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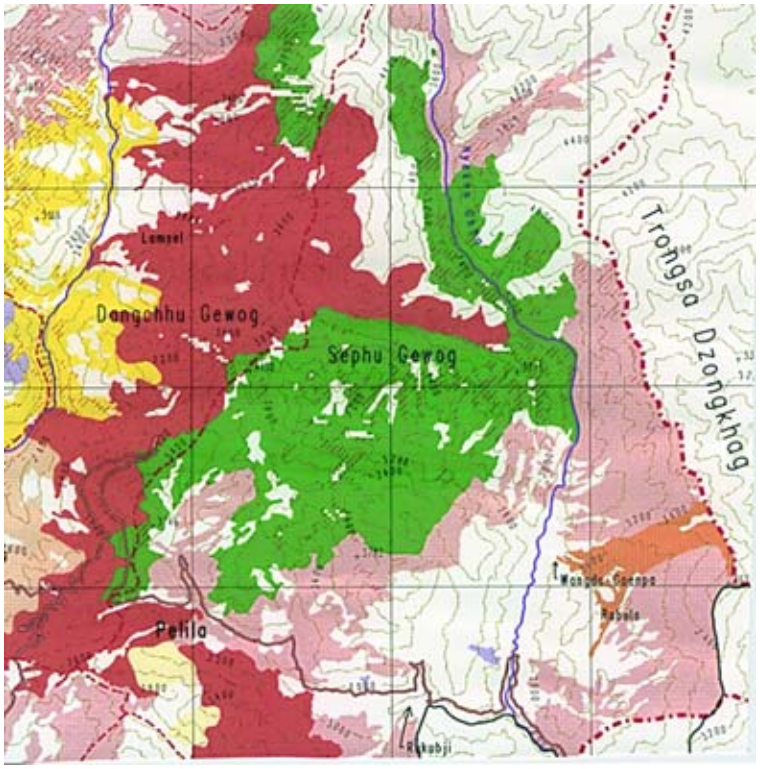
Forest Resources Potential Assessment for the Dzongkhags of Gasa, Punakha and Wangdue - Phodrang



Mission Report on Forest Resources Potential Assessment and Forest Management within the Scope of the Bhutan - German Integrated Forest Management Project

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Acronyms

AAC	annual allowable cut
a.s.l.	above sea level
BG-IFMP	Bhutan - German Integrated Forest Management Project
BLC	Bhutan Logging Corporation
BMNP	Black Mountain National Park
CF	Community Forests
FMU	Forest Management Unit
FRPA	Forest Resources Potential Assessment
FRDS	Forest Resources Development Section
FSD	Forestry Services Division
GIS	Geographic Information System
GOI	Government of India
GPS	Geographic Positioning System
hydel	hydroelectric power stations
JDNP	Jigme Dorji National Park
LUPP	Land Use Planning Project
LUWM	LUPP land use working maps, scale 1:50.000
MoA	Ministry of Agriculture
NCS	Nature Conservation Section
NP	National Park
NTFP	Non Timber Forest Products
NU	Nulgtrum
PLOT	tailor made EDP program for forest inventory analysis
PRA	Participatory Rural Assessment
PIS	Preinvestment Survey
PIS-Map	PIS-map at scale 1:50.000
RFI	Forest Reconnaissance Inventory
RRA	Rapid Rural Assessment
SE%	standard error
SPES	Social Forestry and Extension Section
topo-map	topographic map with 40m height lines, scale 1:50.000
WMU	Watershed Management Unit

Preface

This Forest Resources Potential Assessment was prepared within the framework of the Bhutan-German Integrated Forest Management Project (BG-IFMP). This Project is a technical cooperation between the Forestry Services Division (FSD) within the Ministry of Agriculture (MoA) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) mbH which provides expatriate advisory services on behalf of the German Government.

The long-term purpose of BG-IFMP is to contribute to the application of economically and ecologically sustainable land use systems in Gasa, Punakha and Wangdue-Phodrang Districts of Bhutan (BG-IFMP, 1995). The Project is at present in it's orientation phase. In order to define the fields of further concerted actions, it was necessary to assess the forest resources of the concerned three districts and to identify potential forest areas for future management.

The purpose of this document is twofold: first it describes the objectives and the methodology and approach on how to implement a FRPA (Part I) in context of the overall forest resources planning approach, and secondly, it contains the FRPA of the project region: Gasa, Punakha and Wangdue-Phodrang (Part II).

This FRPA is entirely based on already existing information: the LUPP land use data and the results of already undertaken forest management inventories. Thus no time and labor consuming field investigations were necessary.

The GIS-based identification of potential forest areas was conducted by the GIS-Cell of the Forest Resources Development Section (FRDS), FSD in close cooperation with the Land Use Planning Project (LUPP) of the Ministry of Agriculture (MoA). The analysis of the inventory data and the linkage with the LUPP forest land use types was carried out by FRDS in close cooperation with the short-term consultant W. Schindele. The results were stored in an EXCEL spreadsheet named FRPACALC.XLS.

The GIS-Cell of FRDS is now in the position to implement FRPA's also for other districts of Bhutan based on the described simple approach and methodology. The attributes of the different forest types (or stand data) can be used on macro-planning level also for other districts. Once the area statistics are available from the GIS-analysis they simply have to be inserted into the FRPACALC.XLS spreadsheet and the results will be calculated automatically.

The FRPA of Gasa, Punakha and Wangdue-Phodrang districts consists out of the following two documents:

- the FRPA-Map of Punakha and Wangdue-Phodrang districts at a scale of 1:100.000
- the FRPA-Working Paper, which contains general information on the methodology, the main results and statistics of the concerned areas and a valuation of the future potential for forest management (production/demand scenario).

Part I: FRPA: Approach and Methodology

1 Objective

The objective of the Forest Resources Potential Assessment can be described as follows:

Objective

The FRPA provides information on the potential of forest resources on dzongkhag level for future forest management for macroplanning purposes.

