Forestry Department
Food and Agriculture Organization of the United Nations

Forest Management Working Paper

Experience in the elaboration, implementation and follow-up of forest management plans using computers, computer software and other technological packages

The Case of Bhutan

Based on the work by:

K. D. Chamling
with inputs from Dhan B. Dhital
Thimphu, Bhutan

April 2006

Forest Resources Development Service
Forest Resources Division
Forestry Department

Working Paper FM/28
FAO, Rome (Italy)

DISCLAIMER

The Forest Management Working Papers report on issues addressed in the work programme of FAO. These working papers do not reflect any official position of FAO. Please refer to the FAO website (www.fao.org/fo) for official information.

The purpose of these papers is to provide early information on ongoing activities and programmes, facilitate dialogue and stimulate discussion.

Comments and feedback are welcome.

For further information please contact:

Mr Froylán Castañeda
Forestry Officer (Tropical Forest Management)
Forest Resources Development Service
Forest Resources Division
Forestry Department
FAO
Viale delle Terme di Caracalla
I-00100 Rome (Italy)
E-mail: Froylan.Castaneda@fao.org

Or FAO Publications and Information Forestry Coordinator: Forestry-Information@fao.org

For quotation:

FAO (2006). Experience in the elaboration, implementation and follow-up of forest management plans using computers, computer software and other technological packages: The Case of Bhutan. By K. D. Chamling with inputs from Dhan B. Dhital. Forest Management Working Papers, Working Paper 28. Forest Resources Development Service, Forest Resources Division. FAO, Rome (unpublished).

Forest Management Working Paper

Experience in the elaboration, implementation and follow-up of forest management plans using computers, computer software and other technological packages

The Case of Bhutan

Based on the work by:

K. D. Chamling
with inputs from Dhan B. Dhital
Thimphu, Bhutan

Rome, 2006

SUMMARY

Bhutan is a small country, located in the eastern Himalayan zone of Asia. The total geographical area is 40,077 square kilometres. Bhutan is bordered to the north by China (Tibet) and to the east, west and south by India. The country is mountainous and the elevation ranges from about 200 metres in the south to over 7,550 metres in the north. The major river systems flow from the high mountains in the north towards the lower area of the south. These river systems create the inner valleys where the population centres are concentrated.

The climate is extremely varied, ranging from hot and humid in the south to permanent ice and tundra type conditions in the north. Most of the rain reaching the country is brought by the southwest monsoon between June and September.

The total area under forest is 72.5 percent of the geographical area of the country; however, the exact area under tree cover accounts for 64.35 percent of the land area. The types of forest are fir, mixed conifer, blue pine, chir pine, temperate and sub-tropical broadleaf species.

The total growing stock (standing timber over bark) available in the country is estimated to be 621.40 million m^3, of which about 40 percent is estimated to be commercial (248.56 million m3). Not all the commercial growing stock in the accessible areas is available; therefore, it is estimated that about 186 million m^3 of growing stock is available in the operable forest area (30 percent of growing stock).

The average annual allowable cut (AAC) for the operable area is estimated to be 1.18 million m^3 per annum. However, for environmental reasons, as well as the harsh topography, not all the forests within the operable area are available for timber harvesting. Therefore, the AAC from the net operable area is around 0.77 to 0.80 million m^3 per annum (27 - 28 million ft^3).

This case study was done in Paro-Zonglela forest management unit (FMU), which is one of the FMUs in the western part of the country. The location of the FMU is approximately between 27° 28′ and 27° 28′ north latitude and 89° 20′ and 89° 30′ east longitude. The total area covered by the FMU is 16,150 hectares; the altitude varies from 2,200 m.a.s.l. at the bottom of the valley to about 4,000 metres m.a.s.l at the ridge top. The area at the bottom of the valley is mostly flat or gently sloping but towards the top of the ridges the topography is very steep with exposed rocks.

The forest types of the FMU consist of blue pine, mixed conifer, fir, a mixture of various species of temperate hardwood and a small area of plantation. Besides the above-mentioned forest types, about 15 percent of the area consist of cultivation, pasture and rock.

The FMU is located in the central crystalline zone in the inner reaches of the Lesser Himalaya. It is dominated by the pre-Cambrian to tertiary series of meta-sedimentary migmatites and granitoid rocks, which are referred to as the Paro and Thimphu formations. These formations are considered as the non-granitized portion of the Thimphu gneissic complex. The area is characterized by red soil in the lower elevation and also large areas of sandy clay-loams on the schist types. In general the soils are fertile and stable.

In the late 1960s and early 1970s, when the management planning process was just beginning to evolve, the procedure adopted was very simple and the plans were based on simple information obtained through inventory. The use of electronic equipment and mechanical devices for collecting data of various types was non-existent. Inventory data were collected in

pre-designed formats, e.g. (i) tally sheet and (ii) compass sheet. The data from these sheets are again entered in the computer and with the help of software the inventory result is calculated. Data on socio-economic status of the people living in and in the vicinity of FMUs and environmental aspects were not collected, which means that public consultation and environmental impacts assessment were not considered necessary at that time.

The use of equipment like GPS for inventory sample location, navigation to plots, forest function mapping, socio-economic and environmental related data collection started only recently. Data collection formats, in paper, are still in use. The Department of Forests is studying the possibility of replacing the pre-designed formats, in paper, with electronic devices. Besides the electronic equipment there are a few other mechanical devices such as relascope, compass, clinometer, zoom transferscope, etc.

After the management plans are prepared by the Department of Forests, the document is put through various levels of a consultation process starting from (i) the FMU level committee; (ii) Dzongkhag Yargay Tshogdu; (iii) national-level consultation at the Department and (iv) thereafter the document is forwarded to the Ministry of Agriculture, through the Department, for approval.

After obtaining government approval, the management plans are implemented in the field. The document is forwarded to the Divisional Forest Officers (DFOs) and Forestry Development Corporation Ltd (FDCL) officials for implementing the plans. Actual execution of the works like road building, timber harvesting and marketing is done by FDCL. Preparation of operational plan, tree marking and passing is done by the DFOs. This division of work is done mainly to create a system of check and balance while implementing the plans.

Since all the FMUs are in government reserved forest, the implementation arrangement described here is applicable to these categories of forest. This arrangement is not meant for forest areas in privately owned land because at present there are no FMUs in the private forest.

All the activities that are implemented are monitored. Some of the activities are monitored yearly; some once in five years while a few activities are monitored once in the plan period. The DFOss are responsible for filling the formats. All information pertaining to the monitoring activities are collected in pre-designed formats. Electronic equipment has not been used for this purpose. However, the data are entered in the computer and are processed.

Evaluation is done twice during the entire plan period. The first is the mid-term evaluation and the final one is the end of the term evaluation. Evaluation is done by a team appointed by the Head of the Department of Forests. The team members are selected from amongst the senior forest officers. All information pertaining to the evaluation are also collected in the pre-designed formats and subsequently entered in the computer and processed.

TABLE OF CONTENTS

List of tables

List of maps

ACRONYMS AND ABBREVIATIONS USED IN THE DOCUMENT

AAC	Annual allowable cut
AIT	Asian Institute of Technology, Bangkok
m.a.s.l.	Metres above sea level
ARCINFO	Computer software
ARCVIEW	GIS software
ft^3	Cubic feet
Chu	River
CV%	Coefficient of variation percent
dbh	Diameter at breast height
DBF	Database file
DEM	Digital elevation model
DFO	Divisional Forest Officer
DYT	Dzongkhaag Yargay Tshogdu
Dzong	Fortress or monastery. Administrative centre of a district
Dzongkhag	District
EA	Environment assessment
FAO/UNDP	Food and Agriculture Organization/United Nations Development Programme
FDCL	Forestry Development Corporation Limited
FMP	Forest management plan
FMU	Forest management unit
FOXPRO	Data processing software
FRDD	Forest Resources Development Division
Geog	Administrative block under the district.
GIS	Geographic Information System
GPS	Global Positioning System
GS	Growing stock
Khukuri/Patang	Knives
km	Kilometre
km^2	Kilometre square
LUPP	Land use Planning Project of the Ministry of Agriculture
LUSS	Land use and statistical section of the Ministry of Agriculture
m^3	Cubic metre
MOA	Ministry of Agriculture
NEC	National Environment Commission
NGO	Non-governmental organization
Ngultrum	Bhutan currency (1 USD == 44.65 Ngultrum)
OP	Operational plan
PIS	Pre-investment survey of forest resources of the Govt. of India.
PRA	Participatory rural appraisal
R	Rotation
RGOB	Royal Government of Bhutan
RNR	Renewable natural resources
RRA	Rapid rural appraisal
SE%	Sampling error percent
Shokshing	A part of government reserved forest registered in the name of an individual and maintained aside for collection of leaf litter required for producing farm manure.

TFDP	Third forestry development project
Thram	Land record register
Tsamdo	Grazing land
TOR	Terms of Reference
Vol.	Volume
WWF	World Wide Fund for Nature Conservation
<PLOT>	A tailor-made computer software for processing inventory data

Experience in the elaboration, implementation and follow-up of forest management plans using computers, computer software and other technological packages
The Case of Bhutan

1. INTRODUCTION

Bhutan is a small country, located in the eastern Himalayan zone of Asia between 88° 45′ to 92° 08′east longitude and between 26° 41′ to 28° 25′north latitude. It measures roughly 300 kilometres (E-W) by 150 kilometres (N-S). The total geographical area is 40,077 square kilometres. Bhutan is bordered to the north by China (Tibet) and to the east, west and south by India. The country is mountainous and the elevation ranges from about 200 metres in the south to over 7,550 metres in the north. The major river systems flow from the high mountains in the north towards the lower area of the south. These river systems create the inner valleys where the population centres are concentrated. The road systems also follow these valleys within the country and also with its neighbours.

The climate of Bhutan is extremely varied, ranging from hot and humid in the south to permanent ice and tundra type conditions in the north. Most of the rain reaching the country is brought by the southwest monsoon between June and September and the rainfall ranges from more than 6,000 mm per year in the foothills to as little as 300 mm in the north.

1.1 Forestry in Bhutan

The flora of Bhutan is very rich because of the great range of altitudinal zones. The total area under forest is 72.5 percent of the geographical area of the country; however, the exact area under tree cover accounts for 64.35 percent of the land area. The types of forest are fir, mixed conifer, blue pine, chir pine, temperate and sub-tropical broadleaf species. The Royal Government is determined to conserve this wealth and has set a national policy to maintain at least 60 percent of the land area under forest cover for all time to come (RGOB, 1996[1]).

In Bhutan, all the land that is not explicitly registered as private is government-reserved forests. The natural, ecological and climatic conditions of the country favour the forests as the dominant form of land use. Due to both cultural and physical remoteness, Bhutan has retained much of its natural vegetation and hence has a relatively intact natural forest estate.

1.1.1 Growing stock and annual allowable cut

The total growing stock (volume of the stem-wood of standing timber over bark) available in the country is estimated to be 621.40 million m^3, of which about 40 percent is estimated to be commercial (248.56 million m^3). Not all commercial growing stock is available in the accessible areas; therefore, it is estimated that about 186 million m^3 of growing stock is available in the operable[2] forest area (30 percent of growing stock) (RGOB, 1991).

The annual allowable cut (AAC) for the operable area is estimated to be 1.18 million m^3 per annum (RGOB, 1991). However, for environmental reasons, as well as the harsh topography, not all the forests within the operable area are available for timber harvesting. Therefore, the calculation of net operable area has become important and this is obtained by excluding the following categories of forest area from operable area.

(i) forest area above 4,000 altitude m.a.s.l.
(ii) forest area that has more than 100 percent slope

[1] Eighth five-year plan document, Vol. I: Main document, 1997-2002, Royal Government of Bhutan.

[2] The operable forest area is derived by deducting from the total forest area the protected areas (including the biological corridors) and critical watersheds.

Therefore, the AAC from the net operable area is around 0.77 to 0.80 million m^3 per annum *(27-28 million ft³)*. At present the total production forest under approved management plans is 169,991 hectares, which is 5.8 percent of the total forest area.

1.1.2 Forest area, forest types

The total forest area of the country is estimated at 29,045 square kilometres which is 72.5 percent of the land area (RGOB, 1995a). However, as mentioned above, the exact area under tree cover is around 64.35 percent of the land area. The major forest types are broadleaf forest, which accounts for 47.5 percent of the forest area, and the rest is conifer, 36.6 percent (RGOB, 1995a). The mixture of broadleaf and conifer forests constitutes about 4.70 percent. Scrub forest is 11.22 percent of the forest area. Table 1 gives details of the forest types and the area occupied by each of them.

Table 1: Area of different forest types

Forest types	Area in km^2	As % of forest area	As % of total land area
Fir	3,453	11.9	8.6
Mixed conifer	4,868	16.8	12.1
Blue pine	1,286	4.4	3.2
Chir pine	1,009	3.5	2.5
Broadleaf + conifer	1,378	4.7	3.4
Broadleaf forest	13,793	47.5	34.4
Scrub forest	3,258	11.2	8.1
Total	**29,045**	**100.0**	**72.5**

***Source**: RGOB, 1995a*

1.2 Legal framework for management and utilization of forest resources

1.2.1 Introduction

The forests of Bhutan are a national resource and part of the country's common heritage. It is, therefore, necessary to conserve the forests and at the same time provide access to their products for both present and future generations.

The forest resources of the country are regulated with a set of healthy forest policies and legislation, oriented towards conservation and sustainable utilization for the benefit of the people. The policy discourages indiscriminate exploitation of the resources. There are also other related acts, such as the land act, the mines and minerals management act, which support the forest act and policy for proper implementation. These acts/policies are described briefly below:

1.2.2 Bhutan Forest Act, 1969

This is the first legal framework for regulating forest resources in the country. The document consolidates numerous directives relating to forest rights, forest uses, forest products royalties, etc.

1.2.3 National forest policy, 1974

This is the first formal statement of forest policy in Bhutan. It takes into consideration economic development but focuses more on the protection and preservation of natural renewable resources of the country. The integral part of the forest policy is to ensure that at least 60 percent of the country's area is maintained under forest cover for all time to come.

The policy also emphasizes the phasing out of shifting cultivation practices in order not to allow the forest condition to deplete and also to maintain soil fertility. Watershed management has been accorded high priority. Restoration of denuded/barren hills is also to be taken up on a priority basis.

1.2.4 National forest policy, 1991 (draft)

The national forest policy of 1991 is still in draft stage; it has not yet been passed by the National Assembly. The policy has four guiding statements, the objectives of which are to ensure that forest resources be used according to sustainable principles, thus contributing to social justice and equity. Further, the policy aims to ensure conservation of the environment, and only thereafter aims at derivation of economic benefits from the forest as a rationally managed resource. The policy statements are given below, in order of priority.

(a) Protection of the land, forest, soil, water resources and biodiversity against degradation, such as loss of soil fertility, soil erosion, landslides, floods and other ecological devastation and the improvement of all the degraded forest land areas through proper management systems and practices.

(b) Contribution to the production of food, water, energy and other commodities by effectively co-ordinating the interaction between forestry and farming systems.

(c) Meeting long-term needs of the Bhutanese people for wood and other forest products by placing the country's entire forest resources under sustainable management.

(d) Contribution to the growth of national and local economies, including exploitation of export opportunities, through fully developed forest-based industries, as well as to balanced human resources development, through training and creation of employment opportunities.

1.2.5 Forest and nature conservation act, 1995

With the enactment of the forest and nature conservation act of 1995, the Bhutan Forest Act of 1969 was repealed. Through this act, the management and utilization of community-based natural resources is encouraged.

Community and private forestry is encouraged with adequate devolution of power to the community and private individuals. The requirement of a scientific management plan is also emphasized.

The management of forests for timber production is elaborately covered though it is strongly emphasized that no commercial harvesting of timber be allowed without an approved forest management plan. Timber trade and harvesting has been defined and systematic modalities developed for each activity. The roles and responsibilities of the FDCL and the Department of Forests have been clearly delineated. Penalties and punishments are well defined as a deterring factor for all concerned individuals if they indulge in offences relating to forest product utilization.

1.2.6 Timber marketing and pricing policy, 1999

As per the provisions of the forest and nature conservation act, 1995, commercial production of timber is to be undertaken by the recognized agencies[3] based on approved forest management plans. The sale and usage of timber are to be carried out as per the provisions mentioned in the policy. Export of timber and firewood, in primary form, is banned.

1.2.7 Forest and nature conservation rules, 2000

The forest and nature conservation rules, 2000, were enacted to implement the provisions of the forest and nature conservation act, 1995, in a more efficient and transparent manner. The rules are being revised to incorporate the provisions that are required to implement the act and rules based on the current situation.

1.2.8 Land act, 1998

This act deals with the procedures for registering land in *thrams* to reduce encroachment in government-reserved forest. It also reiterates different permissible forestry activities in the various categories of land, along with liabilities if not adhered to. The procedure for allotment of land has also been specified for different types of land in the country.

1.2.9 Environment assessment act, 2000

The purpose of this act is to establish procedures for the assessment of the potential effects of strategic plans, policies, programmes and projects on the environment and the determination of policies and measures to mitigate these potential adverse effects.

1.2.10 Mines and minerals management act, 1995

The act provides the legal framework for orderly administration and healthy growth of the mineral sector by focusing on sustainable development, protection and management of the country's mineral resources in a manner compatible with the social and economic policies of the Royal Government of Bhutan.

2. DESCRIPTION OF THE STUDY AREA

2.1 Name and location

The study area is known as the Paro-Zonglela FMU. The forest management plan (prepared in 1992) is one of the first scientific management plans prepared following the standards developed by the Department of Forests through various workshops and seminars. The plan was prepared for ten years, covering the period 1 April 1992 to 31 March 2002. It expired in 2002, after which it was revised and the new management plan was approved in the same year.

The FMU is located in the western part of Bhutan in Paro *Dzongkhag* (see location map). It is situated approximately between 27º17' and 27º28' north latitude and 89º20' and 89º30' east longitude. The total area covered by this FMU is 16,150 hectares. The area drains to the Paro *chu* through four main streams forming the sub-watersheds. The altitude of the FMU varies from 2,200 m.a.s.l. at the bottom of the valley to about 4,000 m.a.s.l. at the ridge top. The areas at the bottom of the valley are mostly flat or gently sloping but towards the top of the ridges the topography is very steep with exposed outcrops of rocks and cliffs. There are areas of sloping land distributed throughout the FMU; however, the topography is mostly steep with gradients ranging from 50 to well over 100 percent (FRDD, 2002).

[3] Forestry Development Corporation Ltd is the recognized government agency for the production of timber.

2.2 Land use

Table 2 gives the areas of various land use types dominant in the FMU. The information has been mostly derived from LUPP land use maps, topographic maps and, wherever necessary, field drawings during the course of inventory (FRDD, 2002).

Table 2: Area statement by land uses

Land uses	Area (ha)	Percent
Blue pine	5,800.00	36
Mixed conifer	5,117.00	32
Fir	2,636.00	16
Plantation	13.00	0
Hardwood	24.00	1
Cultivated, pasture and rock	2,360.00	15
Total	**16,150.00**	**100**

***Source**: FRDD, 2002.*

Of the total area of the FMU, only 13,577 hectares are covered by forest; the rest is plantation, cultivation and rocks, etc. Not all the area under forests is accessible; therefore, timber harvesting from such inaccessible area is not permitted.

