gum Arabic	*Acacia senegal*
Gum karaya	*Sterculia urens*
Hingot	*Balanite roxburghii*
Imli	*Tamarindus indica*
Inderjau	*Wrightia tictoria*
Israeli kikar	*Acacia tortilis*
Jaichi	*Euphorbia dracunculoides*
Jal	*Salaodora persica*
Jal	*S.oloeides*
Jangli Tulsi	*Ocimum sanctum*
Janti	*Prosopis cineraria*
Jhar beri	*Zizyphus nummularia*
Jhojhru	*Tephrosia purpurea*
Kachnar	*Boehnia racemosa*
Kair	*Capparis decidua*
Kakera	*Maytenus emarginata*

Kana	*Saccharum spontaneum*
Kaur tumba	*Citrullus colocynthis*
Kendu	*Diospyros cordifolia*
Khairi	*Acacia senegal*
Kharenti	*Sida cordifolia*
Khajur	*Phoenix dactilifera*
Kheep	*Leptadaenia pyrotecnica*
Kijelia	*Kijelia pinnata*
Lantana	*Lantana indica*
Lapa	*Achyranthes aspera*
Mesquite	*Prosopis juliflora*
Munj	*Saccharum munja*

Appendix 5.3

Individual site features of the land suitability classes

Land class	Type of feature			
	Topography	Soil	Vegetation	Landuse
I	1	1	1	1
	1	1	1	3
	2	1	1	1
	2	1	1	3
	2	2	1	2
	2	2	1	3
	2	3	1	3
	3	1	1	3
	3	2	1	3
	4	2	1	3
II	1	1	2	1
	1	1	2	2
	1	1	2	3
	1	1	3	1
	1	1	3	2
	1	1	3	3
	2	1	2	1
	2	1	2	2
	2	1	2	3
	2	1	3	1
	2	1	3	2
	2	2	2	3
	2	2	3	2
III	2	1	3	4
	2	1	4	3
	2	1	4	4
	2	2	3	4
	2	2	4	3
	3	1	3	3
III	3	1	3	4
	3	1	4	3
	3	1	4	4
	3	2	3	3
	3	2	4	3
	3	2	4	4
	4	1	3	3
	4	1	3	4
	4	1	4	3
	4	1	4	4
	4	2	3	3
	4	2	3	4
IV	1	1	1	2
	2	1	1	2
	2	2	3	3

Appendix 5.3 continued-

V	1	3	1	1
	1	3	2	1
	1	3	3	1
	1	3	3	3
	2	3	1	2
	2	3	1	3
	2	3	3	2
	2	3	3	3
	2	3	3	4
	3	3	3	4
	3	3	4	4
	4	3	3	4
	4	3	4	4

Codes

Topographic zones:
1 Hill top
2 Lower slopes
3 Higher slopes
4 Sandy plain

Soil zones:
1 Skeletal soil zone
2 Table deep soil
3 Medium loam
4 Sandy zone

Vegetation zones:
1 Table land scrub
2 Slope vegetation
3 Bhur vegetation
4 Plain mixed forest

Land use zones:
1 Planting zone
2 Quarrying zone
3 Miscellaneous zone

Appendix 6.1

Products from agricultural land and buying and selling prices

Season	Crop	Cost of production	Labour requirement hour/ha		Grain				Straw			
		Rs/ha	General	Man	Production without dung Kg/ha	Production with dung Kg/ha	Sale price Rs/kg	Buying Price Rs/kg	Production without dung Kg/ha	Production with dung Kg/ha	Sale price Rs/kg	Buying price Rs/Kg
	Pearlmillet	1575	512	440	1530	1700	2.2	2.6	9000	10000	0.30	0.39
Kharif	Guar	700	380	340	1125	1250	6.0	6.9	4815	5350	0.35	0.49
	Vegetables	1500	760	760	9000	10000	3.0	3.5	-	-	-	-
Rabi	Wheat	4575	510	610	3375	3750	2.5	2.9	4163	4580	0.20	0.30
	Mustard	1675	432	600	1350	1500	6.0	6.9	2700	3000	-	-
	Gram	900	280	440	990	1100	6.5	7.5	540	600	0.35	0.49
	Vegetables	8000	760	760	9000	10000	3.0	3.5	-	-	-	-
Summer	Sorghum	5460	-	-	-	-	-	-	16200	18000	0.30	0.39
	Vegetables	8500	8500	840	9000	10000	3.0	3.5	-	-	-	-