Results

- Description and quantification of different forest types with estimates on standing stock and increment.
- Identification of forest areas which have a future potential for timber production and their delineation on the FRPA-map.
- Production potential analysis with special regard to the present and future timber and wood demand on dzongkhag level.
- Identification of potential areas for the establishment of self sustainable forest management units (FMU).

The FRPA-Map is prepared to show the distribution and location of different potential forest areas. It furthermore contains already existing community forests (CF), forest management units (FMU), watershed management units (WMU) as well as all protected (national parks, etc.) and otherwise restricted areas (i.e. hydels). The main purpose of the FRPA-Map is the identification of further management units (FMUs).

(Note: FMU in this context refers not only to commercially managed forest management units (FMU), but also to community forests (CF), watershed management units (WMU), etc.

2 Criteria for Selection of FRPA-Approach

2.1 Available Information

2.1.1 Forest Type Maps

In Bhutan already the following information on different forest types exist:

PIS Resource Maps

From 1974 to 1980 a Preinvestment Survey of Forest Resources (PIS) was implemented by the Ministry of Agriculture, Govt. of India. The forest resources were assessed by interpretation of aerial photos from 1956-58 and by intensive field sampling (forest inventory). One result of this detailed resource assessment are the PIS-Resource Maps at a scale of 1:50.000 which distinguish six different forest types and three different density classes.

It has been experienced during field investigations, that the PIS forest type interpretation is still quite accurate, especially in remote areas, where human impact is low. This is especially true for the forest type classification. Taking into consideration the fact, that the aerial pictures were already taken in 1956-58, it is natural that there has been some changes in the density classes.

LUPP land use data

The Land Use Planning Project (LUPP) under the Ministry of Agriculture has prepared 1992/93 land use working maps (LUWM) at a scale 1:50.000 covering the whole country. Fortunately, LUPP made this land use information also available in digital format as ARC/INFO coverages, in addition to digitized toposheet data.

The LUPP land use classification distinguish also six different forest types (eight including plantation and forest shrub) of three different crown closure or density classes (see chap. 3.1). While the forest types correspond with those of the PIS Resource Maps, this is not the case for the density classes (see table 1).

Table 1: Comparison of LUPP and PIS density classes

Density Class	PIS	LUPP
1	<20%	< 40%
2	20-60%	40-80%
3	>60%	> 80%

The LUPP land use classification is based on SPOT satellite image interpretation (SPOT imagery were taken in 1991) combined with some field truthing. It was experienced during field work that LUWM are fairly accurate as far as forest/non forest boundaries are concerned. However, the interpretation of forest types and - in particular of density classes - does not always correspond with reality as it is pointed out more detailed in chap. 3.2.2. (Note: It was the intention of LUPP to train personnel in land use classification and interpretation and not necessarily to prepare accurate land use maps. Therefore these maps are called "working" maps.)

2.1.2 Information on Growing Stock and Growth

PIS-Inventory Data

During the Preinvestment Survey a forest inventory was conducted and the results were presented in detail by GOI/MoA (1980). While the forest type did not change much since the PIS resource assessment undertaken in 1976 to 1978 (time period for field work), the condition of the forests have changed due to natural succession and increased human impact.

Management Inventory Data

Since the introduction of the PLOT-System in 1991 standardized forest inventories were conducted by FRDS for the purpose of management planning in various FMUs. Most of these data are available in digital form as data bank files (.dbf). The classification of the forest type by FRDS is much more detailed as the one used by LUPP or PIS. While the forest land use defined by FRDS can be easily converted into LUPP land use types, this is not the case for the density class (see LAUMANS, 1994 a).

2.2 FRPA in the Context of Forest Resources Planning

Within the scope of the Bhutan-German Integrated Forest Management Project a proposal for an improved concept on forest resources planning was made (SCHINDELE, 1995 a,b).

In this concept, the FRPA is the first planning step of a four level planning process which consists out of:

- Forest Resources Potential Assessment
- Reconnaissance Survey
- Forest Management Planning
- Operational Planning

and has always to be seen in this context.

In the following the individual planning steps are briefly sketched:

Forest Resource Potential Assessment

As already mentioned, it is the objective of the FRPA to identify on a macroplanning level all forest areas which have a potential for future forest management, in particular, it should identify forest areas which might be suited to be managed as FMUs in future. It furthermore has to provide statistics on forest type distribution and estimates on standing volume and increment on dzongkhag-, gewog- and on potential FMU-level and contain a wood production/demand scenario. A FRPA should be carried out at least on dzongkhag-level.

Reconnaissance Survey

The reconnaissance survey should contain a more detailed assessment of a particular forest area which has been defined as a potential FMU in the FRPA. It has to provide all the necessary information required to enable decision makers to decide whether a potential forest area should be managed as a FMU or not. In particular the Reconnaissance Survey should consist of the following four components:

- Reconnaissance Forest Inventory
- Economic Feasibility Study
- Socio-Economic Study (PRA, RRA)
- Preliminary Environmental Impact Assessment

Forest Management Planning

Once it is decided to open a FMU a management plan has to be prepared which has to provide all the information required by the manager for sustainable forest management within a 10 years period. The plan has to be based on the results of a detailed forest inventory, which should be implemented only in those areas which are subject of forest management within the planning period. Stand data and silvicultural planning should be available on subcompartment or stand level. The AAC should be calculated on the planned silvicultural interventions. It should be based on an holistic approach paying special attention to the needs of the local population. It has to be prepared by the Forest Management Planning Unit of FRDS.

Operational Planning

Operational plans have to be prepared based on the results of the management plan in intervals of two years by the territorial staff of the DFO.

Based on this planning approach the FRPA has to provide on a macroplanning level more quantitative information on potential forest resources. Detailed qualitative assessment of particular forest areas (FMUs), considering both, economical and ecological aspects, are tasks of the subsequent planning steps, the reconnaissance survey and forest management planning.

2.3 Other Criteria Considered

The FRPA-approach was developed based on the following considerations:

- financial and human input should be kept to a minimum; the FRPA therefore should be based on already existing information;
- it should be designed in such a way, that a FRPA can be conducted entirely by the FRDS without additional external support;
- it should be based on GIS-technics and be compatible with LUPP´s GIS-system;
- it should be applicable for all districts of Bhutan;
- it should provide precise enough information for macroplanning purpose.