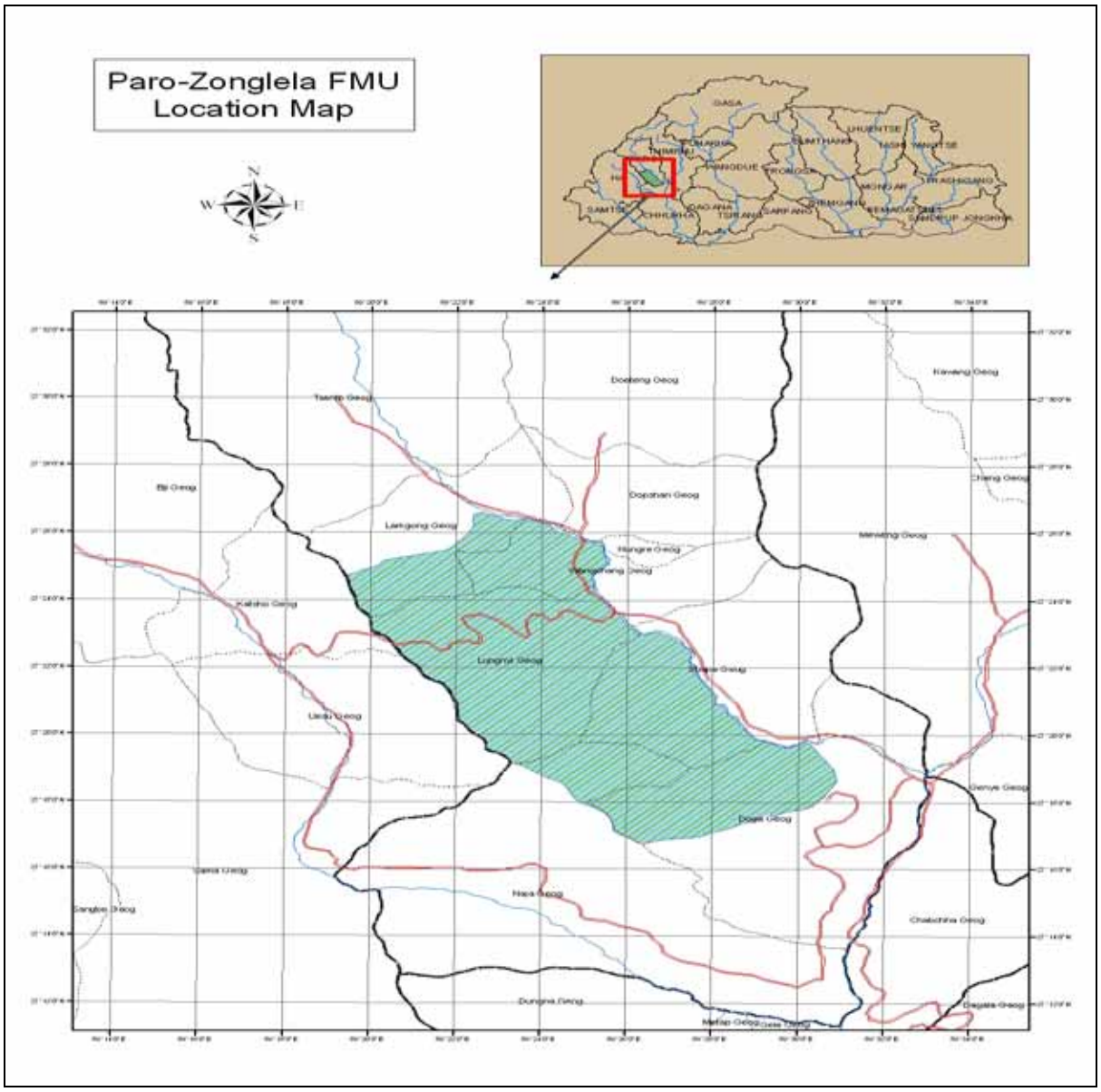
2.3 Site factors

2.3.1 Topography

The FMU extends from the bottom of Paro valley to the ridge dividing the watersheds of the Paro and Haa valleys. The area in the bottom of the valley has low slope angles and there is a progressive increase in the slope angle until outcrops verging on vertical are encountered below the ridge-line. The south-eastern extremity of the FMU is particularly steep. Topography is a limiting factor for operating within most part of the FMU (FRDD, 2002).

2.4 Climate

The climate of Paro valley is typical for the western part of Bhutan, although it may be somewhat drier than other areas. It is strongly influenced by the southwest monsoon (June-September). Summers are moist and winters are often dry enough to cause water stress. The range of elevation also greatly affects the climate**:** in the bottom of the valley the summers are hot (≈ 24°C is common) and the winters fairly mild. At the ridge top the climate is alpine type, with mild summers, severe winters and sometimes heavy snow. The road to the upper part of the FMU is often blocked for long periods by thick ice. The average monthly temperature recorded at the bottom of the valley is given in Table 3. (FRDD, 2002)



Map 1: Location map of Paro-Zonglela FMU

Table 3: Average monthly temperatures of the FMU (recorded at bottom of the valley)

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Year													
1985	max	15.0	x	x	23.0	x	25.0	23.0	25.0	23.0	21.0	18.0	19.0
	min	-3.2	x	x	10.0	x	13.0	17.0	17.0	15.0	11.0	3.0	2.0
1986	max	17.0	17.0	19.0	21.0	18.0	21.0	22.0	21.0	19.0	14.0	15.0	14.0
	min	3.0	2.0	12.0	7.0	9.0	15.0	16.0	15.0	14.0	7.0	3.0	2.0
1987	max	x	17.0	17.0	x	22.0	24.0	24.0	23.0	23.4	21.3	20.5	15.5
	min	x	2.0	4.0	x	7.0	15.0	16.0	15.2	14.5	8.1	8.1	-1.9
1988	max	16.4	17.0	18.0	24.4	24.0	26.4	24.7	24.7	24.9	x	19.4	16.9
	min	-2.3	0.5	4.3	7.2	11.1	13.8	16.6	14.3	14.3	x	1.3	-1.0
1989	max	12.0	14.4	18.5	20.9	23.5	24.2	24.0	24.6	x	x	x	x
	min	-0.7	-0.4	3.4	16.5	11.4	14.8	16.2	15.7	x	x	x	x
1990	max	x	14.8	17.6	20.6	23.1	25.7	24.4	24.6	24.7	21.0	21.0	16.5
	min	x	0.2	0.8	4.9	10.9	15.1	15.9	13.9	13.6	7.4	-0.2	-0.4
Aver.	max	15.1	15.8	18.0	22.0	22.1	24.4	23.7	23.8	23.0	19.3	18.8	16.4
	min	0.8	0.9	4.9	9.1	9.9	14.5	16.3	15.2	14.3	7.9	1.7	0.1

Note: x indicates data not available

2.4.1 Precipitation

The dominant feature is the southwest monsoon (June-September) when the great majority of precipitation occurs. Precipitation varies greatly with altitude and location although the paucity of rain gauges within the FMU makes this difficult to determine. Heavy snowfall occurs in the winter months in some years.

2.5 Geology and soil

The FMU is located in the central crystalline zone in the inner reaches of the Lesser Himalaya. It is dominated by the pre-Cambrian to tertiary series of meta-sedimentary migmatites and granitoid rocks, which are referred to as the Paro and Thimphu Formations. These Formations are considered as the non-granitized portion of the Thimphu gneissic complex.

The main rock formation in the general area of Chelela and Zonglela consists of flaggy quartzites (Quartz-muscovite schist; calc-silicate rocks of gneissic type; graphite schist; quartz-mica schist; marble-crystalline dolomite limestone; inter banded graphite schist; and marble).

The area is characterized by red soils in the lower elevation (associated with the gneissic calc-silicate rocks) and large areas of sandy clay-loams on the schist types. In general the soils are moderately fertile and, due to clay content, can retain water fairly well. The pH is closer to neutral and is buffered by limestone. The soils tend to be fairly stable, and are not prone to large-scale or frequent surface erosion or landslides. However, there is dominant risk of surface erosion and gulling. The soil type is suitable for forestry activities as long as the silvicultural and management practices are appropriate. These soils will erode if large areas are exposed or the soils are not looked after (e.g. ensuring the organic content) (FRDD, 2002).

2.6 Hydrology

The FMU is drained by the Paro Chu via four main tributary streams: the Isuna Chu (south-east part of the FMU); Gebjalumi Chu (Gebjaphu valley below the Zonglela road); Jew Chu (Jew phu valley); and the Ngobephu Chu in the Ngobephu valley. The FMU is generally well drained.

The entire area of the FMU is of special importance as a source of water for Paro, Bondey and surrounding villages. The Ngobephu valley is of particular importance as this is designated as the water supply area for Paro town. Water quality and quantity are, therefore, of great significance and are values that have to be maintained.

2.7 Forest types

The forested land in the FMU may be classified into the following forest types:

(a) Barren exposed rock – few trees, usually stunted. Only a small proportion of the FMU is of this type.

(b) Alpine pasture and meadows – open natural meadows above the tree line characterized by a variety of short grasses. This zone also includes meadows in the forested land created by man.

(c) Alpine scrub – zone between alpine meadows and tree line characterized by scrub such as rhododendron, juniper, willow, dwarf oak, etc.

(d) Fir forest – zone of almost pure fir *(Abies densa)* stands between 3,400 metres and the tree line. Occasional pockets of hemlock and birch are found. In some places heavy undergrowth and second storey of rhododendron, birch and other broadleaved species are found. Most of the fir trees are overmature and show a considerable degree of decay. The upper parts of the zone display considerable areas of fir dieback.

(e) Mixed conifer forest – The forest lies between blue pine and fir zone. The forest is characterized by a mixture of spruce *(Picea spinulosa)*, hemlock *(Tsuga dumosa)* larch *(Larix griffithii)* and blue pine *(Pinus wallichiana)*. Oak *(Quercus griffithii)* forms a substantial proportion of this zone and in some parts almost pure stands can be found. This mixed conifer forest is highly variable and reflects local site conditions:

- Hemlock is found along moister bottoms of valleys and forms pure stands.
- Spruce is found in the upper reaches and cooler sites. They can also be found in pure, and sometimes in large, stands.
- Fir can be found at higher elevations frequently mixed with larch, spruce and hemlock;
- Blue pine is found on drier and warmer sites.

(f) Blue pine forest – the areas confined to the lower elevations. Blue pine is dominant and forms pure, often heavily stocked, stands. It is sometimes found mixed with oak forming the lower storey. Blue pine is an aggressive colonizer and has covered large areas of abandoned agricultural land in the lower part of the FMU. Currently, almost all stands of blue pine are immature because of close proximity to the villages (FRDD, 2002.).

2.8 Infrastructure, transport and equipment

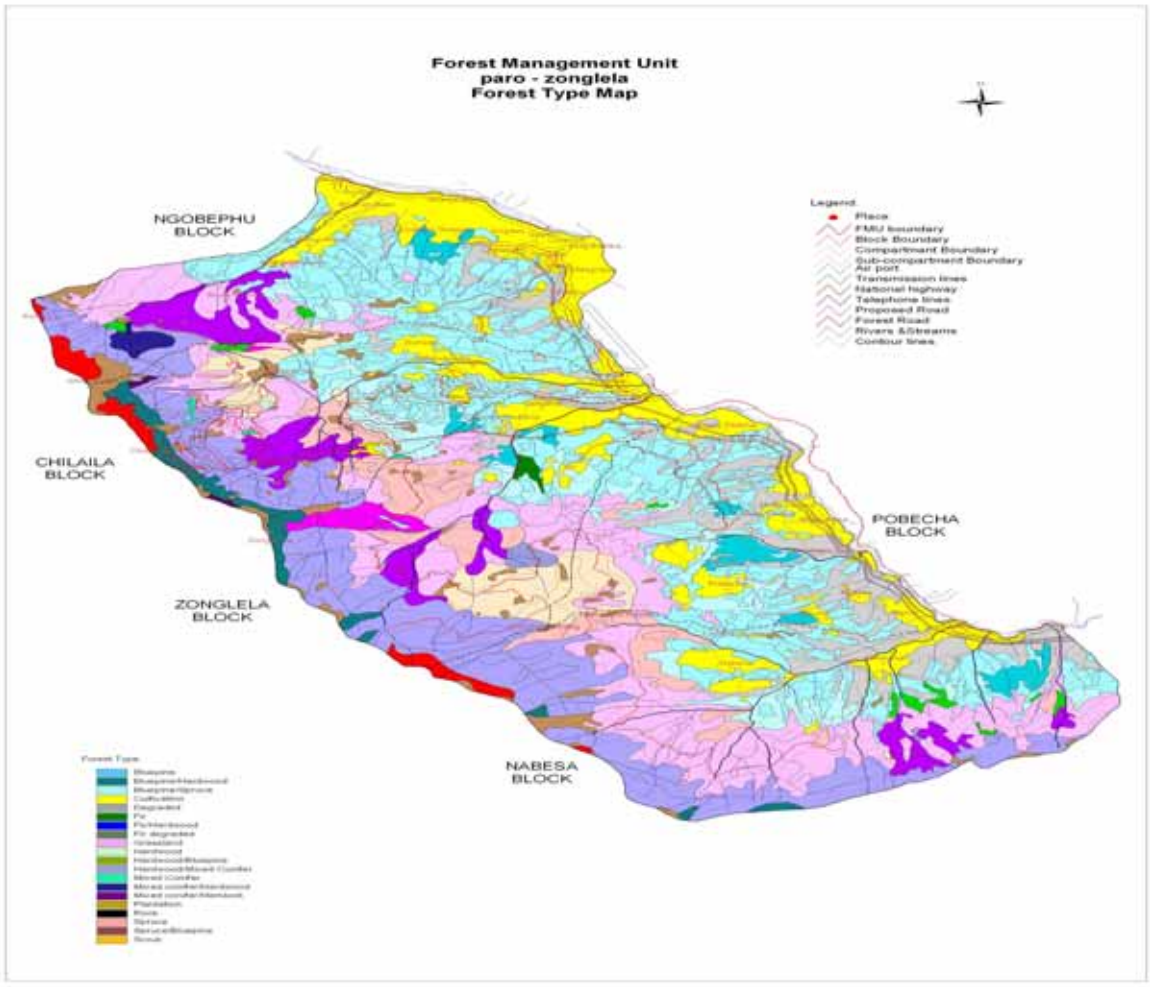
2.8.1 Road

The Paro – Haa National highway runs through the FMU dividing it into nearly two equal halves. There are numerous roads in the lower part of the FMU making access possible to most of its lower valleys and settlements. Table 4 illustrates the extent of the road network in the FMU.

Table 4: Extent of road network in the FMU

Sl No	Name of road	Length (km)	Remarks
1	Gebjana	5.500	
2	Dzongdakha	1.500	
3	Ngobephu	6.000	Repaired by FDCL in 1993
4	Chandana	6.897	
5	Kalaila	2.210	
6	Gorina	2.168	
7	Gorina spur	0.900	
8	Zonglela	13.480	
9	Upper zonglela	1.200	Constructed in 1994
10	Zonglela extension	1.909	Constructed in 1997
Total		**41.764**	

***Source**: FRDD, 2002.*



Map 2: Forest-type map of Paro-Zonglela FMU

Road construction is probably the most significant financial investment in the FMU as well as having one of the greatest environmental impacts. Well structured roads require less maintenance and have fewer environmental impacts than if cheaper construction techniques are used.

A bulldozed forest road traditionally costs Ngultrum 700,000 – 800,000 per kilometre but an excavator built road can cost up to Ngultrum 1000,000 to 1200,000 per kilometre. Far better and more durable roads can be constructed with the use of excavators together with bulldozers and vibration rollers.

3. DESCRIPTION OF THE ELECTRONIC EQUIPMENT AND SOFTWARE USED IN THE PLANNING

3.1 Electronic equipment

3.1.1 Global positioning system (GPS)

GPS is a means of pinpointing the location in terms of latitude and longitude, based on information obtained from a number of satellites orbiting in space. The system works 24 hours a day and under almost any weather conditions. The instrument used on the ground is a small hand-held unit, which operates from batteries and receives information from satellites. The latitude and longitude positions are obtained through the unit contacting three or four satellites.

When the unit is set to receive information from four satellites, the altitude of the unit's location is also recorded.

GPS is used in forestry for various purposes, including the following:

(i) identification of inventory plot location;
(ii) positioning ground features that are not on maps;
(iii) locating oneself and the ground position on maps;
(iv) locating the route followed when travelling by road or on foot;
(v) mapping of stands (coupes) and calculation of areas;
(vi) boundary demarcation;
(vii) road alignment;
(viii) location of important sites, sample trees or seed trees in the forests.

The topographic maps (topo sheet) that are available in Bhutan were produced in the early 1960s from aerial photographs taken in the 1950s and early 1960s. Therefore, these maps are very old and often not very reliable, as most of the existing information is not available on these maps. GPS helps to verify the ground location with the maps and also to map features that are not visible on aerial photos or satellite imageries, such as cardamom plantations under dense forest cover, different types of forest uses (forest pasture, yak/cattle wintering locations, etc.) and natural regeneration areas. It is also used in locating inventory take-off points.

For forest management planning and for preparation of FMU maps, for example, it is of great importance to have the latest information on existing infrastructure (settlements, roads and footpaths) and on land use and forest types.

Perhaps one of the most useful purposes of GPS is enabling the planner to align and map a tentative road for the FMU. GPS is set (in continuous reading mode) to take an automatic series of continuous readings, e.g. every minute, as the planner walks through the forests. The readings so obtained are then used for plotting the tentative road on the base map.

The combination of GPS with an electronic compass, like the SILVA GPS compass, facilitates navigation in the field extremely well. Using continuous readings the instrument leads a person direct to any point in the field one has specified before. This is of great advantage for forest inventory as it helps to avoid time-consuming field measurements and also solves the problem of the lack of reference points for re-adjustment of the inventory grid lines.

Another advantage is that the readings taken and stored by GPS can be fed into a GIS system and thus the features pinpointed in the field are directly mapped. The time-consuming task of transferring inventory plot location into the GIS system or digitizing field maps is thus facilitated to a great extent.

3.1.2 Personal computer (PC)

Personal computers are extensively used in preparing forest management plans. All data collected during the forest inventory are fed into the computer and analyzed. The data collected during the environment assessment and socio-economic data collection exercises are all fed into the computer for analysis. PCs are used for making maps using GIS software. Therefore, the usefulness of the PC in management planning activities cannot be overemphasized.

3.2 Software

<PLOT> is tailor-made software developed in FRDD for analyzing the inventory data. The programme runs on FOXPRO. The data collected in the field are too voluminous and cannot be

analyzed quickly and efficiently using commercial computer software. Therefore, special software called <PLOT> was elaborated in early 1990. The programme was initially developed to run on dBase version 1.1. Later on, it was upgraded and made compatible to run on FOXPRO. During the upgrading of this programme, new features were added and known mistakes corrected. The type of data collected during the inventory can be divided into four major components as follows:

(1) Tree measurements
Species, diameter, height, log grading and defects. For conifers, also bark thickness and radial increment are measured.

(2) Site and past history classifications
Land use, altitude, slope, aspect, soil, undercover, evidence of commercial or domestic use (example: timber and fuelwood extraction), grazing, availability of non-wood forest produce.

(3) Regeneration
Small trees (dbh<10 cm) and seedlings of commercial species on a sub plot.

(4) Evidence of wildlife
While measuring the distances between lines and plots, the crew keeps a diary of measurements of forest types and wildlife on the compass sheets. They can also be entered into the <PLOT> system if the additional information so provided is considered necessary. Their entry, however, takes a lot of time and most often they are not used in data processing other than for checking the plot location.

3.2.1 Geographic Information System (GIS)

GIS is a computerized database for storing, manipulating and displaying map (spatial) data and tabular (attribute) information. It permits the users to produce customized maps, perform database queries, analyze complex relationships, apply models and assist in decision-making. The GIS software that is being used in FRDD as a tool for assisting in management planning is ARCVIEW. It is one of the leading software for desktop GIS and mapping. It is very powerful software, which enables the planner to visualize, explore, query and analyze data geographically. GIS has been used in FRDD since the early 1990s as a tool for forest management planning.

In GIS, forest inventory information can be stored in a computer and linked direct to the associated forest map, which makes it both easier and faster to analyze and graphically display the results of forest inventories.

GIS can make forest inventory information more powerful by allowing resource managers to integrate it with other data commonly needed to make management decisions. For instance, managers may need to know the location of roads, streams, threatened or endangered species or sensitive soils when developing management plans. Combining forest inventory data with other land resources information allows managers to make more informed decisions. GIS has been and continues to be developed to provide essential information quickly and efficiently.

In GIS, the basic types of data are separated into individual maps called themes. The locations of each feature in each theme are stored in the computer database, and the characteristics associated with that feature are linked to it. For example, the location and the stand boundaries are stored in the stands theme of GIS, along with the inventory results (e.g. number of trees, volume, etc.) for each stand. Similarly, the location and attributes (pH, species present, etc.) of streams, soil types with their characteristics (soil series, drainage class, texture, erodibility

class, etc) and other relevant resources are entered into GIS. Each of these themes can be examined individually or in combination with others. Once maps of varying scale and formats have been digitized and stored, GIS allows superimposition of map information for different themes. The combination of GIS with timely and efficient resource inventories will continue to play a central role in resource management decision-making.

3.2.1.1 Use of GIS in forest management planning

Forest management planning requires data that describe present and future forest resources in terms of both condition and geographic distribution. These spatial data typically consist of conventional inventory information that describes the physical condition of the forest stand and cover type. Maps that define the geographic location of stands, and forest management programmes that generate a great demand for computer-based information handling systems capable of accommodating both data types, are needed.