Appendix 6.2

Select list of management options on common-forest land

Land capability class	**Management options**
I	Ia Quarrying with control Ib. Quarrying without control Ic. No quarrying
II	IIa. Monoculture plantation of native species IIb. Monoculture plantation of exotic *Prosopis juliflora* IIc. Mixed plantation of native species IId. Area closure against biotic interference with aided natural regeneration IIe. Grass planting with tree & shrub species
III	IIIa. Monoculture plantation of native species IIIb. Monoculture plantation of exotic *Acacia tortilis* IIIc. Mixed plantation of native species IIId. Area closure against biotic interference with aided natural regeneration IIIe. Grass planting with shrub & tree planting IIIf. Develop residential and industrial infrastructure
IV	IVa. Grass planting only IVb. Grass planting with scattered trees and shrubs
V	Va. Miscellaneous use such as tourism, nursery, buildings, research installations, etc.

Annexure 6.3

Common-forest land: land classes, costs, outputs, prices and labour requirement

	Season	Cost (Rs/ha)	Stone (Truck loads)	Fuelwood Kg/ha	Fodder Kg/ha	Timber Ft^3	Fruit Kg/ha	Labour (hours)	
								Man	Woman
Land class I	Kharif	43350	626					8670	
	Rabi	64500	930					12900	
	Summer	21400	310					4280	
Land class II	Kharif	767		900	1043		57	93	18
	Rabi			1200	1390		76	70	14
	Summer			900	1043	50	57	70	14
Land class III	Kharif	749		600	614		43	90	16
	Rabi			800	819		57	67	12
	Summer			600	614	23	43	67	12
Land class IV	Kharif	606		850	1500			90	16
	Rabi			1100	2000			67	12
	Summer			850	1500			67	12
Land class V	Kharif								
	Rabi								
	Summer								
Selling price			75	0.4	0.15	100	3		
Buying price			-	0.5	0.2	150	4		

Appendix 6.4

Village goal types and their target level

Goal	Season	Socio-economic group	Target level Khod	Marola	Rojka	Raipur	Sohna	Sehsola
		LL	16.38	18.18	17.13	16.18	14.95	24.05
	Kharif	SF	15.98	17.73	16.71	15.79	14.59	23.47
		LF	14.38	15.96	15.04	14.21	13.13	21.13
Food energy		LL	25.03	27.78	26.18	24.73	22.85	36.77
(Kcal)	Rabi	SF	24.44	27.12	25.56	24.14	22.31	35.89
		LF	22.65	25.14	23.69	22.37	20.68	33.27
($* 10^5$)		LL	7.99	8.87	8.36	7.89	7.29	11.74
	Summer	SF	7.79	8.65	8.14	7.69	7.11	11.44
		LF	7.39	8.20	7.73	7.30	6.75	10.85
		LL	26.87	47.10	149.40	170.45	235.02	170.34
	Kharif	SF	41.93	34.91	111.01	20.71	77.77	408.05
		LF	15.53	10.06	27.07	1.28	47.27	233.86
Fuel energy		LL	40.09	70.26	222.87	264.70	350.60	254.12
(MJ)	Rabi	SF	62.56	52.79	165.61	30.89	116.01	608.73
		LF	23.17	15.00	40.39	1.90	70.52	348.87
($* 10^4$)		LL	13.44	23.55	74.70	88.72	11.75	85.17
	Summer	SF	20.97	17.45	55.50	10.35	38.88	204.02
		LF	7.77	5.02	13.54	0.64	23.64	116.93
		LL	97.60	324.52	163.48	234.24	285.48	1293.20
	Kharif	SF	61.00	251.32	329.40	226.92	1220.00	2213..08
		LF	95.16	226.92	207.40	119.56	1844.64	2159.40
		LL	145.60	484.12	243.88	349.44	425..88	1929..20
Fodder	Rabi	SF	91.00	374.92	491.40	338.52	1820.00	3301.48
(Kg DM)		LF	141.96	338.52	309.40	178.36	2751.84	3221.40
($*10^3$)		LL	48.80	162.26	81.74	117.12	142.74	646..60
	Summer	SF	30.50	125.66	164.70	113.46	610..00	1106.54
		LF	47.58	113.46	103.70	59.78	922.32	1079.70
		LL	28.70	49.09	157.66	185.29	248.65	179.89
	Kharif	SF	48.34	39.27	126.44	24.52	88.80	465.09
		LF	18.13	11.46	31.22	1.45	54.65	269.84
		LL	43.90	75.09	241..18	283.45	380.40	275.18
Employment	Rabi	SF	73.94	60.07	193.42	35.71	135.85	711.46
(Hours)		LF	27.72	17.52	47.75	2.23	83.60	412.78
($*10^3$)		LL	15.19	24.23	83.43	98.04	131.59	95.22
	Summer	SF	25.59	20.79	66.9	12.97	46.99	246.18
		LF	9.59	6.06	16.52	0.77	28.92	142.83
Timber (Ft^3)	Annual	All	189	183	606	432	861	1251