3 Description of FRPA-Approach and Justification

3.1 Selection of Approach

For the purpose of a FRPA the following two types of information are essential:

1. Information on area distribution and location of potential forest areas (different forest types).
2. Information on forest condition (i.e. growing stock, increment, species, etc.) .

ad 1) Information on area distribution and location of potential forest areas

Information on forest land use is available and can be derived from the following two sources:

- LUPP Land Use Working Map (LUWP)
- Preinvestment Resource Map (PIS-Map)

LUWP-data have the advantage, that they are already available in digital format and can be directly used for GIS-analysis. The PIS-data are on the other hand more precise as far as the identification of the forest type is concerned. However, to make use of the PIS-data would require the digitizing of all the relevant PIS-map sheets, which would be a tremendous work load for the GIS-Cell. The differentiation into the following six different forest types is the same for both sources of information:

Fir forest	Mixed conifer forest
Bluepine forest	Mixed broadleaf with conifer forest
Chirpine forest	Broadleaf forest

and is quite suitable for the purpose of a FRPA. Beside the forest type another important criterion for the assessment of the production potential is the forest density. The density class determined from satellite (LUPP) or aerial photo (PIS) data is mainly linked with standing stock and age. Therefore the differentiation of the forests into three crown closure or density classes is quite suitable. From the foresters point of view, the classification key used by PIS is more relevant than that of LUPP (see table 1).

Although the PIS forest type data would be of more relevance for the FRPA, it was decided to use the LUWP-data out of the following reasons:

- they are already available in digital format for the whole country;
- they are more accurate in terms of forest/non forest boundaries;
- they are precise enough for macroplanning purposes.

The combination of both - the PIS and LUWP data - would have been in fact the best solution.

ad 2) Information on forest condition (i.e. growing stock, increment, species, etc.)

The information on the condition of the different forest types distinguished by the GIS-analysis have to be derived from actual field investigation. Usually, for this purpose own inventories are designed and implemented (see LAUMANS, 1995), which are quite time consuming and costly ventures.

In order to keep financial and human impact at a minimum, it was decided to use the existing data bases of the management inventories (see chap. 2.1.2 and 3.3) and to link them with the LUPP land use classes. This could be done in the following two ways:

1. transformation of the FRDS land use and density classes to the LUPP classification system based on transformation codes (Laumans, 1994 b);
2. identification of the terrestrial location of the inventory plot and direct linkage with the corresponding LUPP land use class.

The first option, to calculate attributes based on the land use cover codes of FRDS by transforming them to LUPP land use codes (LAUMANS, 1994 b), was skipped out of the following reasons:

- Transformation keys are only available for the new land use codes of FRDS (LAUMANS, 1994 b). However most of the inventory data available contain the old land use codes.
- The minimum area unit of land use interpretation differs between LUWM and FRDS inventory data. The LUPP interpretation was done at a scale 1:50.000 and therefore small areas of different land use (i.e. gaps, pasture areas, shrubs, etc.) were included into the overall surrounding land use. The inventory land use code, however, is the actual land use on the exact spot of the inventory plot. For example, if the inventory plot would fall into a small pasture gap within a mixed conifer forest of density class 2, the corresponding FRDS land use cover code would be Gr (for grassland) while it would be classified by LUPP as FCm2 (for mixed conifer forest). The linkage of both information based on the transformation key would definitely have led to an overestimation of the standing stock and growth of the different forest types.
- Misinterpretations in land use classes by LUPP would be disregarded. For example all fir forests identified by FRDS would be linked to LUPP land use FCf while the inventory plot may lay in reality in an area classified (misinterpreted) by LUPP as mixed conifer forest FCm.

The transformation of FRDS land use cover codes and - based on this - the calculation of average attributes (i.e. growing stock, growth, etc.) for the different LUPP forest types would have given quite wrong results.

It was therefore decided to feed the inventory plot location into the GIS-system by digitizing the inventory base maps and to link the plot directly with the LUPP land use class. For more details see chap. I 3.3)

The alternative to use the results of the PIS inventory and to link them with LUPP land use data was skipped out of the following reasons:

- the results are out of date (from 1976-1978), forest condition has changed in the mean time;
- incompatibility of density classes of PIS and LUPP.

3.2 GIS-based Analysis of Potential Forest Areas

3.2.1 Definition of Potential Forest Area

The most important step, which had to be conducted before implementation of the GIS-based analysis and preparation of the FRPA-Map, was the selection of criteria for the definition of the potential areas and for map classification.

The term potential in this context refers only to timber and wood production (see chap. 1). At this planning level it is almost impossible to assess other aspects such as NTFP, wildlife, pasture potential etc.; this will be subject of the subsequent planning steps (see chap. I 2.2).

The selection of the parameters and criteria used for map classification of potential forest areas was based on the following considerations:

- In order not to overload the GIS-system (each additional parameter or criteria requires additional computer memory, see also chap. I 3.2.2) the number of parameters set should be kept to a minimum.
- The methodology of the GIS-analysis should be designed in such a way, that it is practical and not too much time consuming, in order to be carried out by the GIS-Cell also for other districts without external support. To overload the FRPA with a lot of different parameters would also lead to confusion and increase the probability of making mistakes.
- The criteria set should be already available in digital form, no additional data input or analysis should be required.

While in general all forest types in Bhutan have a potential for timber production, it is a question of the terrain if a forest can be exploited and a question of it's condition (which of course depends also on the site) when and to what extent it can be used. Also the legal status of the area is of importance. It is the policy of the RGOB not to carry out forest management within protected areas such as national parks (RGOB/MOA/FSD, 1993 and RGOB, 1995). Accessibility of a forest area is also an important aspect, but this depends rather on economic consideration (cost/benefit of road construction) than on resource capability. In the long run, all forests in Bhutan should be managed in one or the other ways anyway.