The Forest Resources Development Division (FRDD) of the Department of Forests decided in the early 1990s to test the applicability of GIS to support forest management planning. Based on this decision, ARC/INFO was purchased and one Consultant from AIT, Bangkok, was invited for two weeks to demonstrate the basic capabilities of GIS to support the forest management planning process. On the advice of the Consultant, FAO/UNDP supported one two-month consultancy that helped to train two technicians who are now capable of producing maps and other management support information, as and when required by the management planners.

Subsequently, one GIS cell was established under FRDD in April 1991, which is equipped with hardware and software suited to the needs of a GIS section at that time. Over the years some technical improvements have been made and the staff intensively trained in the use of GIS package ARC/INFO. With the fielding of two short-term consultancies in 1996 and 1997, GIS staff obtained further on-the-job training to run GIS more efficiently. The missions also strengthened the workflow for GIS and gave examples, hints and recommendations for the improvement of GIS applicability to support forest management planning.

The mandate of the GIS cell of FRDD is to provide the planner with maps and statistical listings or other information as required. The preparation of maps starts with digitizing the FMU area from the 1:50,000 topographic sheets. Other data digitized from the topographic sheets are the 200 metre contours, drainage, blocks, compartments and sub-compartments, infrastructure, identifying accessible and inaccessible limits, creating and analyzing buffer zones, inventory strata and calculation of areas. The interpreted data from the aerial photographs are also digitized, e.g. the different forest types, height and density classes, cultivated areas, water bodies, rocky areas or other existing vegetation types, footpaths/mule tracks or motorized roads/highways, etc.

Output from GIS

The outputs from GIS are (i) maps and (ii) management data as per the requirement of the management planners.

1. **Maps:** GIS prepares various types of map, such as base maps, thematic maps, land use maps, forest type maps, slope maps, aspect maps, management maps (operable areas), etc. Maps are plotted in any scale and with different colours/hatches and legends as per the decision of the planner. Overlay of certain map features like forest types, infrastructure and other features can be drawn using different types or symbols. Perhaps the greatest advantage of map production is that maps of any scale can be produced from GIS.

2. **Management data:** Various types of data are produced either in tabular form or as ASCII file, which the planners can use word processors and spreadsheets to format the files. Areas of individual forest types and stands are also calculated and presented as tables. Nowadays GIS is becoming a very powerful management tool in the management of forests, both in the planning stage and subsequently in the implementation phase.

3.3 Mechanical devices

Besides the electronic equipment mentioned and described above, the following mechanical devices are also used extensively during forest inventory, road alignment, environment assessment and also socio-economic data collection. These devices are described briefly:

3.3.1 Relascope

Relascope is a small hand-held mechanical device developed for point sampling. The instrument, which is very compact and rugged, is used for determining the basal area per unit area, upper-stem diameter, tree heights and horizontal distances with correction for slope and measurement of slope on percent and degree scale. FRDD uses this instrument for reconnaissance forest inventory (RFI).

For RFI a sampling error of ± 20 percent of the average gross volume per hectare at 95 percent confidence level is used. GPS is used for identification of cluster position, which is compatible with GIS of FRDD. The design is stratified inventory based on randomly distributed cluster samples, which consist of satellites (or cluster) of triangular shape with a triangular arrangement of relascope cluster that are randomly distributed according to the size and coefficient of variation (CV %) of each stratum.

Planning and preparation of RFI is done by the Inventory Section of FRDD. The information required for this exercise is PIS/LUPP[4] maps, satellite imageries and other working maps of 1:50,000 scale, which are available in FRDD. The reconnaissance inventory also defines the accessible area, mapping out non-forest and inaccessible areas, and considers future strata.

3.3.2 Suunto compass

The bearings are usually measured with a Suunto compass. This instrument is well suited for gentle terrain. In steep terrain, however, a prismatic type compass (Wyssen, topochain) is preferred. The Suunto compass usually gives the azimuth in 360°. Experience has shown that there is no apparent difference between the magnetic north and the true north indicated on the base map. Therefore, both are assumed to be equivalent for our purpose.

3.3.3 Suunto clinometer

A clinometer is a small hand-held mechanical device used for measuring slope percentage in the field. Measurement can be done both uphill and downhill. Two types of model are in use. In one of the models the left-hand scale gives the slope in degree (0° to ± 90°) and the right-hand scale in percent (0 % to 150%). In Bhutan, normally the slopes are measured in percentage[5].

3.3.4 Altimeter

An altimeter is also used for determining the altitude of the place. A barometric type altimeter is used which of course does not measure elevation directly. It measures the air pressure and is

[4] PIS/LUPP maps are normal topographic maps. They contain information like contours, land use types and most of the important features.

[5] While taking the readings care must be taken because there is a difference in scale graduation for slopes less than or greater than ± 70 percent. If the slope is less than ± 70 percent each scale unit corresponds to 1 percent. If more than ± 70 percent, then it is 2 percent.

therefore, in fact, a barometer. However, making use of the non-linear relationship between elevation above sea level and the weight of the column of air above sea level (air pressure), the instrument has been calibrated to indicate the elevation equivalent. Since the air pressure is not only determined by elevation, but also by weather conditions, it is important that every morning before going to the field the instrument be adjusted against a known height taken from the base map. Usually this is the elevation of the base camp. Experience has shown that, due to changes in weather and inconsistencies in the base map, deviations between the base map reading and the altimeter reading of 20 metres and even more are not uncommon. At present the elevation readings obtainable from a single GPS instrument do not offer an alternative to the altimeter. They are much less accurate.

3.3.5 Zoom transferscope

Zoom transferscope is mono scopic equipment that is used for transferring interpreted photo imagery to the topographic base maps (scale 1:50,000). These base maps are prepared at the Survey of Bhutan (SOB) office. The equipment, being mono scopic, is mostly used for transferring data from photographs taken in flat lands where the displacements are minimal. Transfer of interpreted images is done using one of the following methods: (i) photogrammetric equipment; and (ii) zoom transferscope. The photogrammetric equipment is used only at SOB and is the most accurate method, planimetric- and also location-wise.

Land use and forest type maps are produced using the interpreted information from the aerial photographs. These maps are taken to the field and each polygon and forest type/land use type labels on the maps is checked/verified thoroughly. The changes are then rectified on the maps, based on the field information. The changes noted and rectified are (i) forest types; (ii) density class of each type; and (iii) the area. These corrected maps are re-digitized using GIS facilities. Tabular statements are also produced, e.g. (i) area of each land use/forest type; (ii) the density class for each forest type computed and species composition ascertained/verified.

3.4 Presentation and approval procedure

3.4.1 Presentation

The plan, when it is in its final shape, is discussed at two different levels with relevant and key persons: (i) Dzongkhag level and (ii) departmental level.

Dzongkhag level: A one-day management workshop is conducted and the planner introduces the plan to this forum. The rationale behind the forest management planning, its goals and objectives and implementation methods and strategy are presented and discussed. During the presentation, key issues pertaining to demand and supply, socio-economic benefits, rights and privileges of the local people, grazing and forest resources utilization and overall management, including nature conservation issues of the FMU, in general, are discussed and debated. The roles of the Dzongkhag administration and linkages with other agencies during the implementation phase are also discussed. Generally, technical issues are not discussed at this level; they are discussed at the departmental level.

The participants in the Dzongkhag-level workshop are normally from the Dzongkhag administration, renewable natural resources sector heads (representing agriculture, livestock, horticulture and research), Gups (village headman) and representatives of the communities, forest contractors and other stakeholders. The DFO of that FMU area would also be present at the workshop, as the FMU will be implemented later under him. The divisional manager and his staff represent the Forest Development Corporation Limited (FDCL), as they will be operating in the FMU. The Dzongdag of that particular district normally chairs the workshop.

The workshop proceedings are recorded and the findings and recommendations are incorporated in the management plan.

Departmental level: This one-day workshop is held at the Department of Forests headquarters and deals with the technical details. The participants are normally senior officers of the Department of Forests including some DFOss from the territorial divisions and FDCL. Representatives from other sectors, such as livestock, agriculture, research within the Ministry of Agriculture, the National Environment Commission, the Royal Society for the Protection of Nature (which is an NGO) and WWF-Bhutan are also invited to attend the workshop, as well as representatives from other forestry projects. The Head of the Department of Forests normally chairs this workshop. The draft plans, along with the invitation to the various participants, are distributed in advance for comments, views and suggestions. As mentioned earlier, this workshop deals with technical issues concerning the management of the forests. The planner presents the plan in two parts - Part One: The current situation, and Part Two: Future management.

Part One: The current situation - provides information on the FMU such as (i) location; (ii) area and status; (iii) physical features; (iv) climate; (v) socio-economics; (vi) environmental issues; (vii) infrastructure; (viii) current administration; (ix) the forest resources demand and supply; and (x) research.

Part Two: Future management: This section deals with (i) the policy, goals and objectives; (ii) management strategy; (iii) resource allocation; (iv) infrastructure; (v) environmental issues; (vi) grazing; (vii) forest research; (viii) staff and labourers; (ix) financial aspects; (x) implementation; and (xi) control. *(Details of the management plan structure are given in Annex 1a.)*

The planner specifies how the FMU is going to be organized and what the management priorities are. Based on the inventory results and the demand and supply situation, the plan specifies the type of silviculture to be adopted and subsequent regulation of the yield. The determination of annual allowable cut (AAC), the rotation period and cutting cycles are discussed and debated. The silvicultural systems proposed for the FMU are also discussed for their appropriateness. Harvesting systems to be adopted and the infrastructure required for the management of the FMU and other implementation issues are also discussed. At the end of the workshop the findings and recommendations are recorded and incorporated in the final plan

3.4.2 Approval

After the plan has been discussed in the above-mentioned two *fora*, the Head of FRDD submits three copies to the Head of the Department of Forests for final endorsement and onward submission to the Ministry for approval.

The Head of the Department of Forests, after final review, submits the plan with a recommendation for approval to the Minister, Ministry of Agriculture.

The management plan becomes a legal document for the FMU once the Minister, Ministry of Agriculture, on behalf of the Royal Government of Bhutan, grants approval.

4. IMPLEMENTATION OF THE MANAGEMENT PLANS

4.1 Overview

The implementation arrangement described in this section is applicable for FMUs in government-reserved forests. At the moment there is no FMU in the privately owned forests because these forests are very small in area. However, it is expected that, in the near future, the concept of FMU will be in the privately owned forests as well.

The management plans for FMUs are prepared by FRDD of the Department of Forests. The plans, after obtaining government approval, are handed over to the concerned territorial DFO for implementation. The DFO then becomes the chief forest resources manager in the district. He has the authority to allocate, control and monitor the utilization of forest resources within his territorial jurisdiction. However, the actual execution of the work in the FMU is carried out by FDCL under the overall supervision of the DFO.

As the management plans prepared by FRDD are for a period of ten years, it would be difficult to implement the plan without having an operational plan of shorter duration. Therefore, to facilitate the smooth implementation of the plans, annual operational plans are prepared by the DFOs. In order to explain the implementation arrangement of the management plan, in the FMUs, the division of responsibility needs to be understood clearly. Even though the local DFO becomes the overall resource manager, some of the activities are entrusted to FDCL. They carry out the activity under the overall supervision of the DFO. Some of the important activities carried out by the DFO and FDCL are discussed in detail in the following section. It is mandatory that all activities that are prescribed to be implemented in the FMUs be clearly indicated in the operational plan and approved by the Department of Forests.

4.2 Responsibility of the DFO

4.2.1 Preparation of the annual operational plan

The DFO is responsible for preparation of operational plans (OP) in close collaboration with FDCL field offices. He is also required to consult the local communities while preparing OP. Activities such as planning, allocation of coupes for both local and commercial uses, operational inventory design, map preparation, road alignment, plotting the data and computation of earth work, cable line survey, preparation of maps and any other prescriptions contained in the management plan are clearly indicated in OP.

4.2.2 Protection of buffer along river/stream and national highways

The forest and nature conservation rules, 2000, have provisions for protecting certain areas on either side of rivers and perennial streams. These areas are mapped out using the topo sheet of the area and GPS. The data are transferred to GIS and a buffer area map is prepared. The reasons for mapping and protection of rivers/streams buffer and also the buffer along the highways are for protection against soil erosion and landslides.

4.2.3 Silvicultural system adopted

The objectives of forest management emphasize sustainability of wood supply in conjunction with the conservation and improvement of the environment. Therefore, the priorities are to ensure prompt regeneration of the harvested areas and improvement of the degraded forest areas.

The vegetation of an area responds accordingly to the interventions. Therefore, depending on the type of forest that is being managed, different kinds of intervention, such as through canopy manipulations, can promote natural regeneration.

Often more than one silvicultural system, treatment or combinations are required to obtain an adequate regeneration. Areas where regeneration is inadequate need to be restocked through planting and fencing for a couple of years till the young seedlings are established. Regeneration is adequate in most of the coniferous zones, except in the fir zones, where regeneration is not very satisfactory.

Nor is regeneration satisfactory in the broad-leaved forests. As most of the tree species are palatable to cattle, whatever little regeneration is obtained is either eaten, browsed or trampled. Given the heavy cattle grazing pressure, regenerating the FMU through natural regeneration methods is difficult. The overgrowth by other pioneer species in the opened-up areas is another factor that has to be dealt with. The selection-cum-improvement silvicultural system applied in the past has not been very successful in the broad-leaved forests. Theoretically this system is very sound and works on the principle that dead, dying and diseased trees be removed in order to improve the quality of the stand/forest. Perhaps, more than the system itself, it may have been the faulty execution of the system.

In the broad-leaved forests the regeneration of the main species is complex and difficult. Therefore, efforts are being made to study and learn more about the regeneration aspects and other forest dynamics of the broad-leaved forests.

4.3 Responsibility of FDCL

4.3.1 Cable cranes

In all FMUs cable cranes are used to lift and transport the logs/timber. FDCL makes a number of tentative cable lines on the base maps. These lines are surveyed and the alignment is taken on the ground to find the suitability of the proposed line. However, the alignment often changes and it is important to get the best and ideal cable line alignment, keeping in mind the landing site for the logs. The landing sites are required to be proper and not too steep so as to prevent the logs from rolling down the slopes.

The marked trees are felled and cut to required lengths using power chain saws. After crosscutting, the logs are hauled to the landing sites by cable cranes and are loaded and transported to the depots. Depending on the volume of logs at the landings, loading is carried out by log loaders or manually by the contractors.

The local demand for timber for domestic and industrial uses are met from the FMUs and the excess logs are then sold from the depots at open auction. The export of timber in log form is banned, except as finished products.

The people living in the rural areas still enjoy the privilege of getting timber at subsidized rates for their house construction/repairs. This timber may be obtained direct from the FMU under the rural house building timber allotment scheme, or from sawmills, or partly from both these sources at subsidized rates.

Equipment/accessories used for surveying are (i) topo maps of the area in 1:50,000 or, if available, 1:25,000 scale; (ii) compass; (iii) clinometer; (iv) measuring tapes, etc. Recently GPS has been used for locating cable lines. When GPS is used, the data are transferred direct to the computer and with the help of GIS the cable lines map is prepared. Because not everybody

in the field is very conversant with the use of GPS, staff are mostly dependent on compass, clinometer, etc.

4.3.2 Harvest

The volume of timber to be harvested and the area to be operated is indicated in the annual operational plan. FDCL makes arrangements for harvesting of the area. The area is demarcated into several coupes and for each coupe one cable line is normally installed. Thereafter, FDCL makes a formal request, in writing, to the FMU officer-in-charge to mark the trees to be harvested. The number of trees to be marked for felling depends on the type of forest, the growing stock and the type of silvicultural systems prescribed under the overall guidance of the AAC for that FMU. The trees to be harvested are marked by authorized hammers of the Department of Forests. All the trees that are marked are recorded in the tree marking register, in which the following parameters are measured and recorded: (i) name of the species; (ii) diameter measurement at breast height; (iii) total height of the tree.

At the moment no electronic equipment/mechanical devices are used for recording the data. FRDD is studying the possibility of using such equipment in the future.

5. DESCRIPTION OF MANAGEMENT PLANNING ACTIVITIES

5.1 Overview

This section describes various activities that are required to be completed before the actual field works begin. The electronic equipment and also the mechanical devices used for undertaking these activities such as data collection, data analysis, map production and drafting of the management plan, etc. are also described.

5.1.1 Introduction to planning process

Forest management plans in Bhutan are prepared at FMU level. The concept of an FMU as a unit of planning and management has its origins in Europe. In Bhutan the concept is applied with adaptation and modification as necessary.

In the forest and nature conservation rules of 2000, FMUs are defined as geographic areas of government-reserved forest designated according to the rules for scientific management of forests. They are discrete forest areas of variable size (typically ranging from 8,000 – 20,000 hectares) primarily identified for their potential for multiple function forest uses. The FMUs generally encompass a sub-watershed; they therefore include a range of forest types and conditions that are prevalent in a watershed. However, FMUs can also comprise a number of relatively small potentially operable areas that are not geographically contiguous. The requirement of a forest management plan in Bhutan is mandatory for operating in all such forest areas as per the forest and nature conservation rules, 2000.

The forest management plans are complete long-term silvicultural plans for specific forest areas (i.e. FMUs). The preparation of scientific forest management plans is one of the most important activities of the Department of Forests. A scientific management plan forms the basis for efficient and sustainable forest management. The national forest policy of 1974 takes a firm stand by ordering that all forest areas should have approved forest management plans and that no harvesting of timber and any other forest produce may take place without a management plan approved by the Royal Government.

The forest management system is characterized by different levels of management and planning horizons. The forest management plan derives its mandate from national-level plans, forest act and the rules, etc. They are as follows:

National level

- Forest sector master plans
- Forest policy
- Forest act

Forest management unit

- Forest zoning
- Forest Resources Assessment
- Yield regulation

Operational level plan

- Silviculture and harvesting
- Non-wood forest products
- Timber harvesting operation
- Forest road construction

At the national level, management planning is handled at the forestry sub-sector level. It deals with the relationship between forestry and various other public sectors such as agriculture, animal husbandry, industry, tourism and mining. It involves policy decisions on (i) land use planning based on forest functions mapping; (ii) forest resources assessment; and (iii) yield calculation and regulation.

At FMU level, management planning is undertaken for all forestry activities that are required by the management plans. The forest management plan, among others, also contains the prescribed measures to mitigate the environmental impact of forestry activities, as required by the environmental assessment act, 2000.

At the operational level, silviculture, harvesting, non-wood forest products, management of compartment-level forestry operations, road construction and monitoring of different activities are carried out.

In the following sections, a brief description is given to indicate various steps and formalities that are required for preparing forest management plans for the FMUs.

5.2 Planning activities

Detailed planning activities that are required to be undertaken are outlined and strategies to achieve them are properly planned before going to the field. Further equipment that is going to be used is also identified. The objectives for undertaking these activities, as well as the output, are indicated in Table 5. The electronic equipment or any other mechanical devices used for accomplishing each of these activities is also indicated.

Table 5: Planning activities and output

Activity (planning step)	Objective	Output	Electronic equipment/mechanical devices used
Forest function mapping	To identify the commercially operable area, areas to be reserved for local use and areas with management restrictions	Map showing zones and sub-zones based on forest functions	GPS is used for data collection Maps are prepared using GIS facilities
Social surveys and participatory resource use mapping	To provide information about local use of the forest area	Participatory resource use map Social information on stakeholders	GPS used for data collection GIS for map preparation

Activity (planning step)	Objective	Output	Electronic equipment/mechanical devices used
Inventory, survey and mapping	To collect forest resource data and map the FMU	Inventory data entered in database	GPS for data collection GIS for mapping
Data analysis, preparation and AAC calculation	To assess the status of the resource To identify management zones To determine the AAC for the operable area	Estimated AAC for the operable zone Area statement and other tabular data	<PLOT> for data analysis and computer for report preparation.
Environmental assessment	Identification of environmental issues, potential impacts and mitigating measures	Environmental statement as integral part of FMP	GPS for data collection GIS for mapping
Draft goal and vision for FMP	To draft an overall goal for the FMP	Statement of goal	
Stakeholder analysis	To determine which stakeholders need to be involved in the planning process and decide how their interests can best be represented	a. List of stakeholder representatives to be invited to initial FMU-level management committee meeting b. Stakeholder analysis matrix	

In addition, the following activities are also identified before going to the field but they will have to be addressed only after collecting some very pertinent data from the field.