Appendix 6.5

Use of LINDO to solve Preemptive Goal Programming Problem

Incorporate deviational variables in the goal programming model. Begin by asking LINDO to minimize deviations from the highest priority goal, as illustrated below.

Achieving goal 1 (highest priority)

$\min z = s_1^-$

s.t $\quad A_{11} + A_{12} + s_1^- = 0$

All variables nonnegative

If the solution gives $s_1^- = 0$, that means goal 1 (food energy target) is met. We now want to achieve or come as close as possible to meeting goal 2 while ensuring that deviation from goal 1 (underachievement = 0) remains less than or equal to its current level (0).

Achieving goal 2 (fuel energy target)**:** Using an objective function of s_2^- (to minimise goal 2) we add constraint $s_1^- \leq 0$ (to ensure goal 1 is still met) and ask LINDO to solve

$\min z = s_2^-$

s.t. $\quad A_{11} + A_{12} + s_1^- = 0$

$A_{21} + A_{22} + s_2^- = 0$

$s_1^- \leq 0$

All variables nonnegative

$s_2^- = 0$ in the solution means goal 2 is met.

Achieving goal 3: Since goals 1 and 2 can be simultaneously met, we now minimise goal 3 (fodder target) deviational variable s_3^-. while keeping deviational variables s_1^- and s_2^- as constraints.

$\min z = s_3^-$

s.t. $A_{11} + A_{12} + s_1^- = 0$

$A_{21} + A_{22} + s_2^- = 0$

$A_{31} + A_{32} + s_{3-} = 0$

$s_1^- \leq 0$

$s_2^- \leq 0$

All variables nonnegative

A value of more than zero of s_3^- in the solution means that goal 3 is not achieved.

Achieving goal 4: Now to achieve or come as close as possible to meeting goal 4 (employment generation), ask LINDO to minimise s_4^+ & s_4^- deviational variables while keeping s_1^-, s_2^- and s_3^- less than zero or at their current level. This requires LINDO to solve the following LP:

min $z = s_4^+ + s_4^-$

s.t. $A_{11} + A_{12} + s_1^- = 0$

$A_{21} + A_{22} + s_2^- = 0$

$A_{31} + A_{32} + s_{3-} = 0$

$A_{41} + A_{42} + s_4^- + s_4^- = 0$

$s_1^- \leq 0$

$s_2^- \leq 0$

$s3- \leq F$ F is the level of underachievement of goal 3.

All variables nonnegative

A value of more than zero of s_4^+ in the solution means that goal 4 (employment generation) is not achieved i.e. there is surplus of labour.

Following the procedure outlined above underachievement of goal 5 (timber output) can also be minimised.