The parameters finally applied for map classification (GIS-analysis) were the following:

Criterion 1: Forest Land Use Type

All LUPP forest land use classes with a density above 40% were considered as potential forest areas, except for chirpine forests of density class 40-80% (FCc2) and forest scrub (FS). chirpine forests are rather managed as silvopastural systems than for timber and wood production. Usually Chirpine forests also appear on shallow sites of low productivity.

The remaining forest land use classes were further subdivided into potential and high potential forest types, depending on growing stock and diameter distribution. It has been experienced during inventory data analysis (see chap. I 3.3.2), that the standing volume of the forests were generally higher in forests of density class 2 than in those of density class 3. This was however not the case for pine forests FCb and FCc (see also Annex 3).

High potential (FCf2, FCb3, FCc3, FCm2, FBc2, FB2)

All forest types having a fairly high standing volume particularly in the upper diameter classes were considered as high potential. In general these forest are overmature and in the fragmentation phase. The timber should be harvested as soon as possible otherwise it may no longer be usable. Also due to the high grazing pressure in almost all forest areas of Bhutan, natural regeneration is hardly coming up. Therefore, in order to make best use of these valuable natural resources as well as for the purpose of their conservation, it is of highest priority to take them as soon as possible under management.

It has to be mentioned here that the growing stock itself can be a misleading parameter. In case of fir forest the amount of exploitable timber depend on the cull percentage. In overmature forests with a high standing volume most of the trees are decayed and no longer usable, thus the commercial value is low. But, on the other hand, there is however an urgent need to rejuvenate or even rehabilitate these forests. Therefore, it was decided to include FCf2 into the high potential category (more information on fir forests and decay can be obtained from the Austrian funded Integrated Forest Management Project in Ura).

Potential (FCf3, FCm3, FCb2, FBc3, FB3)

These forest are of comparatively good condition, they are younger in age and their canopy is generally closed. The growing stock is distributed more to the middle diameter classes. They are mature forests and generally in the old-age phase. Their potential for timber exploitation is quite high, but there is not such an urgent need for rejuvenation of the stand and for conservation measures.

Forests of density class 1 were considered as non-potential. They either stock on poor sites or they are in the building phase. Their potential for timber and wood exploitation is low, and there is no urgent need for conservation measures.

Criterion 2: Slope

According to "The Guidelines on Land Capability Classification and Management Recommendations" which have been prepared by LUPP, October 1995, forest management should only take place on slopes up to 100%. This limit seems to be a conservative one compared to the slope limit of 60° (173%) defined by the PIS as limit for forestry interventions (GOI/MOA, 1980, page 122).
The slope is calculated in the GIS-analysis based on a digital elevation model (DEM) of a 90 m resolution (see chap. I 3.2.2). However slope maps generated from DEMs with a relatively low resolution tend to underestimate the steeper slopes considerably.

Keeping this in mind and to give a rather conservative estimate, it was therefore decided to classify the slope into the following three categories:

Slope up to 75%: Potential
Generally suitable for forestry, might however include inoperable areas such as narrow valleys, rock formations or slopes exceeding 100%.

Slope 76-100%: Limited Potential
Principally suitable for forestry, however terrain condition is generally very difficult and percentage of inoperable areas is extremely high. This slope class has been marked with red lines on the FRPA-map. It's potential for forest management is very limited due to the high costs and ecological risks of timber harvesting.

Slope above 100%: Non-potential
Due to the extreme steepness these sites should be excluded from any forestry intervention. Even if it would be possible, the ecological and environmental risks would be too high.

Criterion 3: Management status

Designated national parks, reserves and other protected areas were considered as non-potential, as it is the policy of RGOB not to carry out forest management activities within these areas.

To assess the criterion accessibility was skipped, as it appeared to be extremely difficult to be done by GIS-analysis. To assess accessibility properly the existing infrastructure would have to be linked with terrain features such as slope, aspect, drainage and altitude. To simply specify a distance limit from existing roads would neglect the fact that it is more easy and economic to construct a road 20 km along a valley than to cover 5 km horizontal distance over a mountain ridge. If a parameter like this would have been included, then for example the potential FMU area of Gogona would have most probably been excluded from the potential areas. The decision, whether a particular potential area is accessible or not needs more detailed investigation and has therefore to be determined by the subsequent planning step, the reconnaissance survey (see chap. I 2.2). To impose an altitude limit was skipped, too. First the tree line depends also on the aspect and secondly, why should a potential fir forest above a determined altitude not be managed? The limit for management is already given by nature (tree line), and it can still

be decided by the management planners whether it would be necessary to abandon forest management for ecological or environmental reasons.

The GIS-analysis provides the following results: the FRPA-Map and statistics on potential areas.

Map classification (FRPA-Map)

The FRPA-Map contains all potential and high potential LUPP forest land use types, which are outside protected areas and on slopes up to 100%. Slopes from 76% to 100% are marked with red lining. As it is the main purpose of the FRPA-Map to identify potential FMU areas, already existing FMUs (incl. CFs and WMUs) were excluded on the FRPA-Map. It goes without saying, that the map also contains infrastructure (roads, villages, settlements) and 200 m altitude lines.

Statistics on potential areas

Other results of the GIS-analysis are the statistics on potential areas. They are compiled separately per dzongkhag and gewog and the potential areas are listed separately for 1000 m altitude intervals and for slopes < 76% and 76% to 100% (see part II).

To be on the save side, for the purpose of calculating the production potential of a particular area, only the potential areas on slopes below 76% have been considered. It was assumed, that the potential areas within slope class 76%-100% substitute the amount of inoperable areas within slope class < 76%. To determine correction factors for the amount of inoperable areas per slope class was not possible due to lack of information.

3.2.2 Methodology of GIS-Analysis

The methodology for the GIS-based analysis and map classification was developed by the GIS-Cell of FRDS with some logistic support of LUPP. LUPP also provided land use and topographic information in digital format and did the outprint of the final maps (note: the plotter of FRDS had too little memory to do the job).