Table 6: Planning activities that are required to be addressed after collecting field data

Activity (planning step)	Objective	Output	Remarks
Establishment of FMU-level management committee	To agree on the composition and role of the FMU–level management committee	a. List of committee members b. Agreed ToRs for FMU-level management committee	A meeting needs to be convened in the field.
Problem analysis and objective setting	To draft forest management representing the interests of different stakeholders for different forest zones	Agreed forest management objectives for each zone (prioritized)	This is done after obtaining field information
Organization of the forest	To establish or review block, compartment and sub-compartments	Map of block, compartment & sub-compartment boundaries	Topo map is used. Consultation with local people is also required
Silvicultural systems	To determine appropriate silvicultural and harvesting strategies and systems for the FMU	Statements of options and recommendations for silvicultural and harvesting strategies and systems	This has to be in line with the forest management code.
Harvesting systems	To determine appropriate harvesting systems for the FMU	Statements of options and recommendations for harvesting systems	This has to be in line with the forest management code.

Activity (planning step)	Objective	Output	Remarks
Financial and economic appraisal	To identify factors affecting supply and demand, to assess cash flow and financial viability, to undertake cost-benefit analysis including consideration of non-market costs and benefits	Statement of factors affecting supply and demand for forest products in FMU and implications for forest management. 10-year cash flow forecast. Long-term cost-benefit analysis. Statement of non-market costs and benefits and implications for forest management.	Field information on demand and supply is required. The activity is addressed after coming back to the office.
Draft plan preparation (management strategies, options, activities, indicators)	To prepare the document and maps for further consultation and discussions (in an agreed format)	Draft plan describing management activities (management options) for each identified zone and containing options, strategies and management guidelines for operations aimed at achieving stated objectives	This is done in the office.
Writing an executive summary	To write an executive summary which effectively communicates the key points of the FMP in a highly concise manner	Executive summary to be included in FMP	This is done in the office.
Draft plan presented to FMU-level management committee	To create an opportunity for comment To reach consensus on the plan content To ensure that there are no errors or omissions	Forest management plan (endorsed by FMU-level management committee)	This is field work. The planner convenes a meeting and the plan is presented to the people.
Endorsement by DYT	To ensure that FMP is endorsed by DYT	FMP endorsed by DYT	Office activities
Environmental clearance of FMP by NECS	To obtain environmental clearance for all proposed activities in FMP	Environmental clearance granted by NECS for five years	
Recommendation by Director of Forests	To ensure that the plan is consistent with the agreed planning process and technical quality	Plan approved by Director	
FMP approval by Minister	To approve the plan for implementation	Approved FMU management plan	
Preparation of a summary of the FMP for local use	To produce an easily understood summary of the plan in Dzongkhag	Short, highly visual summary in Dzongkha.	
Mid-term evaluation of FMP	To review progress against FMP objectives and amend the FMP if required	Amended FMP	Field and office activity. However data from the implementation of the plan would be required.
End of term FMP evaluation	To review progress against objectives	Recommendations for new FMP	

6. DETAILED DESCRIPTION OF FIELD WORKS

6.1 Overview

This section describes, in detail, different activities that are undertaken in the field, which are required as part of the input for forest management planning. It also describes the equipment that is used for data collection and analysis. Various steps are involved and the procedure for forest function mapping, inventory, environmental assessment and socio-economic works in the field is also described.

6.2 Forest function mapping and zoning

In FMUs, forest areas are zoned according to the functions for which they are suitable. In order to accomplish the activity, forest function mapping is carried out in a very elaborate manner; it is, therefore, an essential tool for forest management planning. It defines all the forest areas within the FMU, e.g. (i) ecological; (ii) environmental; and (iii) social functions, and as such serves to balance the often diverging interests of commercial logging, local forest use and nature conservation, etc.

After the forest function map is produced the map provides information on the total commercially operable area and identifies which areas have to be reserved for local use; it also gives management planners and implementers information on management restrictions for particular areas.

Forest function maps are prepared for the entire permanent forest areas of the FMU (which includes bare land or rangelands to be reforested) and are done in a planning step that basically follows land use planning methodology. The responsibility of forest function planning lies with the management planner in FRDD supported by the GIS staff of FRDD. The forest function map is reviewed and updated/revised every 10 years when a new management plan is prepared.

6.2.1 Definition and description of forest functions

In Bhutan, five main groups of functions are identified for management planning purposes. However, based on local conditions and situations, there could be more or less than five main groups. Each one includes a number of sub-functions, which are differentiated by their influence on forest management. For the sub-function the term ‘protection’ is used; if commercial use is prohibited the term ‘conservation’ is used, if the function imposes management restrictions on commercial use. If a function group should contain both protection and conservation functions, then the term ‘conservation’ is used for the function group (i.e. soil conservation, water and watershed conservation, nature conservation etc.). A list of different functions and sub-functions is given in Table 7.

Table 7: List of different forest function groups and sub-functions

Soil Conservation	Water and Watershed Conservation	Nature conservation	Social function	Road buffer
SP Soil Protection	**WRR** Riparian reserve protection	**NWP** Wildlife protection	**SocRS** Religious site protection	**RB** Road buffer
SC Soil Conservation	**WLS** Local water supply protection	**NWC** Wildlife conservation	**SocL** Social (local use only)	
	WSMA Special management areas around water courses	**NB** Biodiversity protection	**SocLC** Social (local cum commercial use)	
	WSh Watershed conservation			

***Source**: Schindele & Dhital, 1997, and RGOB, 2004*

6.2.2 Effects of forest function on forest management

For each forest function, management prescriptions/restrictions are defined that are to be strictly observed during implementation. Management restrictions are recorded for each stand in the stand or compartment register.

In many cases forest functions overlap, especially those that depend on the same parameter (e.g. slope) particularly SP/SC and WSh. On the other hand, functions are overlapped intentionally in order to maximize the production forest area and to make optimal use of the forest potential. This applies, for example, to NWP/NWC with SP and SC. In case several functions are classified for one particular forest area, then all prescribed management prescriptions/restrictions have to be considered.

Forest functions are ranked according to their impact on commercial forest management. There will also be cases in which forest functions exclude each other, such as SC and SP, NWC and NWP, WRR/WLS and WSMA. Also, SocLC (local cum commercial use) cannot be defined in areas already classified with one of the following functions**:** NB, SP, WRR, NWP, WLS, SocRS, RB, and SocL. The impacts of forest functions on commercial forest management and local use are explained in Table 8.

Table 8: Impact of forest function on commercial forest management and local use

Rank	Code	Function	Restriction on commercial use	Restriction on local use
1	NB	Biodiversity protection	no commercial use	no local use
2	SP	Soil protection	no commercial use	no tree felling; no *tsamdo* no *sokshing*
3	WRR	Riparian reserve protection	no commercial use	only collection of NWFP; no *tsamdo*; no *sokshing*
4	RB	Road buffer	no commercial use	no tree felling
5	NWP	Wildlife protection	no commercial use	restriction to activities that do not change habitat quality and disturb wildlife
6	WLS	Local water supply protection	no commercial use	low impact use only; no cattle grazing
7	SocRS	Religious site protection	no commercial use	only uses which do not disturb sanctity of place
8	SocL	Social (local use only)	no commercial use	no restriction
9	SC	Soil conservation	no clear cutting; no conversion to plantation; extension of rejuvenation periods	low impact local use; no intensive cattle grazing
10	WSMA	Special management area around water courses	no clear cutting; no conversion to plantation; minimize disturbance to understorey vegetation	low impact local use; no intensive cattle grazing
11	WSh	Watershed conservation	no clear cutting; no conversion to plantation; minimize disturbance to understorey vegetation	no intensive cattle grazing
12	NWC	Wildlife conservation	no clear cutting; no conversion to plantation; leave snags; leave some undisturbed patches; minimize disturbance to understorey vegetation (bamboo)	local use should minimize disturbance to wildlife
13	SocLC	Social (local cum commercial use)	depends on type of local use; has to be individually determined from case to case	no restriction
14		Production	no restriction	no restriction

***Source**: Schindele & Dhital, 1997, and RGOB, 2004*

Based on the impacts of forest functions on commercial forest management the forest functions are classified into three zones, as shown in Table 9.

Table 9: Forest zoning according to functions

Protection zone (no commercial use)	**Local use zone (no commercial use)**	**Limited production zone (commercial use restricted)**
1. Biodiversity protection 2. Soil protection 3. Riparian reserve protection 4. Road buffer 5. Wildlife protection 6. Local water supply protection 7. Religious site protection	1. Social (local use only)	1. Soil conservation 2. Special management area around water courses 3. Watershed conservation 4. Wildlife conservation 5. Social (local cum commercial use)

***Source**: Schindele & Dhital, 1997, and RGOB, 2004*

All areas that have no defined function are considered as production zone without any particular management restriction except those imposed by the forest and nature conservation act 1995 and relevant rules issued from time to time by the Department of Forests.

During the implementation of the management plan, it is of the utmost importance that all the prescriptions/restrictions specified for the buffer zones be respected even if they are not identified on a map. Management prescriptions/restrictions are drawn based on the forest zones identified and mapped according to the functions. Detailed procedures followed in Bhutan for mapping forest functions are given in Annex 3. Electronic equipment and mechanical devices used for mapping are also included in the write-up.

6.3 Forest inventory

Forest inventory is another very important activity that is essential for forest management planning. The detailed steps followed while conducting the inventory and different equipment used for data collection and analysis are given below in a logical sequence:

Various steps involved in the forest inventory process are:

- reconnaissance survey of potential new FMUs and decision whether to undertake inventory;
- production of base/thematic/GIS maps and preparation of sampling design;
- execution of field works;
- compilation of collected field data;
- reporting;
- archiving and making available data sets and follow-up.

6.3.1 Reconnaissance survey

Given the intensive utilization of forest resources in the country and the requirement of a management plan to guide forest resources utilization, new forest areas are being gradually taken up as FMUs. After a decision is made to consider a certain new FMU, existing information is gathered and a reconnaissance survey is conducted in the field in order to become familiar with the conditions of the area.

6.3.2 Procurement of remote sensing imagery and base map

Once the boundary of a new FMU is known, aerial photographs covering the entire FMU area are procured from the Survey of Bhutan. Usually the photographs obtained are in the form of panchromatic black and white prints at scale of around 1: 30,000 (varying from 1: 35,000 to 1: 15,000). In many cases aerial photographs are not available and in such cases the forest type maps are prepared using either PIS or LUPP map information. In both cases intensive field

checking takes place. The use of high-resolution satellite imageries in this phase is expected to become prominent in the near future.

6.3.3 Sampling design

A stratified systematic sampling design is used to achieve the objective of the inventory that is conducted in the FMU. The natural forest areas are grouped into several more or less homogenous strata in which the sample plots are distributed in a systematic way. The objectives of stratification are to:

(i) obtain a more specified presentation of the inventory results;
(ii) improve the precision of final estimates by keeping the variation within the strata as small as possible.

After the stratification has been done, based on area of individual stratum and CV%, the number of sample plots required for the inventory is calculated for each stratum.

An example: Suppose we have three strata with the area as indicated below and also estimated CV%. The number of sample plots required is calculated for each stratum to achieve a target sampling error of ± 10% at 95% confidence level over the whole area:

	Area (ha)	CV%
Fir	100	50%
Mixed conifer	200	70%
Blue pine	300	105%
	600	

The weighted average CV is therefore 84%,
$n = t^2 \times CV\%^2 / SE\%^2$
$n = (2)^2 \times (84)^2 / (10)^2 = 282$ plots.

To allocate the plots to the three strata:

Fir	100 ha x 50% CV	= 50	50/505= 0.10	n = 0.10 x 282 = 28
Mixed conifer	200 ha x 70% CV	=140	140/505=0.28	n = 0.28 x 282 = 79
Blue pine	300 ha x 105% CV	=315	315/505=0.62	n = 0.62 x 282 = 175
		505		Total no. of plots 282

After the number of sample plots required for each stratum has been calculated and allocated proportionally, based on the area and variability, maps are produced indicating the number and location of the plots.

The GIS facility is used for preparing the plot location map. With the help of GIS the latitude and longitude of each plot are calculated and transferred to the map. The output is the plot location map.

6.3.4 Transfer of sampling grid to base map

Once the *sampling grid* has been determined then the plot locations are transferred to the base map for use in the field. As a *starting point for the grid,* defined as the first plot on the first line having plot number AA00, a clear but random point on the base map is selected. Usually the intersection of a fixed longitude/latitude just outside the FMU area is chosen since its coordinates can be determined exactly.

The determination of the geographic plot locations is done in the office using GIS. The table below gives a list of plot locations (expressed in decimal degrees) as determined for the study

area using the GIS facility. *Example:* (partial) listing of plot numbers and their geographic (longitude/latitude) locations, in decimal degrees, for the study area, as determined by GIS, is given in Table 10.

Table 10: Listing of plot numbers and their geographic locations.

Plot No.	X	Y
AJ1	89.37491	27.43976
AK1	89.38209	27.43958
AL1	89.38928	27.43939
AJ2	89.37473	27.43390
AK2	89.38190	27.43371
AL2	89.38909	27.43353
AM2	89.39626	27.43334
AN2	89.40344	27.43315
AI3	89.36736	27.42821
AJ3	89.37454	27.42804
AK3	89.38171	27.42785

***Source**: FRDD, 2002*

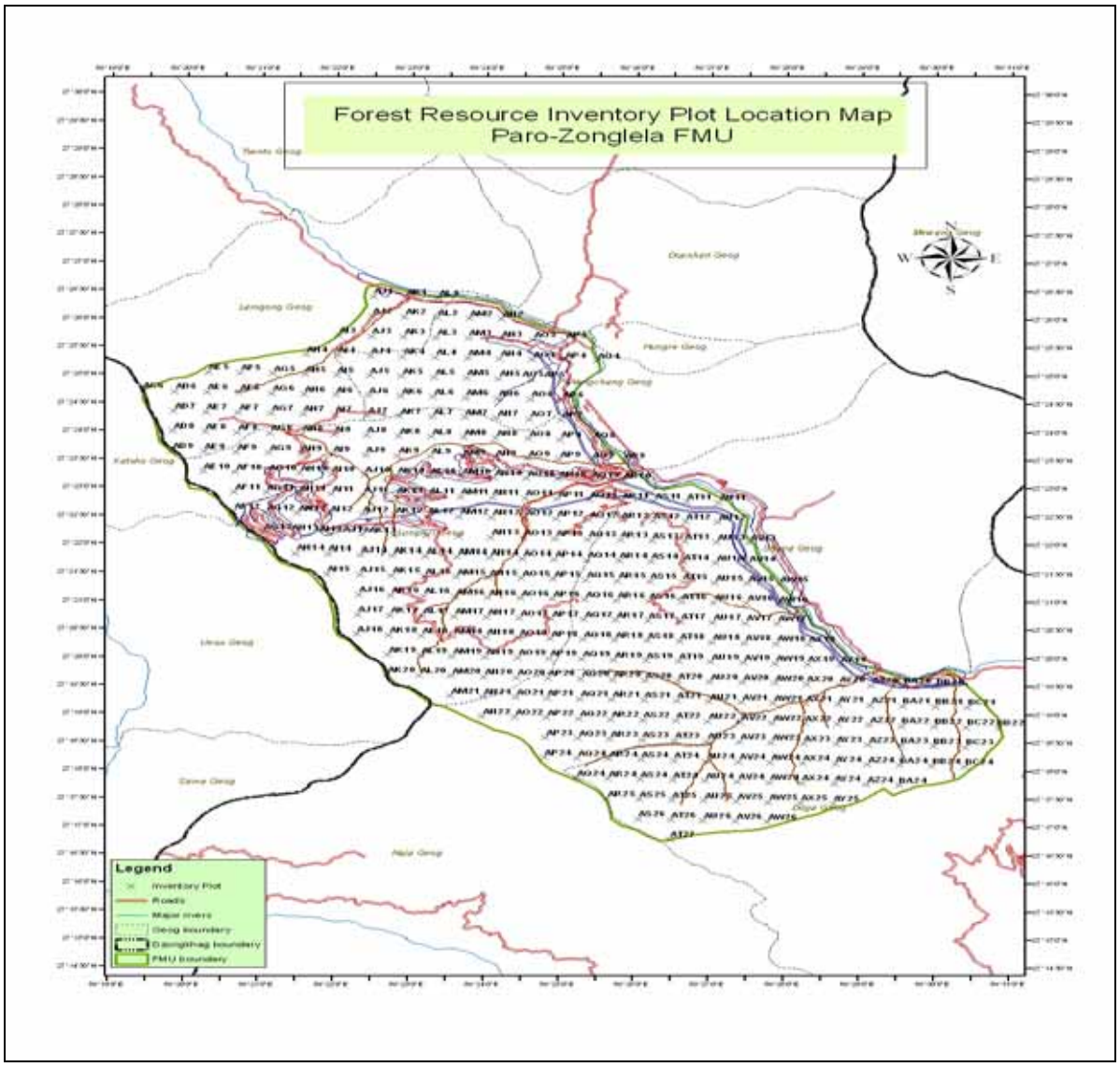
The availability of this list with the geographical plot coordinates, in decimal degrees, is helpful in the determination of plot locations in the field using GPS. It also facilitates the spatial referencing of all inventory plots, so that inventory data from all over the country can eventually be retrieved on the basis of their location. Inventory lines are labelled AA, AB, AC, etc. with the plot numbers on each line 00, 01 02, etc. Thus, each plot gets a unique identifier, e.g. AD22 etc.

After the transfer of details on the base map using the GIS facility, the map is taken to the field and the details are checked thoroughly. If some discrepancies are found they are recorded, brought to the office and duly corrected.

The ground truth verification is required mainly to:

(i) determine the accuracy of the interpreted data and to correct misinterpretations;
(ii) observe and make corrections with regard to the field situation;
(iii) check and correct the location-wise errors caused by interpretation as well as at transfer of interpreted data using the equipment;
(iv) observe and mark the hidden or invisible details on photographs;
(v) ascertain the status of planimetric accuracy by observation.

The degree of ground truth verification will vary and depend on the purpose for which the photographs are interpreted and the final map expected. For forest management purposes, detailed ground truth verification with a higher accuracy is required. This necessitates that, in order to carry out an accurate ground checking, trained personnel in the field use photographs with pocket stereoscopes. The use of altimeters and compasses helps to correct orientation in the field and the use of binoculars expedites field activities. The base map is finalized after ground truth verification.



Map 3: Plots location map of Paro Zonglela FMU.

Fieldwork

With the location of the sample plots, which are indicated in the base map, measurement of the plots is started. Measured data are recorded manually on two types of form, which are known as compass sheet and tally sheet. GPS is used for finding the location of the plots in the field with reference to the base map. Any existing footpaths, trails and other permanent structures are also recorded with the help of GPS.

Plots are approached from the same inventory line, since the distance between plots on a line is usually shorter than that between lines. For example, the crew proceeds from plot AN12 to AN13, from there to AN14, etc. Therefore the correct location of the inventory line is important. Usually it will take some time before a suitable starting point for a line is found. Such a starting point is located using clear reference points on the base map such as roads, bridges, intersection of streams, hilltops, monasteries, etc. It requires familiarity with the terrain. GPS is very handy and in FRDD the crew uses GPS for locating and recording the above-mentioned structures.

Apart from the measurements done on the plots, additional information needed for management planning is also collected during the course of fieldwork.

At regular monthly intervals the completed recording forms are then handed over to FRDD after checking that all data and codes have been properly and neatly filled in. Currently, FRDD do not have electronic equipment or any mechanical devices to record the data from the plot direct. All the data are recorded in the compass and tally sheets. However, it should be mentioned here that the usefulness of the palmtop computer is being investigated. If that works well, the data from the tally sheets will be entered in the palmtop computer in the camp itself, using some standard spreadsheet facility of the palmtop. The entered data can then be transferred to a desktop computer at FRDD using serial cable. This approach could lead to fewer data entry mistakes later on. Further, the use of more rugged and dedicated data loggers (such as Husky Hunter) to replace the pre-recorded forms, which would avoid many of the most common data entry errors, may be of potential value in the future.

6.3.5 Starting point of inventory line

Inventory plots are normally measured along the inventory line; therefore, it is important that the correct *positioning of the line* be ensured in the field. Field positions are carefully checked on the base map, using clear reference points (roads, monasteries, bridges, farm houses, small clearings, cow/yak sheds, streams intersection, hilltops etc.), altimeter and GPS. If a logging road runs through the area, the alignment is recorded with the help of GPS and is plotted on the base map so that its features (distance, bend) can be used as additional guidance and reference.

6.3.6 Navigation to plots

Whilst the use of tape, compass and clinometer to navigate between plots is generally sound, the terrain most of the time will make it difficult to locate plots precisely and to move along a transect; thus the errors should be compounded. The process is also incredibly time consuming; moving between plots in most terrain is by far the most time-consuming element in the whole inventory. Given that location of the plot is very important in defining strata (and fine tuning the map) FRDD is considering the use of GPS as replacement for the compass/tape/clinometer method of moving to plots. It is likely to be a cost-effective and time-saving means for inventory crews to improve accuracy.