Appendix 7.1

Marginal value product of agicultural land

Village	Kharif		Rabi		Summer	
	Small farmer	Large farmer	Small farmer	Large farmer	Small farmer	Large farmer
Khod						
- VM	91140	90608	21073	20302	18500	18500
- CM	1050731	1050244	578295	568980	73425	73425
Marola						
- VM	88680	82634	21135	13200	21500	12700
- CM	290321	284079	328265	311633	44329	35248
Rojka						
- VM	163969	163209	38700	36380	28890	28130
- CM	289998	288839	285697	284925	17842	17082
Raipur						
- VM	88883	88883	21262	19721	9482	9482
- CM	288839	288839	317193	284925	32722	32722
Sohna						
- VM	0	0	0	0	0	0
- CM	0	0	0	0	0	0
Sehsola						
- VM	78123	77451	17709	17028	16936	16936
- CM	289998	289326	285607	284925	40139	40139

VM=Village management; CM=Community management

Appendix 7.2

Marginal value product of common-forest land

Village	Class-I Kharif	Class-I Rabi	Class-I Summer	Class-II	Class-III	Class-IV	Class-V
Khod							
- VM	244165	69750	23250	-	13838	27992	21985
- CM	51285	3469256	177910	-	226217	510974	369773
Marola							
- VM	234042	68750	23250	-	19335	35401	31730
- CM	0	0	21400	-	119593	404196	257975
Rojka							
- VM	870995	236947	52507	-	32094	52724	43315
- CM	0	0	21400	-	118919	403522	257189
Raipur							
- VM	193368	64817	0	24962	14947	26523	-
- CM	0	0	0	257566	119207	403810	-
Sohna							
- VM	0	0	0	12127	0	15572	-
- CM	0	0	0	144157	11059	295661	-
Sehsola							
- VM	0	0	0	33258	18864	39541	-
- CM	0	0	0	257625	119258	404015	-

VM=Village management; CM=Community management

Appendix 7.3

Simulated agricultural land use under community management (ha)

	Khod	Marola	Rojka	Raipur	Sohna	Sehsola
Kharif						
Small farmer						
- Pearlmillet	8	9.5	26.5	6.5	-	54.3
- Guar	20	20	80	50	211.5	400
- Vegetables	-	-	-	-	-	-
% utilisation	100	100	100	100	32.5	100
Large farmer						
- Pearlmillet	8	9.5	26.5	6.5	-	54.3
- Guar	20	20	80	50	464.4	400
- Vegetables	-	-	-	-	-	-
% utilisation	100	100	100	100	71.4	100
Rabi						
Small farmer						
- Wheat	14	20	40	30	350	75
- Mustard	14	9.5	66.5	26.5	93.4	379.2
- Gram	-	-	-	-	-	-
- Vegetables	-	-	-	-	-	-
% utilisation	100	100	100	100	68.2	100
Large farmer						
- Wheat	14	14	40	30	350	75
- Mustard	14	15.5	66.5	26.5	25.3	379.2
- Gram	-	-	-	-	-	-
- Vegetables	-	-	-	-	-	-
% utilisation	100	100	100	100	57.7	100
Summer						
Small farmer						
- Vegetables	5	7	20	25	106.5	50
- Sorghum	5	7	10	20	100	30
% utilisation	100	100	100	100	68.8	100
Large farmer						
- Vegetables	5	7	20	25	21.2	50
- Sorghum	5	7	10	20	100	30
% utilisation	100	100	100	100	40.4	100

Simulated common-forest land use under community management (ha)

	Class-I Kharif	Class-I Rabi	Class-I Summer	Class II	Class III	Class IV	Class V
Khod							
- area	1	1	1	-	18.4	15	1
- % utilisation	100	100	100	-	100	100	100
Marola							
- area	1	1	1	-	12.7	21.4	0.1
- % utilisation	100	100	100	-	100	100	100
Rojka							
- area	2	2	2	-	55.3	3.2	2.6
- % utilisation	100	100	100	-	100	100	100
Raipur							
- area	7.15	7.15	5.4	6.3	9.7	2.8	-
- % utilisation	100	100	75.5	100	100	100	-
Sohna							
- area	0	0	0	3.5	21.2	2.9	-
- % utilisation	0	0	0	100	100	100	-
Sehsola							
- area	0	0	57.4	319.4	4	69.6	-
- % utilisation	0	0	40.0	100	100	100	-