For the purpose of a FRPA on district level a map at a scale 1:100000 had been considered appropriate. It was decided to prepare an own FRPA-Map for each dzongkhag. For Gasa no map was prepared as the whole dzongkhag falls within Jigme Dorji National Park.

The whole process of the GIS-analysis is briefly described in the following:
The land use information (LUWM) from LUPP was available as vector based ARC/INFO coverages based on individual toposheet (scale 1:50.000) format. Therefore, first of all, for each dzonghkag the land use information had to be joined and edgematched. By doing this, it was experienced, that in some cases the polygons did not match from one map to the other. It was therefore necessary to check the joined LAND USE coverage and to correct mismatching polygons. In case of Wangdue-Phodrang Dzongkhag, which is covered by 14 topo-sheets, the computer's memory was too small to join all the coverages at once. Therefore, the area of Wangdue-Phodrang had to be split first into five separate land use coverages which were joined afterwards.

For analysis of the slope it was decided to use the satellite-derived digital elevation model (DEM) which has approximately a 90 m resolution. It was experienced before by the GIS-Cell, that the quality of this DEM is better than a DEM generated by interpolation of the 200 m interval contour lines (see also LAUMANS, 1995 a). Using the raster-based IDRISI software and the DEMO3 coverage of Bhutan, the area covered by the concerned dzongkhag was clipped by indicating reference x and y coordinates. The slope was then classified into three classes (<76%, 76-100%, >100%) and this SLOPE coverage was converted into vector based ARC-file. All further analysis was carried out by using the PC-ARC/INFO software.

The next step was to create LANDSLP coverage.by joining the LAND USE and SLOPE coverages. Then all areas which had to be excluded from the analysis (i.e. protected areas, FMUs, etc.) had to digitized, coded and and saved as FMU coverage.

LANDSLP and FMU coverage were joined to create FINAL1.

CONTOUR coverage containing altitude classes in 1000 m intervals was joined with FINAL1 to create FINALX coverage.

GEWOG coverage was prepared and joined with FINALX to FINALXX

Finally the map lay out and the legend were prepared and the FRPA-maps were printed. Additionally, for each of the FMUs and protected areas, which were not included in the FRPA-Map, separate maps were prepared and handed over to BG-IFMP. The calculation of the area statistics was done based on FINALX and FINALXX coverages using the PC-ARC/INFO software.

Table 2: GIS coverages prepared for FRPA

Coverage	**Content**	**Variable name**
LAND USE	land use classes	SYMB
SLOPE	slope classes	GRID_CODE
FMU	areas excluded from analysis	CODE9
CONTOUR	altitude classes	CNLNVALUE
GEWOG	gewog boundary	NAME
LANDSLP	LAND USE joined with SLOPE	
FINAL1	LANDSLP joined with FMU	
FINALX	FINAL1 joined with CONTOUR	
FINALXX	FINALX joined with GEWOG	

Table 3: Definition of variables used for preparation of GIS-coverages and statistical calculation

Variable name	**Content**	**Code**
SYMB	land use class	i.e. FCf2, FCf3, FBc2, FB3
GRID_CODE	slope class	1: <76% 2: 76-100% 3: >100%
CODE9	protected area name	i.e. Dawakha, Rimchu, JDNP
CNLNVALUE	altitude range	1: <1000 m 2: 1000-2000 m 3: 2000-3000 m 4: 3000-4000 m 5: >4000 m
NAME	gewog name	i.e. Nyisho, Khazi

3.3 Calculation of Attributes for Potential Forest Types

As already mentioned, the FRPA should provide a more quantitative estimate for the planner on the standing stock and the production potential of a particular area. This information is sufficient to be used as a criterion for the selection of potential management areas (FMUs) and for the calculation of production/demand scenario. A qualitative assessment taking into consideration also ecological and environmental aspects needs more detailed investigation and has to be carried out by the subsequent planning steps, the reconnaissance survey and forest management planning.

For the purpose of the FRPA the following attributes were compiled for each of the potential forest types based on the results of already conducted inventories:

Standing Stock

- average gross volume per ha
- total gross volume

Increment

- average annual increment per ha
- total annual increment

Diameter Distribution

Increment and standing stock are calculated for 10 cm dbh-intervals to get a criterion on maturity and on the development phase of the particular forest type.

Species

In forest management inventories more than 300 different tree species are distinguished. For the purpose of the FRPA it is sufficient to specify the stand data for the most important commercial species and to group the other ones. The following species and species groups were distinguished:

Coniferous Trees

Abies
Picea
Pinus roxburgii
Pinus wallichiana
Tsuga
Other Conifer

Broad-leaved Trees

Acer
Betula
Michelia
Persea
Quercus glauca
Quercus griffithii
Quercus lanata
Rhododendron
Other Broadleaves

Unfortunately, only for conifers the increment could be calculated, as no increment functions are available for broad-leaved species yet. The average gross volume and the increment estimate are the parameters which are used in management planning for the calculation of the sustainable AAC and as thus, they are the most valid parameters for the FRPA.

3.3.1 Selection of Suitable Inventories

Since the 1960´s numerous forest inventories for the preparation of forest management plans (altogether 33) have been carried out throughout the country and thus there is an enormous amount of data on different forest resources of Bhutan already available. Inventory design and methodology has been standardized in 1991 when the PLOT-System for data analysis was introduced at FRDS.

For the calculation of attributes (note: in this context the term attribute stands for average gross volume and increment for different species and diameter classes) for the "potential" forest types only those inventory data can be used which fulfill the following criteria:

1. Original inventory data must be available in digital form.
2. Terrestrial location of inventory plots must be exactly known.
3. No forestry intervention should be carried out before 1992.

ad 1) For most of the inventories, especially for those undertaken since 1991, original inventory data were available on computer discs.

ad 2) For the calculation of attributes the LUPP land use class interpreted on the inventory plot location has to be known. Only by having this link an unbiased calculation of attributes is possible. This criterion was just fulfilled by few inventories. Only for Nahi, Chapleykhola and Chendebjie, the terrestrial coordinates of the inventory plot locations were already incorporated into the GIS-system of FRDS. Original inventory maps were available for part of Paro-Zonglela, for Wangdigang, Kamichhu, Haa East, Karshong, Shengana and Kothoka. The inventory plot locations were digitized and the terrestrial coordinates were calculated by the GIS-Cell. In case of Helela, the inventory map was still available but the plot reference numbers did not correspond with those of the inventory data.