6.3.7 Selection of measurement plots

The first plot in the field is established with the help of compass or GPS. Nowadays, FRDD is using GPS for establishing the sample plots. Thereafter the subsequent plots are approached from the same inventory line; e.g. the crew proceeds from plot AA22 to AA23, then to AA24, etc. Therefore, the correct location of an inventory line and plots is important. Locating or finding a suitable starting point for a line usually takes some time. The updated base map, following the aerial photo-interpretation with the newer information that was not shown on the toposheet, also helps in providing more reference points.

6.3.8 Recording forms

Observations made during the measurement of the sample plots are recorded in two types of form (i) compass sheet and (ii) tally sheet. This information, which is currently recorded in the tally and compass sheets, can be easily recorded in electronic equipment. However, FRDD is still exploring the possibility of such equipment, which should be user friendly and accurate for use in mountainous situations. The procedure for recording in each form and the parameters recorded are described briefly hereunder.

6.3.8.1 Recording of compass sheet

The compass sheet is used to record observations made while approaching a given plot. The main purpose of the compass sheet is to provide a wider overview of the conditions of the FMU compared to observations made only in the plots themselves. Each plot that is to be

enumerated according to the sampling design and the related GIS map should have its compass sheet filled in. If in the field a plot is found to be inaccessible or not in natural forest, the compass sheet is still filled in as far as possible, providing relevant remarks so that the situation is clear for the data entry and compilation phases. The information filled in the compass sheet is as follows:

(i) Line identification information
(ii) Inventory unit
(iii) From plot
(iv) To plot
(v) Sheet number
(vi) Crew leader
(vii) Date
(viii) Azimuth
(ix) Remarks

6.3.8.2 Recording in tally sheet

The tally sheet is used to document all measurements made on the plot itself. The main purpose is to record the outcome of the various variables for the selected sampling units. For each plot that has been visited in the field, a tally sheet (as well as a compass sheet) is filled in. If the plot happens to be in an inaccessible area, the tally sheet is not filled in. The variables recorded in the tally sheet are as follows:

(i) Plot identification information
(ii) Inventory unit
(iii) Plot number
(iv) Special plot
(v) Sheet number
(vi) Name of the crew leader
(vii) Date
(viii) Altimeter reading
(ix) Land use types
(x) Canopy height
(xi) Canopy closure
(xii) Accessibility
(xiii) General remarks
(xiv) Tree above 10 cm dbh
(xv) Species codes
(xvi) dbh
(xvii) Total tree height
(xviii) Last ten years radial increment
(xix) Single bark thickness
(xx) Regeneration <10 cm dbh
(xxi) Site
(xxii) Azimuth, downhill
(xxiii) Slope percent down/up hill
(xxiv) Understorey cover percent
(xxv) Main understorey type
(xxvi) Bamboo cover percent
(xxvii) Main bamboo type
(xxviii) Cane cover percent
(xxix) Cane dbh

(xxx) Sign of commercial wood extraction
(xxxi) Sign of domestic wood extraction
(xxxii) Sign of grazing
(xxxiii) Sign of forest fire
(xxxiv) Stoniness cover
(xxxv) Depth litter + humus
(xxxvi) Top soil moisture
(xxxvii) Top soil colour
(xxxviii) Top soil texture
(xxxix) Wildlife

6.3.9 Data collection in the field

Carrying out inventory works is not only time-consuming, it also entails a high degree of professionalism. Perhaps it can be stated that the quality and accuracy of the management plan depend on the inventory of the forest resources.

With the locations of the sample plots on the base map, measurement of the plots can be started. Measured data are recorded manually onto the two types of form, *compass sheet* and the *tally sheet* (Annexes 5a, 5b and 5c).

The information in the compass sheet serves as a logbook to verify the location of the line as against the base map, for future reference, and also as a ground control of the image interpretation and to assess the wildlife status of the area.

The field crews operate from a base camp when the lines are within one hour's walking distance and the base camp is shifted to another location when the close-by inventory lines are completed. For distant plots on a line the crew establishes a temporary transit-camp, using lightweight hill tents and other camping materials. The completed tally sheets are handed over to FRDD on a monthly basis along with the progress report for the month.

6.3.9.1 Equipment used

Each inventory crew has the following set of equipment:
(i) haversack
(ii) clipboard
(iii) notebook
(iv) set of field instructions manual (field manual, slope corrections, species code, land use codes)
(v) set of recording sheets (compass sheets, tally sheets)
(vi) base map (1:20,000 – 1:25,000 scale) showing plot locations and contours
(vii) pocket calculator
(viii) sharp pencil (refill type) + separate eraser
(ix) marker pen
(x) ruler
(xi) hill tent
(xii) compass (Suunto or Wyssen type)
(xiii) clinometer
(xiv) barkguage
(xv) increment borer
(xvi) magnifying glass (increment cores)
(xvii) sharp razor blades (increment cores)
(xviii) diameter tape

(xix) distance tape (30 m)
(xx) altimeter
(xxi) reference height pole of 1.3 m length
(xxii) red/white sighting/flag pole (also called ranging rods)
(xxiii) 4-6 bush knives *(khukuris/patangs)*

Desirable additionally
(i) topographical maps (1:50,000) for the area
(ii) Satellite images (1:50,000) for the area
(iii) Land use maps (1:50,000) for the area
(iv) GIS map (1:20,000 –25,000) of the FMU
(v) listing of plots, their geographic location (decimal degrees longitude/latitude) and land use type according to the GIS map
(vi) GPS unit
(vii) Relascope for broadleaf forest (for upper stem diametres)

6.4 Environmental assessment (EA)

EA of FMUs is undertaken in accordance with the environmental assessment act (2000). The objective for conducting this exercise is to identify actual and potential impacts on the environment as a result of planned forestry operations and accordingly plan to minimize, mitigate or avoid negative, and maximize positive, environmental impacts.

Forestry operations in FMUs will have impacts (both positive and negative) on a wide range of *receptors*. Examples of some of these receptors would include watershed areas (including water quality), precious ecology (including wildlife), employment levels and local economy.

Possible negative impacts might include erosion and siltation resulting from road construction or logging and disturbance of sites of ecological importance, including endangered and protected wildlife species.

Possible positive impacts might include increased opportunities for local employment and improvement of degraded land, protection of wildlife corridors and protection of watershed and smaller catchments.

Therefore, the primary purpose of EA is to ensure that decision-makers are provided with sufficient, unbiased and balanced information about the likely consequences of a proposed project before a decision is taken on whether or not consent should be granted.

EA consists of three major phases:

(i) information collection on the state of the environment prior to the initiation of a proposed project;

(ii) baseline data from the first phase is used together with information about the project's proposed activities, in order to make predictions about the nature and the scale of changes that would be likely to occur in the environment if the project were to go ahead;

(iii) baseline data and predictions are incorporated into an environmental statement (ES). The ES is then submitted to the *competent authority* and taken into account in reaching a decision on whether or not the proposed project should be allowed to go ahead. The environment clearance is granted by the competent authority responsible for granting

environmental clearance for projects. In the case of FMUs in Bhutan, ES is considered to be an integral part of the forest management plan.

6.4.1 The legislative context

The EA act (2000) establishes procedures for the assessment of the potential effects on the environment of strategic plans, policies, programmes and projects, and for the determination of policies and measures to reduce potential adverse effects and promote environmental benefits.

The direct implication for forest management is that for all forest operations an environmental assessment must be undertaken and environmental clearance granted. The process of preparing a forest management plan includes undertaking an environmental assessment in accordance with the requirements of EA act (2000).

The regulation for environmental clearance of projects (2002) defines responsibilities and procedures for the implementation of the EA act (2000) concerning the issuance and enforcement of environmental clearances for projects. The act refers to the role of the competent authority, which means any agency of the Royal Government that has the power to issue development consent for a project. The regulation states that the competent authority is the Department of Forests under the Ministry of Agriculture for surface collection of sand and boulder and all other activities governed by the forest and nature conservation act, 1995, and rules 2000, except sections that require clearance by the National Environment Commission Secretariat (NECS).

Article 16 of the act requires that: *The applicant shall ensure that concerned people*[6] *and organizations are informed and consulted before submission of the EA documents to the competent authority.*

6.4.2 Environmental sectoral guidelines

Sectoral guidelines have been developed to assist staff at the National Environment Commission, line managers and project proponents in order to incorporate environmental protection parameters into the project cycle, particularly at the early planning stage (NEC, 1999). According to the sectoral guidelines, a key objective in the environmental assessment process is to ensure that projects are dealt with in the simplest manner possible, consistent with anticipated impacts. This is achieved by predicting potentially important impacts and in the selection of an appropriate review procedure. However, the sectoral guidelines have been superseded to some extent by act and regulation (NEC, 2002).

6.4.3 The environmental assessment process for FMUs

EA is a multidisciplinary process; this means that it involves a team-based approach with a range of experts and stakeholders following a sequence of steps or stages. Within the context of FMUs, the EA process is complementary to the overall forest management planning process, whereby the environmental statement section of the forest management plan will outline the likely environmental impacts and the corresponding mitigating measures that the plan should encompass.

The institutional mechanism and the flow of information regarding the process for obtaining environmental clearance for the FMUs from NEC are briefly explained below. FRDD, through the Head of the Department of Forests, submits the proposed management plan to NEC and,

[6] Concerned people mean individuals, groups and communities whose interests may be affected by a project. In the case of FMU planning, the fora for consultation are the FMU level and/or divisional-level Forest Management Committees.

upon receipt, NEC reviews the environmental statement contained in the plan and accordingly makes the following decisions for granting/rejecting environmental clearance.

Decision A: *Environmental clearance granted*
Decision B: *Further study required: Forest management plan returned to the Head, Department of Forests, for further information/clarification/assessment*
Decision C: *Environmental clearance not granted based on justifications provided by NEC.*

A summary of the environment assessment process followed in Bhutan is given in tabular form below. Table 11 explains the activities undertaken and the outcome of these activities.

Table 11: Summary of environmental assessment process

Activities/step	Objective	Outcome
1. Description of project	To provide detailed information on proposed activities	Detailed description of proposed activities
2. Description of baseline environment	To provide detailed description of baseline environment	Detailed description of baseline environment
3. Prediction of impacts	To identify and estimate changes in the environment	Statement of predicted impacts.
4. Evaluation of significant impacts	To determine magnitude and significance of impacts	Statement of significant impacts with reference to thresholds of concern
5. Identification of mitigating measures	To identify mitigating measures for all adverse effects (and to define responsibilities for their implementation)	Statement of mitigating measures
6. Presentation of findings in ES	To clearly state methodology, data, results of assessments and assumptions	Comprehensive, accurate & well structured statement to inform competent authority (including non-technical summary)
7. ES considered by competent authority	To achieve environmental clearance	Environmental clearance granted
8. Monitoring and auditing	To improve understanding of environmental impact To compare predicted impacts with those that actually occur	Information on the accuracy of predictions and effectiveness of mitigating measures

***Source**: RGOB, 2004*

6.5 Socio-economic assessment

The management planner carries out the socio-economic survey using rapid rural appraisal (RRA) and participatory rural appraisal (PRA) tools.

A household survey is conducted with the help of structured or semi-structured questionnaires. Attempts are also made to visit all the households within the FMU; if this is not possible, sample households are visited. An interview is requested of the head of the family or other member available. Normally the interviews are carried out face to face in the house or sometimes with one or several household members. The answers and the feelings of the respondents are duly recorded. Later, in order to cross-check the data, some key informants are also interviewed and the data verified accordingly. Additionally, if required, the planner makes further field trips to the FMU to fill in gaps in the data that are overlooked during the earlier visits. For the purpose of management planning, the inquiry focuses particularly on the following topics:

- Socio-demographic setting *(information on population).*
- Economic condition of the people living in the FMU *(information on land holdings).*
- Economic activities *[information on (a) agriculture; (b) livestock (domestic animals, their numbers, types etc.]; (c) contract works.*
- Grazing issue *(grazing pattern, seasons etc.).*
- Impacts and effectiveness of opening FMU with special reference to the following: *(a) on forest resources; (b) on wildlife; (c) on community; (d) on water resources; (e) on cultural resources.*
- Attitude of the people towards forest resources management.
- Forest resources utilization.
- Availability of forest resources, (a) wood resources; (b) non-wood resources.

Further to the above-mentioned information, general data that are required are reviewed and compiled from past records in consultation with the Forest Range Officers from both the Department of Forests and FDCL who are in charge of the FMU. The office of the DFO is also consulted on various issues that are found doubtful. Clarification on data found doubtful is done in consultation with available renewable natural resources (RNR) census records from the Land Use and Statistical Section (LUSS) of the Ministry of Agriculture and relevant sections of the concerned *Dzongkhag* Administration.

6.5.1 Participation of local communities in the planning process

As mentioned above, a socio-economic survey is required in order to collate socio-economic information about the communities that live in and adjacent to an existing or proposed FMU. It provides useful information on local populations and their forest product requirements. Much of this information is already available or can be collected by the planner from secondary sources, e.g. at the *Dzongkhag* or *Geog*. It is essential that local people be actively involved in the planning process.

The specific objectives of the socio-economic survey are to:

(i) prepare a socio-economic overview of villages/communities;

(ii) raise awareness of the FMU; to ascertain what is already known and perceived and what information is needed and to inform communities at an early stage about the FMU planning process;

(iii) prepare a complete overview of local use of the forests (including holy sites, *tsamdo* and *sokshing*);

(iv) identify possible ways in which the community can benefit from the FMU;

(v) minimize any negative impacts that might result from the establishment or continued management of an FMU and to pre-empt and avert future conflicts.

From the above-mentioned objectives/exercise the following output is produced:

(i) communities are informed about the FMU and their involvement in planning;

(ii) a socio-economic survey report containing socio-economic information on stakeholders is produced (especially local stakeholders). Information obtained is used for stakeholder analysis.

The report is normally included or summarized in the forest management plan; it also includes a participatory resource use map[7].
The socio-economic survey also contributes to the forest function map by delineating the local/social uses of the forests; therefore, such a survey is conducted at the same time as forest function mapping.

The socio-economic survey group is led by a forest management planner from FRDD, in close collaboration with territorial and *Dzongkhag* staff.

6.5.2 Methodology

The procedure given below is indicative only; therefore, the management planners are advised to select carefully and refine the appropriate methods to suit the particular needs of the FMU. Socio-economic surveys for second and subsequent plans are, of course, based on data collected and analyzed during previous planning periods.

The first step in the socio-economic survey is to prepare terms of reference (ToR) for the team. However, a combination of methods may then be used in order to address the issues and objectives presented in the ToR. The methodology followed is summarized in Table 12.

Table 12: Detailed activities followed for socio-economic survey.

Activity	Purpose/objectives	Output
Develop ToR	To define the scope of the survey, identify key tasks and work plan	Agreed ToR
Coordination with *Dzongkhag* & *Geog*	To ensure cooperation from local and government stakeholders To source official data from RNR staff	Endorsed by *Dzongkhag* & *Geog* staff. Data made available.
Community meeting	To introduce concept of FMU and planning, to inform villagers of work plan and elicit initial views on FMU	Minutes of meeting
Timeline map	To track the history and development of the community/village	Community timeline diagram
Social mapping	To gain insight into institutions and strengths of community organization in order to assess organizational capacity	Social map (GPS is used for recording the data for mapping)
Participatory resource use mapping	To involve local people in the planning process To map village and forest resources	Participatory resource map
Forest utilization calendar	To identify use of forest resources throughout the year	Forest utilization calendar
Household interviews	To collect socio-economic information and gain further insight into interests and perceptions	Detailed information for socio-economic survey report

***Source**: RGOB, 2004*

6.5.3 Stakeholder analysis

The objectives of conducting stakeholder analysis is to determine which stakeholders need to be involved in the planning process and decide how their interests can best be represented. Stakeholder analysis in FMU planning is carried out with the following objectives:

(i) to find out which groups of people need to participate in planning, implementing and monitoring FMU management activities;

(ii) to work out how different stakeholder groups can best be involved in the planning processes for forest management plan preparation and in the implementation of different activities;

[7] Nowadays these maps are produced using the GIS facility. GPS is also used in the field.

(iii) to identify the interests of different stakeholder groups, to see how they will be affected by the planned activities, and to see whether any changes in plans may be required to accommodate this;

(iv) to optimize the benefits of the FMU and to effectively integrate these benefits into management planning.

The processes of stakeholder analysis, stakeholder meetings and establishment of an FMU-level Forest Management Committee are essential components of the management planning process. Effective stakeholder participation is vital to the effectiveness of plan preparation and implementation.

Before carrying out these planning steps careful consideration is given to the capacity requirements and any gaps identified. Very often training is required or specific expertise may need to be brought in.

The timing for undertaking the activities is very important. Generally, stakeholder analysis and meetings are undertaken as an integral part of two major planning steps: (i) During the forest function mapping, stakeholder analysis and stakeholder meetings are used as part of participatory resource assessment (PRA) in order to determine social functions. (ii) During the environmental assessment process, stakeholder analysis and meetings are also undertaken. GPS is used to locate and map out all important installations that are present in the villages within the FMUs. Farm roads, bridges, etc. are also mapped. The data are later fed into the computer and with the help of GIS social maps are produced.

6.6 Road construction

The management plan will have already prescribed, and indicated on maps, the road network and the length that needs to be constructed for the effective implementation of the plan. The road network indicated on the resource map is the result of extensive field works, working with a land use type map and also using GPS to record the coordinates that the GIS uses to plot on the maps.

The operational plan spells out the schedule of the road construction activities in detail. It will specify the length required, time frame of its construction period and budget estimates for the road.

The engineering section of FDCL carries out planning, survey and alignment, designing and cost estimation for the road. The survey and alignment are carried out based on the land use type map provided with the management plan.

FDCL, using private contractors, executes the actual road construction. The construction work is tendered out to the successful bidder. A contract document is signed between FDCL and the contractor, who works within the terms and conditions of the contract. Overall supervision of the road construction is done by the local DFO as well as the FDCL engineer.

FDCL supervises the construction works to ensure that the quality and specifications of the road are maintained and environmental damage during construction is minimized.

With the emphasis on environmental friendly road construction, more and more importance is given to the use of construction equipment that reduces/minimizes environmental damage. There is a shift in road construction, i.e. from conventional use of bulldozer to a combination of using excavator and bulldozer. As far as possible, a half-cut and half-fill method is being

followed. The excavated material is transported and dumped at a pre-identified safe dumping site. The slopes are being treated with fast growing species of grasses and trees and other bioengineering methods to stabilize the slopes faster.

All measurements of the earthworks are recorded in the measurement book. The recordings are brought to the office and the volume of the earthwork to be cut or filled is calculated. The compass is used for tracing the direction of the road alignment and the clinometer is used for measuring the gradient. The use of GPS would have been very handy and useful. The data could be recorded direct in GPS and later transferred to the GIS system. FDCL is, however, strongly considering the use of GPS in road alignment in the near future.

6.7 Marking of trees for felling

Using the authorized marking hammer of the Department of Forests, the trees selected for felling are marked close to ground level by FMU staff. The diameter measurement along with the estimated total tree height and tree species is entered in the marking register. The volume of each tree is estimated using an appropriate volume table. The estimated number of logs to be cut is also estimated and recorded in the marking register. Marking of trees for felling will depend on the silvicultural system that is being prescribed for that particular FMU, e.g. (i) single tree selection system; (ii) group selection system, etc.

Electronic equipment for recording the parameters mentioned above is not being used at the moment. All measurement recordings are done in the pre-designed formats, which are later transferred to the computer. Some of the important prescriptions for the single tree selection trees marked for harvesting are evenly distributed throughout the stand;

(i) diseased, malformed, dead and decaying trees are marked on a priority basis, especially where these are hampering better ones;

(ii) trees of exploitable size are marked, particularly if defective or lacking in vigour. Mature and over-mature trees over 50cm dbh. outside bark are also marked;

(iii) no more than one-third of the stand volume is marked for harvesting;

(iv) in mixed stands, an even and suitable distribution of species is left standing;

(v) where cable cranes are used, the extraction lines are to be as narrow as possible and not wider than 4 metres.