Appendix 7.4

Marginal value product of labour

Village	Kharif			Rabi			Summer vegetables		
	Men	Women	General	Men	Women	General	Men	Wome	General
Khod									
- VM	-21.7	-23.6	-27.7	-5	-4.3	-5	-5	-4.3	-5
- CM	-5.5	-5	-5	-268	-228	-268	-41.1	-35.7	-41.1
Marola									
- VM	-26.6	-22.6	-26.6	-5	-4.3	-5	-5	-4.3	-5
- CM	794	674	-5	6.7	5.4	-268	-4.6	-30.1	-41.1
Rojka									
- VM	-100	-85	-100	-18	-15.3	-18	-11.9	-10.1	-11.9
- CM	794	674	-5	6.7	5.4	-268	-4.6	25.9	-41.1
Raipur									
- VM	-21	-18	-22	-4.6	-4.3	-5	-0.4	-0.04	-5
- CM	794	674	-5	6.7	5.4	-268	0.4	-25.94	-41
Sohna									
- VM	127	107.7	-5	39.9	33.6	-5	6.7	5.3	-5
- CM	1604	136.3	-5	292	248	-268	32	-16	-41
Sehsola									
- VM	0.4	0.02	0.03	0.4	-4.9	-5.9	0.4	-4.3	-5
- CM	794	674	0.5	6.7	5.3	-262	0.4	-30.1	-35.6

VM=Village management; CM=Community management

Publication - 1

Title: Multiobjetive Management Planning for Forest and Common Lands Through Participatory Approaches[1]

Multiobjective Management Planning for Forest and Common Lands Through Participatory Approaches

J.P. Yadav, J.B. Dent, M. McGregor and J. Blyth
University of Edinburgh, Insitute of Ecology and Resource Management and SAC.

BACKGROUND

- Site degradation due to water erosion, wind deposition and biotic pressure;
- Shortage of firewood, small timber and other non-timber forest products, priority to supply them;
- Need to conserve soil and moisture for ecorestoration and improve agriculture in surrounding areas;
- To limit mineral extraction activity;
- Generate employment opportunities; and
- Shift in management policy from unitary to participatory approach

INPUT

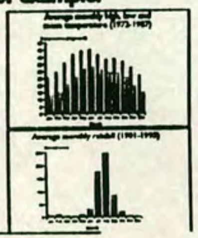
Site Classification and Mapping

- Topographic Map
- Soil Zones
- Vegetation Map
- Land Use Pattern
- Drainage

Socio-Economic Profile

- Population
- Livestock
- Industries
- Demand
- Supply
- Employment
- Attitudes
- Preferences
- Indigenous Knowledge

Agroclimatic Context for example:



MODELLING

Composite Site Map

↓ GIS

Delineation of Homogenous Site Zones

Participant's Preferences
- Forest Department
- Villagers
- NGOs
- Other Agencies

Agricultural and Aggregate Parameters

Management Options

MCDM

Stakeholders Analysis
- Government
- Villagers
- Industries
- NGOs
- Local Institutions
- Conservation Groups
- Researchers

Multicriteria Decision Making Models

OUTPUT

Multicriteria Decision Making Models

↓

Participatory Management Plans

↓

Result

- Rational and Transparent Decisions
- Villager's Demands Fulfilled
- Equitable Distribution of Benefits
- Sustained Flow of Products
- Active Participation of People
- Eco-rehabilitation
- Use of Indigenous and Modern Management Techniques

[1] Poster paper presented in Agricultural Economics Society Conference, 7-9th April 1995, Cambridge, United Kingdom.

Publication - 2

Title: Contribution of Non-Market and other Benefits in Developing a Sustainable Participatory Forest Management System - a case study in India[1]

Authors: Yadav J.P., Dent J.B., Blyth J.B. and McGregor M.J.