The inventory plot location was identified based on terrestrial field survey, starting from reference points. Due to difficult terrain conditions and lack of suitable reference points to re-adjust the grid net periodically, sometimes survey errors summed up and the inventory plot location in the field did no longer correspond with that on the inventory map. This was observed in particular in the case of Chendebjie. During restratification of the inventory data it was noticed that the inventory land use codes did not correspond at all with those on the LUWM.

ad 3) Only those inventories were suitable for the calculation of attributes where there was no change in forest condition from the time the inventory was conducted and the time the satellite imagery was taken (rem: 1991), otherwise inventory data and imagery interpretation would not correspond. This was the reason, why the data of Rimchhu and for part of Kothoka FMU could not be used.

Table 4 compiles the FMUs which have fulfilled the above mentioned criteria.

FMU	District	Area (ha)	Year of Inventory	Size of Grid	Date of Man. Pl.	Planning Period
Nahi	Wangdue	7645	1991	1000*250	1/5/93	1993-2002
Kamichhu	Wangdue	8728	1994/95	700*400	in prep.	-
Kothoka	Wangdue	8175	1994/95	700*400	in prep	-
Shengana	Punakha	6862	1993	575*575	-	-
Paro-Zonglela	Paro	16154	1989/90	600*300	28/4/92	1992-2002
Wangduegang	Zhemgang	9620	1990	600/900*300	28/4/92	1992-2002
Chapleykhola	Zhemgang	15542	1992	1000*750	-	-
Chendebjie	Tongsa	9720	1994/95	600*400	in prep.	-
Haa east	Haa	7040	1991	500*400	5/3/94	1994-2003
Karshong	Bumthang	4716	1991	500*200	26/11/94	1994-2003

Table 4: Inventories selected for the calculation of attributes

All the FMUs are located in similar vegetation zones as most of the areas of Punakha and Wangdue-Phodrang dzonkhags. In a mountainous area like Bhutan the effect of altitude and aspect on the vegetation is larger than any regional influence. The altitude and aspect ranges of the selected inventories correspond with the conditions of the project region. Figure 1 shows the geographic location of the selected inventories (FMUs).

Figure 1: Location of selected inventories (FMUs)

3.3.2 Attributes of Potential Forest Types

The attributes for the different potential LUPP forest land use classes were calculated as follows.

Identification of LUPP land use class

For all the selected inventories the sample plot locations were transferred to the GIS-System by digitizing the inventory base maps. After calculating the terrestrial coordinates of each sample plot the data were linked with the LUPP ARC/INFO vector land use coverages and for each sample plot the LUPP land use class was identified.

Restratification and Recalculation of Inventory Results

All the selected inventories had to be recalculated in order to gain the results for the different LUPP land use strata. For this purpose first new stratum codes had to be specified for each of the individual sample plots. During this process it was detected, that in case of Chendebjie, the FRDS land use codes did not at all correspond with the LUPP land use codes, while it did correspond quite well with the other FMUs. Therefore it was decided not to use the data of Chendebjie for the final calculation of attributes.

Restratification and recalculation was done with the help of the PLOT-System. However, due to recent changes in the PLOT-System (e.g. update of species codes, change to new land use codes, changes in system parameters, etc.) the data from inventories carried out before 1994 were no longer readable. This made it necessary to adjust the PLOT-System itself and the corresponding data bases as well.

Calculation of Attributes

The attributes were based on the recalculation of the restratified inventories and they are therefore based on the individual local volume and increment functions.

In each FMU the number of sample plots located within a particular "potential" LUPP forest land use class was quite different and also not all potential forest types were represented. The problem was now, how to calculate the average of the attributes. On one hand overrepresentation of a particular area (if the average is weighed only by plot numbers) should be avoided as well as the overrepresentation of just a few samples of a particular area (if the attributes of the different land use classes would gain the same weight for each FMU independent from number of samples). It was therefore decided to calculate the attributes for each potential forest type as the mean of the following both averages:

average 1: weighed by the plot number of each FMU, devided by total
average 2: not weighed (the result for each FMU has the same weight)

Table 5 shows the distribution of sample plots to the different potential forest types for each of the selected inventories.

FMU	FCf2	FCf3	FCb2	FCb3	FCm2	FCm3	FCc2	FCc3	FBc2	FBc3	FB2	FB3
Nahi			7	52	18	6	36					129
Kamichhu					6		36					52
Kothoka			67	8	11	66					14	15
Shengana							29					79
Paro-Zonglela	14	13	48		151							
Wangdigang											23	
Chapleykhola											32	39
Haa east			17		247							
Karshong			89		28							
Total	14	13	228	60	461	72	101				69	314

Table 5: Distribution of sample plots to potential LUPP forest types in selected FMUs

For FCc3, FBc2 and FBc3 no data were available. For the purpose of the FRPA of Punakha and Wangdue this is not of much effect, as these land use classes cover only a minor part of the identified potential areas on slopes <76%, as shown in table 6 below.

Dzonkhag	Potential Area (ha)	FCc3		FBc2		FBc3	
		(ha)	(%)	(ha)	(%)	(ha)	(%)
Punakha	57506	0	0	57	0	0	0
Wangdue-Phodrang	181285	38	0	2110	1	2493	1

Table 6: Area of potential forest types without inventory data available

In the following chapters LUPP land use classes are compared to those identified by the FRDS inventory teams. Discrepancies that occur between both land use classes may have the following reasons:

- The sample plot is located in a small patch of different land use. During forest inventory the land use is classified according to a 50 m circle around the plot, which represents an approximate area of 0.2 ha. LUPP did land use classification on a scale 1:50.000, where a polygon of a size of about 1 cm^2 represents already 25 ha, which was about the minimum size of polygons to be differentiated. So, whenever there was a small patch of different forest type within a large forest stratum (i.e. broadleaf forest in a small valley, or mountainous shrub within fir forest) this patch was included into the dominant forest stratum (see also chap. I 3.1).
- The inventory plot location does not correspond with the location on the map due to accumulated survey errors. This may occur especially if long lines had to be surveyed and if there was a lack on reference points to readjust the grid line. This might have been the reasons for the data mismatch in the case of Chendebjie.
- The land use was misinterpreted by LUPP.