Another important silvicultural system prescribed in conifer is the group selection system. This system aims to secure natural regeneration by imitating nature in the creation of small openings in the forest stand, thus allowing light to reach the forest floor and creating favourable microclimatic conditions for seed germination and seedlings establishment. It is important to avoid damage to the remaining stand by selecting only trees that will fall into the opening and ensuring that accurate directional felling is carried out. Some of the salient features observed in marking trees for harvesting in the group selection system are also given below:

(i) the group selection system is used on suitable sites in mixed conifers, spruce, spruce/pine and, to a lesser extent, fir stands;

(ii) small groups, spaced at specified intervals, are harvested removing all trees over 10 cm dbh;

(iii) the groups are located along the extraction lines;

(iv) the distance between the extraction lines to be not less than 60 metres;

(v) the distance between the groups along the extraction line to be not less than 50 metres;

(vi) the shape of the harvested groups can be irregular, according to site and terrain conditions;

(vii) existing openings in the stand having already established regeneration are normally used as a nucleus for marking in the groups;

(viii) signs of existing windfall in the stand form the basis for opening. In such a case, opening boundaries is to correspond to changes in soil moisture that is often the cause of the windfall;

(ix) wind firm trees should surround the selected groups. This could be achieved by leaving intermediate height trees along the edge of the opening;

(x) trees are marked for harvesting along the extraction corridors;

(xi) the extraction corridors should be as narrow as possible, not wider than 4 metres;

(xii) the maximum size of the groups should be, on average, less than 0.1 hectare in the fir stands and less than 0.15 hectares in the mixed conifers, spruce, spruce/pine stands, depending on the site characteristics and stand condition;

(xiii) diseased, dead and malformed trees are to be marked on a priority basis and such areas should to be used as a nucleus for creating an opening;

(xiv) boundaries of openings, where possible, should correspond to changes in slope. An opening should not end in the middle of a steep slope since trees will slide into the remaining stand during logging;

(xv) care to be taken in choosing the boundary of the opening. Trees, which can be expected to fall into the opening, are to be marked while trees leaning out of the proposed opening should be left standing so as to minimize damage to the remaining stand;

(xvi) trees damaged during harvesting are to be cut and removed in the subsequent cleaning operations.

6.8 Survey and installation of cable crane

The cable crane line is surveyed and installed by the staff of FDCL under the direct supervision of the territorial DFO. Equipment like Suunto compass, Suunto clinometer and GPS are used for surveying the profile. The data are plotted in the topographic map and later transferred to GIS for producing maps.

Upon completion of the surveying of the cable crane profile, a winch is driven into the top of the cable crane line. Thereafter, with the help of the winch, the cable lines are installed. This is very specialized work and one engineer from FDCL is made responsible for it.

6.9 Labourers required for the activity

Local people residing within or in the vicinity of FMUs usually participate in various activities that are implemented in the FMU. Activities such as (i) felling of trees; (ii) cross cutting and debarking[8]; (iii) transportation of logs from the felling site to the road head; (iv) further transportation of logs from road head to the depots, etc. are contracted to the local people who execute the work.

Some specialized activity like (i) surveying the cable line profile; (ii) installation of the cable line in the designated area; (iii) buffer zone surveying and mapping, etc. are carried out by FDCL staff.

7. DETAILED DESCRIPTION OF THE OFFICE ACTIVITIES

7.1 Inventory data processing

The data collected in the field are raw data and are processed through a number of steps before they are finally ready as an inventory report which the planner can use in preparing the management plan of that FMU. The compilation and processing are being done using the tailor-made <PLOT> data processing software developed especially for FRDD (Kowalczyk). Various steps involved in computing and analysis using the <PLOT> programme software is briefly described.

7.1.1 Data entry in <PLOT>

The data from the field are entered into the computer using the *input* main menu option of the <PLOT> programme. The data from the tally sheets will end up in the databases PLOT.DBF, TREES.DBF, REGENER.DBF, SITE.DBF and WILDLIFE.DBF. Data from the compass sheets are stored in the databases COMPUNIT.DBF and COMPASS.DBF. For every new inventory <PLOT> will create the necessary database structure in the file \PLOT\SYSTEM\UNIT.DBF. The databases for a particular inventory are kept in a subdirectory of \PLOT\, e.g. in \PLOT\ZONGL\ for the Paro-Zonglela FMU inventory.

<PLOT> checks for common errors during data entry, such as wrong codes, by consulting databases where these codes have been defined (LAND.DBF contains the land use codes and SPECIES.DBF the species codes).

7.1.2 Manual data correction

A lot of simple typing errors, not intercepted by <PLOT> during data entry, are again cross-checked manually for all the sheets against the output lists of all the records. The errors thus found are then corrected using <PLOT>.

7.1.3 Data validation in <PLOT>

Many mistakes of a more difficult nature, such as double records, missing entries, unlikely entries, incompatible discrepancies between databases, etc. can be caught using the validation main menu option in <PLOT>. The programme creates a text file of potential errors, ERRORS.ERR, in the output subdirectory …\RESULTS, which should be consulted. The essential errors are then corrected, while the non-essential mistakes are left out.

[8] Debarking is required in spruce and to some extent in blue pine to prevent attack by bark beetles.

7.1.4 Models to predict tree height, bark thickness and wood increment

The total tree height is measured in the special sample plots only and, for the other plots, tree height is then predicted from tree dbh by using a height-diameter function/model. The objective is to obtain volume estimates for all the plots.

Curves that predict tree height, bark thickness and radial wood increment from tree dbh. are fitted using regression techniques. The calculations are done using specialized statistical software such as MINITAB and SYSTAT. Custom made programmes have been written for MINITAB HGTFUN.MTB, RADFUN.MTB, BRKFUN.MTB) and SYSTAT (HGTFUN.CMD) can partly automate the curve fitting process.

Once the best fits have been selected, they are entered into special databases in <PLOT> called HEIGHFUN.DBF, RADINFUN.DBF and BARKTFUN.DBF, using the *setup-current inventory models* menu option.

7.1.5 Volume functions

Volumes are calculated in <PLOT> using general and local volume equations available for the main tree species defined in the databases COMBIN.DBF and EQUATION.DBF. An appropriate function for each species is used by adjusting the file SPECIES.DBF, using the *setup-volume equations for species* menu option in <PLOT>.

7.1.6 Preliminary stratification and calculations

Based on the earlier preparation for the sampling design and experience acquired during fieldwork, a set of preliminary strata is defined. Each measured sample plot in accessible natural forest is allocated to one of the strata, using the *calculation-stratum definition* menu option of <PLOT>. Stratum areas have to be known and are obtained from the GIS database. The stratification details are saved in the files (i) PLOTS.DBF, (ii) STRATUM.DBF; and (iii) CSTRATA.DBF.

Subsequent definitions required are the various classifications; tree species groups, tree dbh classes, plot elevation classes, plot aspect classes and plot slope classes are saved in the database files, SPECLASS, DBHCLASS, ELECLASS, ASPCLASS and SLOCLASS, respectively.

As the last step of the calculation menu, intermediary calculations are carried out that form the basis for the subsequent output phases.

With all the definitions and intermediary calculations now in place, a first output is produced using the *output-support table* menu option followed by *output-main table* menu option.

These preliminary output steps are repeated several times in order to fine-tune the stratum and class definitions.

7.1.7 Final stratification and calculations

Once the definitions of the strata and other classes are completed, the final calculations of support and main tables are carried out. An inventory profile is created as a PROFIL.TXT text file using the *output-inventory profile* menu option. In this file the main definitions are used; volume functions are recorded for later reference.

7.1.8 Preparation of local volume tables

The general volume functions used for the inventory may be combined with the height-diameter models to give local volume functions for those species for which a height

model is available. These local volume functions will be used mainly for subsequent preparation of operational plans for the FMU.

7.1.9 Inventory report

The outcome of the inventory data analysis is mainly in the form of stand and stock tables (with estimated number of trees, basal area, gross standing volume, volume per hectare and volume increment per hectare and total volume) and local volume tables. These tables together with an explanatory interpretation of the results are then presented in an inventory report. This report forms the basis for subsequent calculations of the annual allowable cut for the FMU in the management plan.

7.2 Mapping

7.2.1 Overview

The responsibility for preparation of various types of map required for forest management planning lies with FRDD. While the concerned management planner is responsible for data collection, data analysis and the final content of the map, the GIS unit of FRDD is responsible for the technical aspects of mapping, which are GIS-based analyses. Data are collected from various sources, e.g. already available topographic information, LUPP data, aerial or satellite photo interpretation and field surveys.

Most thematic maps are derived from the analysis of already existing information. For others, intensive field surveying is required. In general, the management planning officer from FRDD conducts the field survey together with territorial staff of the Divisional Forest Office, the *Dzongkhag* administration and staff of FDCL. All spatial data collected *(map layers)* are entered into the GIS database of FRDD and stored permanently.

7.2.2 Map standards and GIS

In order that maps be comparable and easily understandable, the same standards and legends are used. Therefore, for all maps, the same themes and shape files containing the same attributes and the same legend files are used. All thematic themes are generally stored in the GIS unit of FRDD.

7.2.3 Types of map

In the following table, a brief description of the different types of map and the related mapping procedures is provided. All maps, which are prepared by the GIS unit, include all features that are specified in Table 13. All these features are based on LUPP land use data.

7.2.3.1 GIS base maps

These GIS base maps are working maps, which are required for either the reconnaissance survey or for forest function mapping. Beside the general map attributes, these also contain slope classes and land use types. Land use types are derived from LUPP land use coverage. The boundaries of the land use classes are indicated and the symbols are included on the map. Slope classification is done based on digitized 40 metre contour lines. If no 40 metre contour lines are available, in digital format, then it is based on the Digital Elevation Model (DEM) with 90 metre contour resolution. Steep areas above 35°, however, are identified and polygonized direct on the topographic maps of 1:50,000 scale.

*Table 13: GIS-themes and *.avl files used for general legend (D:\Bhutan\Data\Legend\General)*

Legend name	Description	Graphic attribute to be shown on map	Name of theme (*.shp)	Name of legend (*.avl)
Not to be shown	Map frame	-	Box.shp	Box.avl
Public road	All motorized public roads	-	Public road.shp	Public road.avl
Footpath	All footpathes, mule treks, etc.	-	Footpath.shp	Footpath.avl
Contour lines	Wherever possible 40m contour lines	Altitude	Contour.shp	Contour.avl
Water courses	All streams according to classes	-	Rivers.shp	Rivers.avl
Settlements	All cities, villages, settlements	Name of settlement	Settlement.shp	Settlement.avl
Religious place	All monasteries, Chorten, Goenpas,	Name of place	Religious place.shp	Religious place.avl
Non forest area	All permanent agric. areas, pastures, etc. To be created from LUPP land use coverage.		Non-forest area.shp	Non-forest area. avl
Boundary	Outer boundary of management unit	-	Boundary.shp	Boundary.avl
Dzongkhag boundary		Name of Dzongkhag	Dzongkha.shp	Dzongkhag boundary.avl
Coordinate system	X/Y-coordinate system for reference for field orientation with GPS	X/Y coordinates	Coordinate.shp	coordinate.avl

***Source**: FRDD, 2004*

7.2.3.2 Forest function map

The forest function mapping procedure is described in detail under the section 'forest function mapping' with details provided also in Annex 3. The GIS unit of FRDD is responsible for the technical aspects of map preparation. For each function a separate theme is created. An example of a forest function map[9] is given in map 4.

Function boundaries are digitized/derived from the working map or direct from GPS data. In addition, the GIS unit of FRDD creates standardized buffers along/around objects as indicated on the working map for:

Riparian reserve protection (WRR)
30 metres along alluvial and semi-alluvial rivers
100 metres along non-alluvial rivers and around lakes

Water supply protection (WSP)
10 metres each side of water (irrigation) channels
30 metres along WRR of water body used for local water supply

Road buffer (RB)
According to the guidelines for forest function mapping, the following road buffers are required.
- along motorized public road: 200 metres uphill, 100 metres downhill
- along forest road in unstable terrain: 30 metres uphill, 10 metres downhill

Religious site protection
50 metres radius around the object.

9 This forest function map does not belong to the study area. It is annexed to this report to illustrate the elements of forest function of the FMU.

7.2.3.3 Inventory base map

The inventory base map is the working map for the inventory teams in the field. It contains all information required for field orientation and identification of sample plots.

The forest management inventory is conducted within the production area only. It is, therefore, ideally scheduled after forest function mapping. The protection zone is derived by merging all functions with protective character, i.e. merger of WRR with SP and NWP with the help of GIS. However, if for any reason this cannot be done, then at least all steep areas (i.e. soil protection areas) are identified.

The inventory grid (i.e. the distance between the sample plots) is determined by the officer in charge of forest management planning. Thereafter the grids are generated using Excel Spreadsheet INVENT.XLS in GIS Unit of FRDD.

7.2.3.4 Forest management map

Once the forest function map is developed, the forest management maps are prepared. The following activities are required to be accomplished:

1. Merging different forest functions into management zones.
2. Decision on working circles.
3. Division of the management unit into blocks and compartments.

Merging different forest functions into management zones

For commercial management of the forest it is very important to know the areas that can be managed for commercial purposes and also to identify the areas in which management restrictions need to be observed. For this purpose, various forest functions need to be merged with different zones according to their impact on commercial logging.

Decision on working circles

This work is generally done by the management planners. LUPP land use maps are not very reliable in terms of forest type; therefore, the land use cover is derived from aerial photo interpretation. If aerial photos are not available, then LUPP maps can be verified by comparing them with PIS maps, which have been prepared using aerial photos taken in the 1950s, but which are more accurate in terms of forest type.

Nevertheless, whether forest types are identified on aerial photos, satellite imageries or derived from LUPP map information, field checking is indispensable. This field checking is linked with field checking for forest function mapping and is done by the forest management planner. Based on the distribution of forest types the management planner finally decides on the working circle, which is identified on the GIS base map. The GIS unit transfers the boundary from this sketch map to a digital theme.

Division of the FMUs into blocks, compartments and sub-compartments

The division of an FMU into blocks and compartments is the task of the management planner. The sub-division into sub-compartments or even stands is done during operational planning. However, if stands and sub-compartments are already identified during the previous planning periods, their boundaries are shown on the map.

7.2.4 Annual allowable cut calculation (calculation of volume to be removed)

A prerequisite of sustainable forest management is that the removal of forest products not exceed the rate of replacement. Without this basic balance, provided by yield regulation,

sustainable forest management is impossible and the forest resources will gradually be depleted.

Yield regulation, irrespective of the silvicultural system being applied, provides a basis for deriving timber harvest which is in balance with forest increment and for controlling the output to ensure that the cut is neither exceeded nor undercut. Therefore, regulation of yield is of great importance to the forest manager who needs to have predictable production levels each year.

It must be clearly understood that the AAC calculated is the total maximum sustainable harvestable timber supply for each year of the plan period. Once the AAC has been calculated it is allocated to the various users, primarily FDCL and local rural users. Other users can be identified and allocations made accordingly; for example, allocation of a proportion of the AAC for *Dzong* and monastery restoration, etc.

AAC calculations are based on the best possible understanding of the forest resource at the time of plan preparation. However, it is essential that the AAC calculated be reviewed during the plan period and any necessary revisions incorporated into the revised forest management and related operational plans. The basic principle of yield regulation is to prescribe a cut that guides the existing growing stock closer to that state which best satisfies the objectives of management.

The regulation of yield requires, firstly, a calculation of what the amount of the yield should be, secondly, an apportionment of the yield to thinnings and final fellings and, thirdly, construction of a cutting plan that determines the identity, as well as the timing, of stands to be felled or thinned.

The forest management plan does not rigidly prescribe the years in which particular stands will be felled but will state the sustained yield by working circle within the operable area of the FMU and define the principles that the forest manager (DFO/Unit Officer-in-charge) should observe in selecting annual coupes. The operational plan clearly identifies the areas to be harvested on an annual basis. It is essential that there be control or annual comparison of what has been prescribed and what is actually done, supported by an explanation of the differences. Unless there is such control, undesirable differences between planning and implementation are liable to occur and multiply.

Yield regulation for the harvesting of timber is often defined by AAC. The procedure presented in this section is designed to guide the forest management planner through the process of working out the AAC for an FMU. The forest management planner, however, is required to exercise professional expertise and judgement in deciding on the appropriate method to use. The AAC is the volume (or area) of timber that is available divided by the number of years required until the next harvest. The production area is divided into annual coupes for harvesting; in theory, by the time the last block has been cut, the first block should be ready to harvest again.

There are many methods of yield calculation, which may be classified by the variables used:

1. A combination of area and rotation (felling cycle).
2. A combination of area, volume and rotation (felling cycle).
3. A combination of volume and forest increment.
4. A consideration of volume only.

Table 14 presents a range of approaches to AAC calculation that has been used in FMUs in Bhutan and briefly presents the advantages and disadvantages of each. This table is not exhaustive but is designed to illustrate to the forest management planner the range of options that need to be considered.

Each of these methods provides only general guidelines for deriving an AAC. The forest management planners are advised to consider the choice of method on a site specific and case by case basis. There is also a possibility of calculating the AAC by a number of methods and then to make comparison of the result and select the most reliable result. The basis and the methods used for calculation are given in tabular form below. The advantages of using each one of these methods are also indicated.

Table 14: Basis and the formulae used for calculating AAC

Basis	Method	Formulae	Advantages
Combination of area and rotation	Annual coupe by gross area	Annual coupe = net operable area/rotation	Easy and rapid to apply. Less inventory data required than for volume-based method. Works well for evenly stocked areas.
Volume only (growing stock volume)	Von Mantel's formula	AAC = 2xGSa/R	Simple. Requires only actual volume of GS and rotation. Does not require increment data. Regulates yield according to actual growing stock. Useful preliminary step in yield regulation.
Combination of area, volume and rotation	As recommended by Whitfield (2001)	AAC per working circle = (Net operable area/R) x mature vol./Ha	Simple, easily understood & robust formula.

***Source**: RGOB, 2004*

8. POST HARVEST OPERATIONS

8.1 Sanitation works

It is very essential that sanitation work be carried out in the operated areas/coupes. All the unutilized debris and slash (branches), barks after debarking, etc. are piled up and burnt. Such practice has invited some criticism from some schools of thought, as the debris should be left to rot in the forests, but past experience has shown that debris on a large scale has resulted in harbouring pests and diseases. The spruce forests in Bhutan experienced a serious bark beetle epidemic (*Ips schmutzenhoferii*) during the 1980s. Although the epidemic has been successfully controlled, sporadic occurrences still exist.

To ensure that the harvesting operation is carried out as per the management plan, the DFO makes use of control forms, as prescribed in the management plan. The control form for post-harvest operations has two columns indicating (i) type of operation prescribed; and (ii) operation executed for a coupe. The other form is the coupe inspection report which gives details such as trees felled, logs, lops and tops extracted or not, felling outside the coupe, width of the corridor, etc.

Once the coupe inspection report is submitted to the DFO, he inspects the coupe to see that all the harvesting operations and sanitation works have been carried out satisfactorily. A coupe clearance certificate is then issued stating that the said contractor has satisfactorily completed the harvesting works assigned and can proceed to another coupe for harvesting operations.

All data are collected in pre-designed forms. FRDD has not used any electronic equipment for recording the data from the sanitation operation. In future, there is an opportunity to use electronic devices for collecting the data direct and feeding it into the computer.

8.2 Planting

Planting involves high cost and so must be restricted to areas where natural regeneration is considered unsatisfactory or to have failed. It should be carried out as soon as harvesting and extraction are over and the area is cleaned up. Supervision of planting is very crucial to ensure and guarantee the highest survival rate with the right choice of species. All planting activities are carried out according to the standards and norms prepared by the Department of Forests.

8.2.1 Post-planting treatment

There are two very important activities involved after planting. They are (a) beating up (replacement planting) and (b) weeding and climber cutting.

(a) **Beating up:** A survival survey in the planted areas is carried out after two years of planting to determine the survival rate. If the survival rate is below 75 percent, a beating up is carried out.

(b) **Weeding and climber cutting:** Weeding, climber cutting and removal of dense bushes and other vegetative cover that could hinder seedling establishment and growth are carried out during the first three years of planting.

8.2.2 Survival counting

After planting there will be dead, suppressed or damaged seedlings, which need to be replaced (vacancy planting/beating up). A random sampling at an intensity of 5 – 10 percent is normally taken up. Therefore, survival counting serves the following purposes:

- To measure the success of establishment.
- To find failed areas.
- To give information for deciding what to do next.

The counting is carried out in two stages:

- First count done at the time of first weeding (4-6 weeks after planting).
- Second count two months prior to next monsoon to confirm final survival percentage and determine what action needs to be taken next.

The methods of survival counting and recording the data are normally annexed in the management plan of an FMU. All these data are recorded in the pre-designed formats and brought to the office where they are entered into the computer. At the moment, no electronic equipment is used for collecting such data.