Keywords: Forests, non-market benefits, management, sustainable, participatory

Summary

Historically, forests have been viewed and managed by policy makers, forest economists and foresters primarily as a source of national revenue, with timber as the dominant product. During recent years awareness has been growing about the forest's diverse values. Services other than revenue generation and forest products other than timber have become important issues in the management of forest lands. The benefits of forests, which are not directly marketed, are important for both subsistence of communities living in and around forest areas as well as from a commercial perspective. These non-market benefits are generally the by-products of forestry processes such as timber, fuelwood and recreation which are managed for other purposes providing direct marketable benefits.

Information about non-market benefits is seldom assessed or used in planning and decision-making about the management of forests lands. Non-inclusion of such information into a management plan may not fulfil the desired objectives on a sustainable basis. With a view to using such information in developing a management plan, a study was conducted in a semi-arid, relatively under-developed, part of Haryana State in India. The site once well covered with vegetation is now severely degraded. The various non-market forest benefits such as environmental amelioration, soil and moisture conservation, biodiversity conservation, wildlife preservation, cultural and aesthetic values, etc., and their importance to the local people were assessed. This paper describes how information on non-market forest benefits can be utilised for designing a sustainable management system for the rehabilitation of the forest site and the overall socio-economic development of local people under a participatory forest management regime.

[1] Paper presented in the International Symposium on the Non-Market Benefits in Forestry, 24-28th June 1996, Forestry Commission, Edinburgh, UK.

Publications - 3

Title: A Practical Approach for Participatory Natural Resource Management: Prospects for Grey Planning[1]

Authors: Yadav, J.P., Dent, J.B. and Blyth, J.B.

Abstract

Holism is a prerequisite if we are to successfully achieve sustainable management of our natural resources. In this paper a natural resource, for the purpose of sustainable management, is discerned into four interrelated sets of biological, physical, socio-cultural-political and economic systems. A holistic management strategy has been designed to incorporate the values enshrined in these systems. The planning process which progressively integrate the aspects of these constituent systems is termed as 'Grey Modelling'. First, the grey model and its process are described and then a model is developed for the management of a resource site in a semi-arid region of India. The methodology involved participatory rural appraisal, resource survey, mapping and site classification with the help of geographical information systems, linear and multi-objective programming techniques and the use of knowledge of individual subjects related with systems' components. The grey management model attempts to satisfy the various biophysical and socio-economic objectives and links the psychological health of an individual and/or the community to the ecological condition of the wider environment. This offers potential within which the local people in partnership with the government agencies and other resource stakeholders are responsible for planning, decision making, implementation and protection functions.

[1] Paper presented in the Conference on Designing Sustainablitiy - Building Partnership Among Society, Business, and the Environment, 3-7th August 1996, International Society for Ecological Economics and Boston University, USA.

Publication - 4

Title: Building Participatory Forest Management Models Through Incorporation of Socio-economic Values[1]

Authors: Yadav, J.P, Dent, J.B. and Blyth, J.

Key words: Forests, participatory management, socio-economic values, land capability classes

Abstract

Forests constitute a major natural resource in India on which large number of people depend for their survival. Historically, these forests have been viewed and managed by policy makers, forest economists and foresters primarily as a source of national revenue, with timber as the dominant product. Traditional forest management has emphasised on biological, technical and ecological considerations to achieve protection and production goals set by the administrative bodies. Local people were not involved in forest management. Recently, there is a policy shift to change the traditional style of management in favour people friendly participatory or joint forest management because of apparent failure of the former. Participatory management emphasises on fulfilling the needs of the local people and ecological maintenance. In order to achieve true participation , the needs, desires, aspirations and perceptions of various participants need to be accommodated in the management planning.

In this paper, a seem-arid forest site at Sohna in Haryana State of India was selected for developing a participatory management plan and to demonstrate the various methodological steps in a practical setting. Socio-economic and bio-physical surveys were carried out to identify relevant socio-economic attributes and the classification of the site into homogenous land capability classes. Management options for the different land capability classes were devised on the basis of bio-physical characters. Socio-economic values were accommodated into the design of management options. The whole process of planning took the help of various management tools such as rural appraisal, Geographical Information Systems and mathematical programming. The planning framework tackles the management of the forest resource in a systematic manner while stressing on people and their values.

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[1] Paper accepted for publication in the XI World Forestry Congress to be held from 13 to 22 October 1997, Antalya, Turkey.