A combination of the above mentioned sources for mismatch is also possible. It was observed that:

- Fir forest (FCf) and, to less extent, bluepine forest (FCb) were frequently interpreted as (FCm).
- Hemlock forest (FCm) was frequently interpreted as bluepine (FCb).
- Broadleaf forest (FB) was classified as chirpine (FCc).

In most cases this is due to misinterpretation of the SPOT imagery by LUPP. For example, it was experienced in the field, that in case of Gogona mixed conifer forest (FCm) was interpreted as Bluepine (FCb) and in Kothoka as Broadleaf forest (FB).

Other discrepancies might be due to errors in field survey or due to the size of the land use polygon.

In the following chapters, the different potential forest types are briefly described based on LUPP, 1993: "The Land Use Classification System". Also for each potential LUPP forest type a table is provided indicating the forest land use classes identified by FRDS inventory. The second column "corresp. LUPP land use" specifies the LUPP land use class which would correspond with the FRDS land use type based on the transformation key prepared by P. Laumans (LAUMANS 1994 a). The rows printed in bold letters show the cases where FRDS and LUPP interpretation correspond with each other. Annex 2 contains a list of the land use codes used by FRDS.
The attributes itself (average gross volume and increment) for each potential forest type are compiled in Annex 3.

3.2.2.1 Fir Forest FCf

LUPP Definition:

"Fir forest, *Abies densa*, either as a pure stand or mixed with juniper (*Juniperus spp*.) and taxus (*Taxus baccata*). Areas mapped as fir may also represent forest that is dominated by fir but mixed with other high altitude coniferous species such as larch (*Larix grifithiana*), hemlock (*Tsuga dumosa*) and spruce (*Picea spinulosa*). These fir forest areas generally occur between 3000 m and the tree line which occurs between 3800 m and 4200 m depending on aspect and microclimate."

For fir forests the attributes or stand data were calculated based on the inventory results of the FMU Paro-Zonglela only. For the purpose of the FRPA it would be better to have more information on fir forests in other areas, too. The LUPP interpretation matches quite well with the FRDS land use interpretation. Only in dense fir forest 2 plots were identified by FRDS as spruce forest and one plot as alpine shrub (see table 7.1). Altogether in 89% of the cases LUPP´s land use classification did correspond with the land use identified by the FRDS inventory.

FRDS Land Use Code	corresp. LUPP land use	FCf2 (Plots)	FCf3 (Plots)
ABID	**FCf**	**14**	**10**
PICS	FCm		2
ASHR	FS		1
Total		14	13

Table 7.1: FRDS land use codes identified in Fir Forest FCf

The average gross volume is about 410 m^3/ha in FCf2 and 250 m^3/ha in FCf3 (see Annex 3.3). In FCf2 96% of the gross volume is fir and 3% are other conifers, only 1% belong to Rhododendron or other broadleaf tree species (see figure 3). In FCf3 the percentage of other conifers, in particular spruce, is with 24% of the volume quite high.

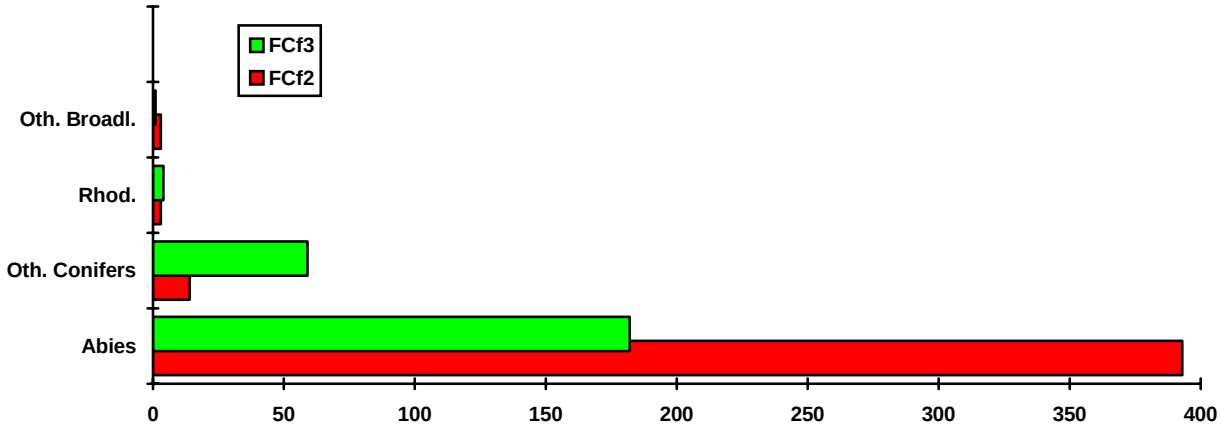

Figure 3: Species distribution of gross volume for fir forest.

The diameter distribution is somewhat different from FCf2 and FCf3, which can be clearly seen from figure 4. FCf3 has a significant gap in diameter class 60-69 cm and a peak in the diameter class 50-59 cm while in FCf2 the diameter 40 cm to 90 cm are well represented and there are also trees within diameter class above 120 cm.