8.3 Regeneration surveys

A regeneration survey is carried out to determine the extent of natural regeneration in the harvested areas. It is carried out in the fifth year after the completion of harvesting in the annual coupe.

The inventory guidelines developed by FRDD specify regeneration survey criteria that for a plant to be considered a seedling it has to be a minimum of 1.3 metres high and a maximum dbh of less than 10 cm. Recording everything above 1.3 metres but below the 10 cm dbh threshold for volume calculation is thought to be a rational approach. The crews are currently not recording the thicket stage material over 1.3 metres and under 10 cm dbh at all, which is a shortcoming.

Recordings of regeneration survey data are done in pre-designed formats. These readings are brought to the office and the data are analyzed. As mentioned above, no electronic devices are currently used to collect data for regeneration surveys.

8.4 Monitoring and evaluation

Monitoring is the examination of whether project inputs activities and outputs are successfully supplied according to the planned schedule. In the context of FMU implementation, *'inputs'* include machinery availability and staff skills availability while *'outputs'* include operational plan completion, road construction, production of forest produce, etc. Monitoring is a short-term exercise.

Discrepancies between expected and actual results detected by monitoring can usually be corrected by straightforward management decisions taken by staff responsible for implementation.

Electronic equipment or any kind of software is not used at the moment. All data pertaining to monitoring are collected in pre-designed formats and are later entered into the computer for analysis.

Evaluation is the examination of whether project objectives are being achieved. This requires enough time to provide a realistic assessment of progress in fulfilling objectives. Evaluation is a long-term exercise. Corrective action, if it is necessary, may require changes to a range of project inputs or to a project methodology. The evaluation is carried out by the staff that is independent of implementation activities.

FMU monitoring and evaluation standards have been developed by FRDD of the Department of Forests in close collaboration with the third forestry development project[10] (TFDP) in 1999. The monitoring process is based on selecting and modifying the Montreal Process indicators for use in FMUs in Bhutan. The indicators decided were divided into **three groups**:

(i) indicators for which information must be collected **every year** (nine indicators);

(ii) indicators involving information that changes relatively slowly. These indicators are to be assessed every **five years** and compared against the initial FMU plan (eight indicators);

(iii) indicators that are evaluated only **once or rarely** (nine indicators). These indicators are about policy, institutions, regulations, guidelines and other similar matters.

Different forms are developed for each of these time scales. Monitoring **Form A** for the annual monitoring process. Evaluation **Form A** for the five-year evaluation and evaluation **Form B**

[10] World Bank-aided project

for the once only evaluation. Forms are also developed for field collection of environmental information for the monitoring and evaluation process.

Some indicators are used for both annual monitoring and five-year evaluation (e.g. forest production) while some data are collected annually and only evaluated at five-year intervals (e.g. fauna diversity). The forms list the indicators, the standards that are accepted as satisfactory and the calculations that are necessary to assess the standard and update the progress score. The indicators have been numbered sequentially but a cross reference to the number of the Montreal Process indicator from the (Bhutan) indicator has been derived.

8.4.1 Procedure for FMU monitoring and the formats used

Computerized/electronic equipment has not been used for data collection during the course of monitoring. All the data are collected using the forms (indicated in the following sections) and the data are later entered into the computer for analysis and feedback. The procedure for monitoring the FMUs and the format used for data collection are explained in the following sections, step by step:

Step 1: **FMU officer-in-charge and staff to fill in the field data collection form (every year)**

Physical and financial monitoring forms 1 to 3 (to be completed annually in July).

Forms 4 to 8: to be completed before the end of March every year. Five separate forms, numbered four to eight, are listed:

FORM 4: Road drainage by culverts
FORM 5: Road drainage by side drains
FORM 6: Stream crossings
FORM 7: Cable lines
FORM 8: Interline spaces

Forms 9 and 10: Plant and animal monitoring (to be completed in April and October every year). These forms are:

FORM 9: Monitoring of animal indicator species and
FORM 10: Monitoring of plant indicator species and regeneration

Short-term monitoring of the effectiveness of community participation in forest management and the meeting of community needs from the forest are monitored on a continuing basis by the FMU staff. **Form 3** of the physical and financial monitoring forms includes a section for social issues where specific mention is made of meetings relating to FMU steering committees, with space provided for other issues. In addition, the FMU Officer-in-charge is required to maintain a '**Participatory forest management diary'** that records day-to-day discussions or comments obtained through talking with members of local communities. These records and observations are summarized annually on **Form 3.**

Step 2: Self monitoring by FMU Officer-in-charge and his staff

During the process of collecting field data, the FMU Officer-in-charge may become aware of deficiencies in field activities, e.g. roads needing maintenance or marked trees left in the forest, etc. **After** entering the information on the data collection form, and provided it is within the FMU Officer-in-charge responsibility to do so, the deficiencies are corrected.

Step 3: FMU officer-in-charge fills in physical, financial and environmental summary form (every year)

This summarizes the information on **Forms 1** to **10** necessary for Monitoring **Form A**. The summary form is then sent to the DFO.

Step 4: DFO fills in Monitoring Form A (every year)

Monitoring of FMU operations is carried out each year by the DFO responsible for the FMU, using the information that is collected annually and supplied to him by the FMU officer-in-charge on the physical, financial and environmental summary form. The purpose is to decide whether corrective action is needed to keep forest management activities on the schedule specified in the management and operations plans. The DFO is responsible for this action if it is necessary. Monitoring Form A is used to carry out this process.

Step 5: FO directs the follow-up and corrective action, as necessary

- Monitoring **Form A** includes a column in which corrective action for deficiency in each indicator may be noted.
- DFO is responsible for nominating and carrying out any necessary corrective action that is outside the responsibility of the FMU Officer-in-charge.
- Copies of the completed forms are forwarded to FRDD and the NEC Secretariat for information.

At the moment, all this information is collected in pre-designed forms. FRDD is exploring the possibility of using electronic devices for collecting this information from the field direct without having to first collect it in the forms and then enter it into the computer.

9. COST INDICATION OF SOME IMPORTANT FORESTRY ACTIVITIES IN FMUs

1. Plantation cost per hectare	Nu. 21,000.00 per hectare
2. Felling and cross cutting per ft^3	Nu. 1.50 per ft^3
3. Transportation cost per ft^3	Nu. 7.00 per ft^3 (within a radius of 14 km)
4. Debarking cost	Nu. 1.75 per ft^3.
5. Road construction per km	Nu. 1,050,000.00 per km

10. CONCLUSION AND RECOMMENDATIONS

Management of forests started in Bhutan only in the early 1960s when the first management plan was prepared and approved. The main focus then was on extraction of large volumes of timber for earning revenue for the country. The management plans were prepared based on simple information obtained from the inventory of the forest, which was considered a potential timber production area. Harvesting of timber was done based on coupes systems that were auctioned to private bidders. Private bidders did not have any interest in improving the forest because their main focus was on maximizing the extraction of timber from the coupe(s) allotted to them. The silvicultural system followed then was to clear-cut the forest and artificially plant the felled area.

Later, forestry operations became more complex, and also the economic value of timber increased, when there was a requirement to practise more scientific forestry. It was then felt necessary to have some form of legal framework to control and protect the forest resources. This led to the enactment of the Forest Act in 1969 by the National Assembly followed by the passing of the National Forest Policy in 1974.

The procedure adopted for management planning was very simple. The plans were based purely on broad assessment of the growing stock in the locality. Environmental and social considerations were not taken into account while preparing the plans. Forest function mapping was not done and, as such, forest zoning based on functions was also not considered. Mapping technology using electronic means was also not possible. The compartments were mapped using very rudimentary manual methods, which was time-consuming and not very reliable.

Beginning in the early 1990s, it was felt important that forest management have broad objectives encompassing the principle of multiple use sustainable forest management. Based on these requirements, a lot of workshops and seminars were held to develop the structure of the forest management plans and various guidelines. This led to the development of guidelines for (i) the development of the <PLOT> programme for analyzing the inventory data; (ii) development of guidelines for forest function mapping; (iii) environmental impact assessment; and (iv) socio-economic assessment. Computers were being used for drafting management plans as well as inventory data analysis.

More recently GPS is being used for inventory works especially in locating the sample plots and guiding the inventory crew in navigating the plots. GIS has added greater dimension in accomplishing the following works pertaining to management planning, e.g. (i) preparation of forest function map; (ii) inventory plots location map; (iii) location map of the FMU; (iv) forest type map; (v) forest management map, etc. It is also felt that there is a slight weakness in the processing of socio-economic data. Therefore, FRDD is exploring the use of appropriate software for processing such data.

Based on the above-mentioned concluding remarks, the following recommendations are made for future management planning, including the types of data to be collected:

1. The usefulness of palmtop computers and data loggers (e.g. Husky Hunter) to replace the pre-recorded formats should be implemented as soon as possible so that the data could be entered direct and recorded in the palmtops in the field. This would help minimize the errors that are being created while entering the data into the computer from the forms.

2. The use of GPS should be encouraged at all levels of inventory, e.g. (i) national forest inventory; (ii) management inventory for the FMUs; and (iii) operational inventory.

3. The <PLOT> programme currently used for inventory data analysis is too bulky a programme. More user-friendly software needs to be either developed locally or purchased from the market.

4. All staff of the Department of Forests needs to be trained in the use of GPS, relascope, compass and clinometers.

5. The staff working in the GIS Unit of FRDD should be given additional advance training in GIS so that they are well versed in the use of software.

6. Recruiting an adequate number of trained manpower has always been a constraint; therefore, the Department should study the possibility of outsourcing the writing of the management plan.

7. Human resources development and management should be carefully planned and implemented to carry on smoothly with the ongoing works.

11. REFERENCES

1. FRDD. 2005. Guidelines on monitoring and evaluation system for forest management units, Forest Resources Development Division, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan..
2. FRDD. 2002. Forest management plan of Paro-Zonglela Forest Management Unit, Forest Resources Development Division, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.
3. Kowalczyk, S. (No date). Forest inventory data processing (User's Manual for <PLOT> System), FAO/BHU/91/002, Forest Management and Institutional Development Project, Thimphu, Bhutan.
4. Laumans, Paul. 1994. Guidelines for forest management inventory fieldwork, UNDP/FAO Forest Resources Management and Institutional Development Project, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.
5. NEC. 2002. Regulation for environmental clearance of projects and regulation on strategic environmental assessment, National Environment Commission, Royal Government of Bhutan.
6. NEC. 1999. Forestry: Bhutanese environmental assessment – sectoral guidelines, National Environment Commission, Royal Government of Bhutan.
7. RGOB. 2004. Forest management code of Bhutan, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.
8. RGOB (2000) Forest and nature conservation rules of Bhutan 2000, Ministry of Agriculture, Royal Government of Bhutan.
9. RGOB. 1996. Eighth five year plan document [1997 – 2002] Volume I Main Document, Ministry of Planning, Royal Government of Bhutan.
10. RGOB. 1995a. Land cover figures for Bhutan (national figures) Land Use Planning Project, Ministry of Agriculture, Royal Government of Bhutan.
11. RGOB. 1995b. Forest and nature conservation act of Bhutan-1995, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.
12. RGOB. 1991. Master plan for forestry development (main report), Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.
13. RGOB. 1991. National forest policy 1991 (draft) Department of Forestry Services, Ministry of Agriculture, Royal Government of Bhutan.
14. Schindele, W and Dhital, D.B. 1997. Guidelines for preparation of forest function map and definition of management prescriptions/restrictions, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan.

Annex 1(a)

STANDARD STRUCTURE OF FOREST MANAGEMENT PLAN

Title and approval sheet
Executive summary
Location map
Résumé (1 page form)
- Name/location
- Author/date
- Period
- Topo sheet

Table of Contents

PART ONE -- CURRENT SITUATION

1. Location area and status

- Location
- Area
- Legal status
- Ownership
- Rights and privileges
- Grazing
- Water rights
- Monuments

2. Historical background

3. Physical features

- Topography
- Geology – mineral resources
- Soils
- Hydrology

4. Climate

- Meteorological data
- Temperature
- Precipitation
- Humidity

5. Socio-economics

- Population
- Forest-based industries
- Forestry Products: demand and supply

6. Organization and administration

- Staff
- Labour

7. Infrastructure

- Roads
- Buildings
- Nursery

8. Transport and equipment

- Cable cranes
- Trucks
- Skidders, etc

9. Research

- Activities (trial plots, etc)

10. Socio-environmental issues

- Grazing
- Mining
- Shifting cultivation
- Forest fires, etc.

11. Historical background

- Past management

12. Forest Resources Assessment

- Land use
- Vegetation
- Forest types
- Inventory
- Growing stock
- Annual increment

13. Other forest resources

- Wildlife
- Non-wood forest resources (mushrooms, medicinal plants, grass, water)

PART TWO - FUTURE MANAGEMENT

14. Introduction

- Policy perspective

15. Goals and objectives

16. Management strategy

17. Organization of the FMU

- Geographical situation (blocks, compartments etc)
- Administrative organization (Division, Beat, Forest Unit)

18. Management priority

- Production forest
- Silvicultural management system
- Community forest
- Social forestry
- Protection forest
- Watershed management
- Nature conservation
- Wildlife
- Livestock grazing
- Protection, rights, etc.
- Consultation with local people

19. Management of production forests

20. Yield regulation

- Determination of AAC
- Rotation
- Yield by species
- Working groups/cutting cycles, etc.

21. AAC – Distribution of cut and allocation of yield

22. Silviculture

Basic: systems, afforestation, site preparation, seed collection, nurseries, planting, fencing, regeneration survey

- Intensive: tending, replanting

23. Harvesting

- Annual coupes
- Sequence of operations relating to annual coupes
- Harvesting systems
- Tree marking rules
- Equipment requirement
- Post-harvesting conditions and treatment

24. Infrastructure

- Road construction and road maintenance
- Building construction and maintenance
- Engineering development (equipment, transport)

25. Social forestry

26. Environmental management and protection

- Fire
- Pest/disease
- Soil conservation – erosion
- Watershed
- Flora and fauna, aesthetic

27. Grazing

28. Forest research

29. Staff and labour

30. Financial aspects

31. Implementation and control

- Implementation of plan
- Responsibility

32. Operational planning

33. Compartment description and prescriptions

Annex 1(b)

STRUCTURE OF OPERATIONAL PLAN

1. **Title and approval sheet**
2. **Introduction**
3. **Period 1-2 years**
4. **Silviculture**
   - Tending of the silvicultural plan
   - Regeneration survey
5. **Production and utilization**
   - Utilisation plan
   - Area, species and quantity
   - Assortments
   - Annual cut
6. **Protection**
   - Fire protection
   - Sanitation work
7. **Social and environmental issues**
   - Social
   - Environmental issue
8. **Research**
9. **Infrastructure**
   - Road construction
   - Quantity, standards
   - Building
10. **Equipment**
    - Machine requirement
11. **Manpower**
    - Manpower requirement
    - Duty sheet of staff
    - Work time schedule
12. **Finance**
    - Budgeting
13. **Maps**

Annex 2

EXAMPLES OF CONTROL FORMS

CONTROL FORM NO. 1

MARKING CONTROL FOR LOCAL USES, GOVT. DEPT./ORGANIZATION

MANAGEMENT UNIT..……..WORKING CIRCLE…….BLOCK…..…..

USER……COMPARTMENT…….....SUB-COMPARTMENT…...….YEAR…….....

Sl. No.	Name of species	*Type of material	dbh in cm	Approx. height (m)	Volume (m^3)	Remarks

*** Type of materials: a) Tree, b) Cham, c) Chim, d) Shingles, e) Dangchung, f) Post/poles, G) firewood.**

CONTROL FORM NO. 2

MARKING CONTROL FOR FIREWOOD SUPPLIED BY CONTRACTOR

MANAGEMENT UNIT..…….WORKING CIRCLE…….BLOCK…..…..

COUPE……..…COMPARTMENT……..SUB-COMPARTMENT…....….YEAR…….....

Species	No. of stem marked	Volume (m^3)	Remarks

CONTROL FORM NO. 3

ALLOWABLE CUT CONTROL FOR COMMERCIAL/URBAN USE

MANAGEMENT UNIT..…….WORKING CIRCLE…….BLOCK…..……..

YEAR ……..COMPARTMENT…....….SUB-COMPARTMENT……..….COUPE ……...

Area (ha)	Estimated total volume (m^3)	Total volume marked (m^3)	Remarks

CONTROL FORM NO. 4

RECORD OF PLANTATION

MANAGEMENT UNIT……..….WORKING CIRCLE……...BLOCK…….…..

YEAR….……COMPARTMENT…..…..……..SUB-COMPARTMENT……....…….…...

Species	Area (ha)	Cost/ha	Remarks

CONTROL FORM NO. 5

POST HARVEST OPERATION

MANAGEMENT UNIT..……...WORKING CIRCLE…….BLOCK….…..…..

COUPE……..…COMPARTMENT…....…….SUB-COMPARTMENT…...……YEAR….…...

1. Type of operation prescribed

(a) …….

(b) …….

(c) …….

2. Operation executed

(a) …….

(b) …….

(c) …….

CONTROL FORM NO. 6

COUPE INSPECTION REPORT

MANAGEMENT UNIT..…….WORKING CIRCLE…….BLOCK…..…..……

COUPE…..……COMPARTMENT…....….SUB-COMPARTMENT…...….YEAR….……

Particulars	Measurements	Species	No.	Volume (m^3)	Remarks
Marked trees not felled					
Felled trees/logs not extracted					
Lops and tops not extracted					
High stumps					
Felling outside coupe					
Avoidable damages					
Width of the corridor					
Any other deviations of the plan					

CONTROL FORM NO. 7

SUMMARY STATEMENT OF AAC CONTROL
AAC (m^3)

Year	Local use (m^3)		Fire wood (m^3)		Commercial/ Urban		Grand Total		Cumulative Total	
	Vol. Form 1 (m^3)	Total Vol. (m^3)	Vol. Form 2 (m^3)	Total Vol. (m^3)	Vol. Form 3 (m^3)	Total Vol. (m^3)	Area (ha)	Vol (m^3)	Excess	Deficit
									Area	**Vol. (m^3)**

Annex 3

PREPARATION OF THE FOREST FUNCTION MAP

Step 1: Preparation of GIS base map

The GIS section of FRDD prepares a GIS base map, which is used as a working map for the identification of forest functions. This map includes the following information:

(i) Contour lines (40 metres or less)
(ii) Slope classes
(iii) Rivers and streams
(iv) Roads, footpaths
(v) Settlements
(vi) Religious sites
(vii) FMU-boundary
(viii) Forest boundary
(ix) Administrative boundaries
(x) Biological corridors

Slope classification is done based on digitized 40 metre contour lines. The slope classes are the following: <10°, 10°-15°, 15°-25°, 25°-35°, >35°.

Step 2: Preliminary identification based on GIS base map and aerial photo interpretation

Soil protection (SP)
Based on the slope classification indicated on the GIS base map and on stereoscopic interpretation of aerial photos, the preliminary boundaries of SP areas are identified. According to the classification made by FRDD, all areas with a slope > 45° shall be classified as SP. Experience has shown that the slope maps derived from digital elevation models with comparatively low resolution tend to underestimate the steeper slopes considerably. Therefore, for the preliminary identification of SP areas, all areas with a high proportion of steep slopes > 5° are polygonized. In the event that the boundary could not be clearly determined, it is indicated on the map for field verification.

Soil conservation (SC)
Further, all areas with a slope of 25°- 45° and exposed or sensitive sites are classified as SC areas

Due to underestimation of the slope, all areas above 15° slope and which are not yet classified as SP are polygonized and preliminarily classified as SC. This includes exposed sites such as ridges, etc.

Watershed conservation (WSh)
WSh areas include slopes > 10°, upper catchment areas and poorly drained or waterlogged sites, moist areas and swamps, as well as all other sites serving as water retention or water feeding bodies.

All slope areas >10° are polygonized and classified as WSh areas[11]. This includes all upper catchment areas. Efforts are made to identify swamp forests on aerial photographs and mark them for verification in the field.

Riparian reserve protection (WRR)
These areas occur along the banks of rivers and streams and around the perimeters of lakes and wetlands.

For the determination of WRR it is necessary to identify the characters of rivers or streams. All alluvial, semi-alluvial rivers and streams are earmarked for a standardized 30 metre buffer. For entrenched rivers and streams, the boundary of the entrenchment slope is determined with the help of stereoscopic aerial photo interpretation. When problems are encountered in classifying these rivers and streams in the office, they are marked for checking later on in the field.

Special management areas (WSMA)
For the determination of WSMA, the characteristics of rivers or streams are determined. If a river cannot be clearly classified, based on topographic map or aerial photo interpretation, then it shall be earmarked for field checking.

Large non-alluvial rivers are earmarked for a standardized WSMA buffer of 100 metres. For alluvial, semi-alluvial rivers and streams, the edge of the active floodplain is identified as function boundary.

Wildlife conservation (NWC)
All forest areas located within biological corridors are classified as NWC areas.

Biodiversity protection (NB)
Swamp forests, gallery forests and alpine shrubs as identified during aerial photo interpretation are classified as NB areas.

Step 3: Identification of functions during participatory rural appraisal
Social functions that otherwise are difficult to identify with GIS and aerial photo-interpretation are done while carrying out PRA. Local people have considerable knowledge of the forest resources surrounding their villages. This knowledge is a valuable source of information for the preliminary identification of forest functions, mainly on the local use of the forest, location of religious sites, water bodies used for local water supply, occurrence of wildlife, site and forest condition.

A small team comprising 2-4 people who are specialized in socio-economic studies and who are experienced in conducting rural appraisal techniques are commissioned by the forest management planner to conduct PRAs in all villages within or in the immediate vicinity of the FMU. Using participatory mapping as a tool, the team locates the following functions on the working map. Mapping normally starts with the identification of the permanent forest area.

Local use only (SocL)
Forest areas in the immediate vicinity of villages, usually about 1.5 km in radius, which are intensively used by the local population and where commercial logging would be in conflict with their subsistence forest use, are classified as SocL forest.

[11] It has to be mentioned that in this slope category the underestimation of the slope determined by GIS-derived DEMs is minor and can be neglected.

Local and commercial use (SocLC)
Forest areas further away from settlements which are used by the local people for the collection of wood and non-wood forest products, and where the commercial use of the forest for timber would not necessarily endanger the subsistence supply of these products, are classified as SocLC forest.

Religious site protection (SocRS)
Some religious sites are mapped with the help of GIS. The GIS base map prepared is thoroughly checked for completeness and the individual religious sites are also checked for buffering during the PRA. If a 50 metre buffer around a religious site is not considered adequate, then the buffer zone has to be determined jointly by involving all parties concerned.

Local water supply protection (WLS)
All water bodies used for local water supply are indicated on the preliminary forest function map, including water channels used for irrigation. If the standardized size of the buffer zone is not considered adequate, then the buffer zone is determined jointly by involving all parties concerned.

Wildlife protection (NWP) and wildlife conservation (NWC)
Using participatory mapping tools, the occurrence of wildlife, namely, those of protected and endangered species, is indicated on the preliminary forest function map.

Biodiversity protection (NB)
The local people have some knowledge of the occurrence and location of rare ecosystems. If such ecosystem were determined with the help of local people then the locations could be indicated on the preliminary forest function map.

Watershed conservation (WSh)
The location of swampy and waterlogged areas is identified with the help of local people. These areas are classified as WSh.

Other map information
During PRA, GIS base maps are normally checked to ascertain whether they contain:

- all villages, settlements and houses
- all roads, footpaths or mule tracks

Step 4: Identification of functions based on forest inventory data

Wildlife protection (NWP) and wildlife conservation (NWC)
The forest management inventory normally starts at about the same time as forest function mapping. As the main objective of the inventory is to provide data for the calculation of the AAC, the inventory is therefore confined to the production zone. Therefore, areas preliminarily identified as SP, WRR and NB during GIS analysis and aerial photo interpretations are excluded from the inventory.

The management inventory also collects data on the occurrence of wildlife. Such data can be used together with the information collected from PRA to identify NWP and NWC areas. For this purpose the location of the plots is identified where wildlife observations were made.

The boundaries of the wildlife functions identified during PRA are adjusted accordingly. Areas where rare and protected species are observed are included in NWP.

Step 5: Field checking
During field verification exercises, verifications are conducted to ascertain whether the boundaries of SP, WRR and WSMA, as determined during aerial photo interpretation, correspond with field conditions. All locations that have been earmarked for field checking need to be checked. For other areas random check is sufficient. In the case of serious deviations it may be necessary to re-do aerial photo interpretation. The intensity of field checking will depend on the accuracy of aerial photo interpretation.

All NB areas identified during PRA are checked in the field and the boundary is identified with the help of aerial photos.

A random check of waterlogged or swampy areas identified by the local people as WSh is also done.

Step 6: GPS measurements
The boundary, location or alignment of the following objects is measured with the help of GPS:

- boundary of permanent forest area
- settlements, villages, houses
- roads, major footpaths and mule tracks
- religious sites
- water channels and water reservoirs

Road buffer (RB)
During GPS measurement of forest roads unstable terrain is marked on the working map and recorded in the GPS. A road buffer of 30 metres uphill and 10 metres downhill is determined.

Step 7: Determination of forest functions during environmental assessment (EA)
Functions such as SP, SC, WRR, WSMA and WSh are usually identified by aerial photo interpretation and can be easily mapped. However, the final identification of nature conservation areas is coordinated with NEC, NCD and RSPN during the EA exercise. The forest management planner will preliminarily determine the nature conservation areas as follows:

Wildlife protection (NWP)

- habitat areas where rare or endangered species (mammals and birds) occur as recorded by PRA or identified during forest inventory
- areas close to settlements or in the vicinity of roads and footpaths frequently used are excluded
- as far as possible, NWP areas (refuge areas and corridors) are to be linked with areas that already have other protective functions (i.e. soil conservation, riparian reserves).
- all the above-mentioned information is linked and marked on polygons (generalize and, if possible, follow natural boundaries).

Wildlife conservation (NWC)

- all areas rich in wildlife based on the information obtained from PRA and forest inventory are identified;
- the above-mentioned information is linked with the corresponding habitat (i.e. mature and over-mature fir forest);
- areas close to settlements or in the vicinity of roads and footpaths that are frequently used, and areas that are easily accessible, are excluded.
- all the above-mentioned are linked and marked on polygons.

Biodiversity protection (NB)
These are identified during aerial photo interpretation and during PRA and field checking.

Step 8: Preparation of forest function map
Once all forest functions have been finally identified, the GIS section of FRDD incorporates the information into GIS by digitizing the boundaries as indicated on the working map. In addition, the GIS unit has to create standardized buffers along/around objects as indicated on the working maps for:

Riparian reserve protection (WRR)
30 metres along alluvial and semi-alluvial rivers
100 metres along non-alluvial rivers and around lakes

Local water supply protection (WLS)
10 metres on each side of water (irrigation) channels
30 metres along WRR of water body used for local water supply

Road buffer (RB)
Along motorized public road: 200 metres uphill, 100 metres downhill
Along forest road in unstable terrain: 30 metres uphill, 10 metres downhill

Religious site protection (SocRS)
50 metres radius around object.

Step 9: Updating and revision of forest function map during operational planning
During operational planning, every part of the FMU is intensively checked in the field and it may happen that conditions are found that require the additional classification of a forest function. In particular, this refers to:

Soil protection (SP)
Inoperable areas, areas with signs of erosion,

Biodiversity protection (NB)
Rare ecosystems, small size swampy areas, etc.

Preparation of forest function mapping report
A report is prepared describing the process of forest function mapping and containing the main results and statistics. For this purpose it is important that the management planner and the field crew keep proper notes during function mapping. The table of contents of the forest function report is as follows:

Foreword
1 Forest function mapping
1.1 Objectives and definitions
1.2 Mapping process and data sources
1.3 Identification and description of functions
2 Forest zoning
3 Implication on forest management
4 Proposal for road alignment (optional)

Annexes
Annex 1: Definition and description of forest functions
Annex 2: Maps
a) Forest function map
b) Forest zonation map
c) Forest inventory map (optional)

Annex 4

FOREST MANAGEMENT PLANNING AND PLAN IMPLEMENTATION
(Forest and Nature Conservation Rules, 2000)

1. Forest management plan

2. Administrative responsibility for preparation of forest management plans

The Ministry shall assign administrative responsibility to the agency concerned for the preparation and adoption of management plans with regard to respective types of forest. The agency charged with administrative responsibility for the respective forest category should ensure that all management plans required by law are prepared, adopted and implemented.

3. Drafting of management plans

(1) **Participation and comment/consultation**

The agency responsible for the preparation of the management plan may consult the following in the preparation process:

(a) local residents, local authorities and other members of the public;
(b) persons operating forest-related businesses and other operations;
(c) government officials in other agencies, divisions and ministries.

(2) **Guiding principles and forest management plans**

(a) Wherever a management plan allows the taking of forest produce, such taking shall be planned on a sustained yield basis.

Review, recommendation and approval

(1) **Review and recommendation**

The Department shall review and comment on the management plan. The Department shall forward the management plan to the Ministry for approval.

(2) **Approval**

The forest management plan shall be complete and given full permanent effect when it is approved by the Head of the Ministry.

Implementation of forest management plans

After the plan is approved, it shall be entrusted to the concerned agency for implementation and enforcement strictly in accordance with the approved plan.

Forest management committees

The following two forest management committees will be appointed. They will oversee and advise the Department and the DFO (territorial) regarding implementation of forest management plans:

(1) **National-level forest management committee**

The national-level forest management committee shall be chaired by the Head of the Department and shall be composed of not less than seven persons who shall be appointed to this Committee by the Head of the Department.

(2) **Divisional-level forest management committee**

The divisional-level forest management committee shall be chaired by the DFO (territorial) and shall consist of not less than seven members appointed by the Head of the Department.

Monitoring and control

For monitoring and control, the guidelines prescribed by the Department from time to time shall be adopted.

Evaluation

Based on monitoring carried out pursuant to Section 13 above, the Department shall, on a regular basis, evaluate the effectiveness of implementation of the management plans. The Department shall issue an evaluation schedule and such procedures as it shall deem necessary regarding the evaluation process.

Offences under Chapter II of the Forest and Nature Conservation Rules, 2000

Any lessee of government-reserved forest and the operator of any industrial facility for which a management plan is required by these rules, following notification by an authorized officer that a management plan is required for such activities, who takes or processes forest produce without there being an approved forest management plan, shall be guilty of an offence.

Any person not complying with the provisions of this chapter in the implementation of the management plan shall be guilty of offence punishable under Section 84 of these Rules.

Annex 5 (a)

FOREST MANAGEMENT INVENTORY: TALLY SHEET 1

Plot Identification

1. inventory unit .....
2. plot number
3. Special? (Y) (N)
4. sheet number
5. crew leader .....
6. date / /
7. altimeter
8. land use type
9. canopy height <5 <10 <20 <30 30+
10. canopy closure <10 <40 40+
11. Accessible? (Y) (N) (if not, remark)

If plot not accessible, or LUT no natural forest/tall bamboo: stop recording here

Trees 10+ cm dbh

(dbh 30+ cm on major plot, r < 12.62 m; dbh 10-29 cm on minor plot, r < 5.64 m)

	species	code	dbh	special	tot hgt	% log grades P	A	B	C	I	X	conifer rad inc	brk thk
1	.....												
2	.....												
3	.....												
4	.....												
5	.....												
6	.....												
7	.....												
8	.....												
9	.....												
10	.....												
11	.....												
12	.....												
13	.....												
14	.....												
15	.....												
16	.....												
17	.....												
18	.....												

Regeneration < 10 cm dbh

(1.30 m height - 9 cm dbh of commercial species on regeneration plot, r < 3.57 m)

	Species	code	nr
1	.....		
2	.....		
3	.....		
4	.....		
5	.....		
6	.....		

Annex 5 (b)

FOREST MANAGEMENT INVENTORY: TALLY SHEET 2

Site

(observations on major plot)

aspect

12. azimuth, downhill ☐☐☐ 13. slope % down ☐☐☐ 14. slope % up ☐☐☐

stand condition

15. common mistletoe (Y) (N) 17. bark beetle (Y) (N)
16. dwarf mistletoe (Y) (N) 18. dieback fir (Y) (N)

non-tree vegetation

19. understorey cover % none <2 <10 <40 40+ ☐
if so, main type moss grass Herbs bamboo < 5m shrubs < 2m shrubs 2<5 m ☐

20. bamboo cover % none <2 2+ ☐
if so, main type spreading clump ☐
dbh (cm) <2 2<4 4+ ☐

21. cane cover % none <2 2+ ☐
if so, dbh (cm) <2 2+ ☐

22. Daphne cover % none <2 2+ ☐

signs of

23. commercial wood extraction (Y) (N) 26. fire (Y) (N)
24. domestic wood extraction (Y) (N) 27. abandoned shifting cultivation (Y) (N)
25. grazing (Y) (N) 28. cardamom cultivation (Y) (N)

soil

29. stoniness cover <70x70cm <4x4m <9x9m >=9x9m ☐
30. depth litter + humus (cm) none <2 2<5 5+ ☐
31. topsoil moisture dry moist permanent-wet ☐
32. topsoil colour dark reddish yellowish ☐
33. topsoil texture sand l.sand s.loam loam clay ☐

Wildlife

(observations on major plot)

	species	code	evidence	code
1	.....	☐☐☐	.....	☐☐☐
2	.....	☐☐☐	.....	☐☐☐
3	.....	☐☐☐	.....	☐☐☐
4	.....	☐☐☐	.....	☐☐☐
5	.....	☐☐☐	.....	☐☐☐

34. general remarks

Annex 5(c)

FOREST MANAGEMENT INVENTORY: COMPASS SHEET

Line Identification

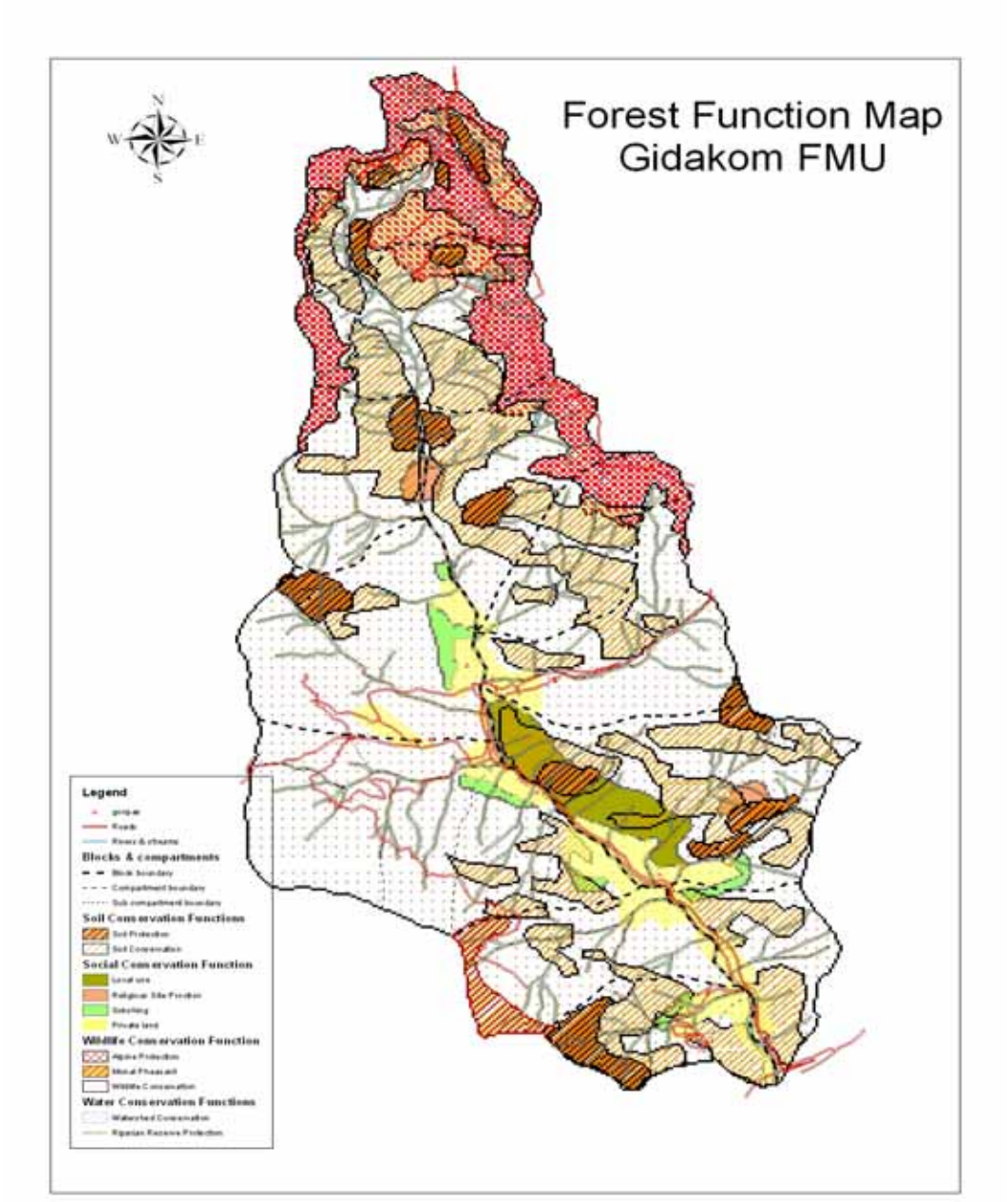
1. inventory unit .....
2. from plot
3. to plot
4. sheet number
5. crew leader .....
6. date / /
7. azimuth

Line Description

	slope correction			***land use type***	***tree canopy***			***remarks***
	dist (m)	slope%	dist (m)		height (m)		closure (%)	
	horiz	up down	slope	code				
1					<5 <10 <20 <30 30+	<10 <40 40+	.....	
2					<5 <10 <20 <30 30+	<10 <40 40+	.....	
3					<5 <10 <20 <30 30+	<10 <40 40+	.....	
4					<5 <10 <20 <30 30+	<10 <40 40+	.....	
5					<5 <10 <20 <30 30+	<10 <40 40+	.....	
6					<5 <10 <20 <30 30+	<10 <40 40+	.....	
7					<5 <10 <20 <30 30+	<10 <40 40+	.....	
8					<5 <10 <20 <30 30+	<10 <40 40+	.....	
9					<5 <10 <20 <30 30+	<10 <40 40+	.....	
10					<5 <10 <20 <30 30+	<10 <40 40+	.....	
11					<5 <10 <20 <30 30+	<10 <40 40+	.....	
12					<5 <10 <20 <30 30+	<10 <40 40+	.....	
13					<5 <10 <20 <30 30+	<10 <40 40+	.....	
14					<5 <10 <20 <30 30+	<10 <40 40+	.....	
15					<5 <10 <20 <30 30+	<10 <40 40+	.....	
16					<5 <10 <20 <30 30+	<10 <40 40+	.....	
17					<5 <10 <20 <30 30+	<10 <40 40+	.....	
18					<5 <10 <20 <30 30+	<10 <40 40+	.....	
19					<5 <10 <20 <30 30+	<10 <40 40+	.....	
20					<5 <10 <20 <30 30+	<10 <40 40+	.....	
21					<5 <10 <20 <30 30+	<10 <40 40+	.....	
22					<5 <10 <20 <30 30+	<10 <40 40+	.....	
23					<5 <10 <20 <30 30+	<10 <40 40+	.....	
24					<5 <10 <20 <30 30+	<10 <40 40+	.....	
25					<5 <10 <20 <30 30+	<10 <40 40+	.....	
26					<5 <10 <20 <30 30+	<10 <40 40+	.....	
27					<5 <10 <20 <30 30+	<10 <40 40+	.....	
28					<5 <10 <20 <30 30+	<10 <40 40+	.....	
29					<5 <10 <20 <30 30+	<10 <40 40+	.....	
30					<5 <10 <20 <30 30+	<10 <40 40+	.....	
31					<5 <10 <20 <30 30+	<10 <40 40+	.....	
32					<5 <10 <20 <30 30+	<10 <40 40+	.....	
33					<5 <10 <20 <30 30+	<10 <40 40+	.....	
34					<5 <10 <20 <30 30+	<10 <40 40+	.....	
35					<5 <10 <20 <30 30+	<10 <40 40+	.....	
36					<5 <10 <20 <30 30+	<10 <40 40+	.....	
37					<5 <10 <20 <30 30+	<10 <40 40+	.....	
38					<5 <10 <20 <30 30+	<10 <40 40+	.....	
39					<5 <10 <20 <30 30+	<10 <40 40+	.....	
40					<5 <10 <20 <30 30+	<10 <40 40+	.....	
			(sum)					

8. Remarks: .....

Map 4: Example of forest function map



This forest function map does not belong to the study area; it has been annexed to this report as an example. The procedure for production of a function map, and the equipment used, is explained in Annex 3.