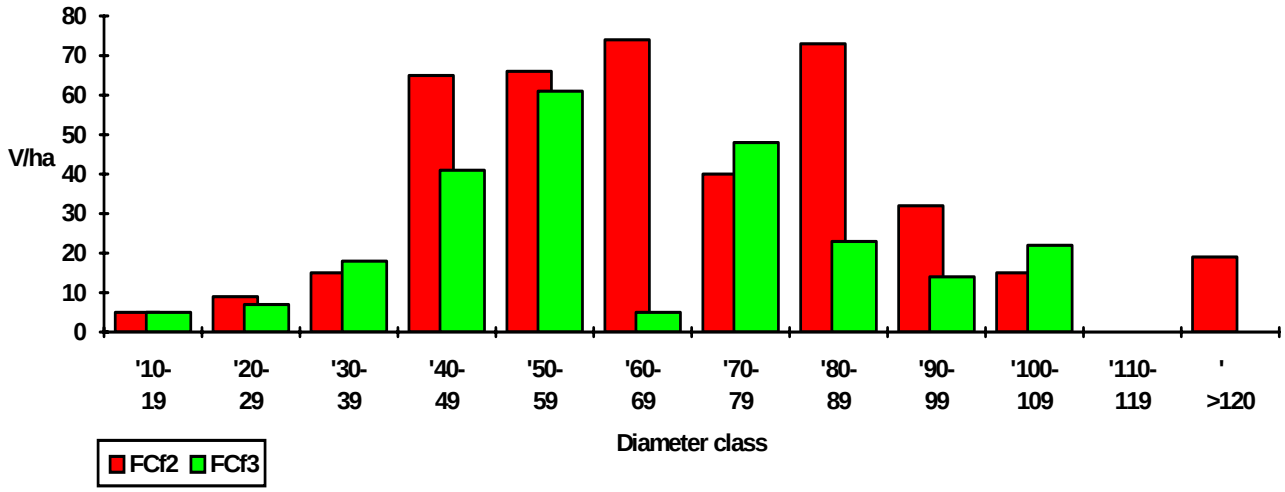

Figure 4: Diameter distribution of average gross volume for fir forest.

The annual increment for conifers (see Annex 3.4) is also higher in FCf2 (3.2 m^3/ha) than in FCf3 (2.7 m^3/ha).

3.2.2.2 Mixed Conifer Forest FCm

LUPP Definition:

"Mixed coniferous forest in which the main species include spruce and hemlock, either as a pure stand or where they dominate when mixed with, for example juniper, bluepine and taxus, and some broadleaf species such as oak and rhododendron. Areas of mixed coniferous forest most commonly occur within the altitude range of 2500 and 3500 m a.s.l."

For FCm2 inventory data were available from the following FMUs: Nahi, Kamichhu, Khotoka Paro-Zonglela, Haa East and Karshong., for FCm3 data were available from Nahi and Kothoka only.

From altogether 533 plots 40 plots (8%) were identified as pure broadleaf forest by FRDS. In 52% of the cases FRDS land use codes did correspond quite well with LUPP. It seems, that LUPP has frequently misinterpreted fir (FCf) and bluepine forests (FCb) as mixed conifers (FCm). Especially in Khotoka bluepine and hardwood & conifer forest were interpreted as mixed conifer by LUPP.

FRDS Land Use Code	corresp. LUPP land use	FCm2 (Plots)	FCm3 (Plots)
mixed conifers	**FCm**	**199**	**33**
ABID mixed	**FCm/FCf**	**21**	
PINW mixed	**FCm/FCb**	**5**	
He-Nb,Qu	**FCm/FBc**	**1**	**6**
Pb-He	**FCb/FCm**	**1**	**10**
ABID	FCf	129	
PINW, Pb	FCb	53	1
Pb-Nb,Qu,Rh	FCb/FBc	6	15
ASHR, SHR	FS	4	
QUES mixed	FBc	9	
QUES, UPHI, Nb, Nb-Qu	FB	33	7
Total		461	72

Table 7.2: FRDS land use codes identified in Mixed Conifer Forest FCm

In FCm2 the average gross volume (see Annex 3.3) is with 353 m^3/ha slightly higher than in FCm3 (326 m^3/ha). While in FCm2 fir is the dominating species (30%) followed by spruce (18%) and hemlock (16%). In FCm3 the share of fir is reduced to 8% in favor of spruce (26%) and hemlock (33%). Broad-leaved species have a share of 22% (FCm3) and of 26% (FCm2). The species distribution is shown in figure 5 below.

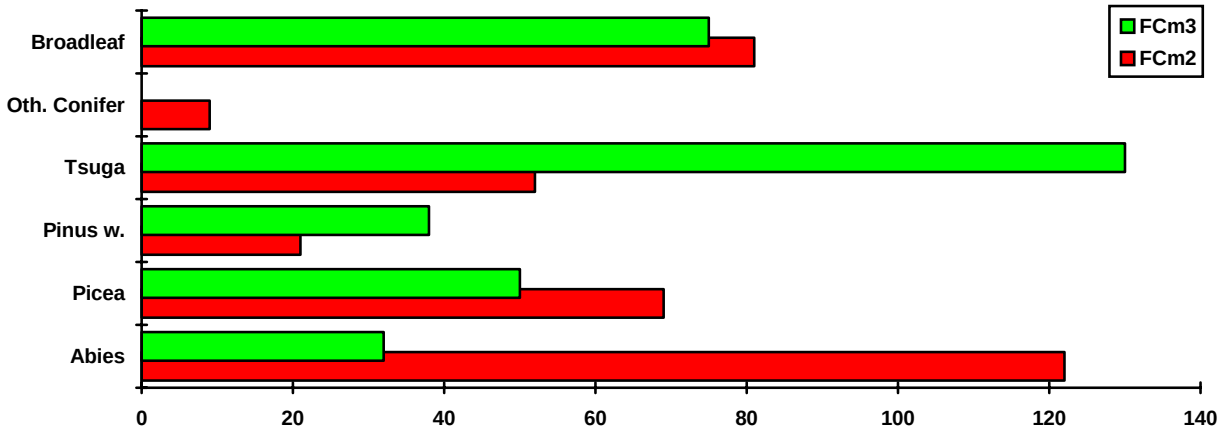

Figure 5: Species distribution of gross volume for mixed conifer forest.

The diameter distribution of FCm3 shows an high volume in the diameter classes above 90 cm. This is due to the fairly high percentage of big hemlock trees. The diameter classes of FCm2 are fairly well distributed (see figure 6).

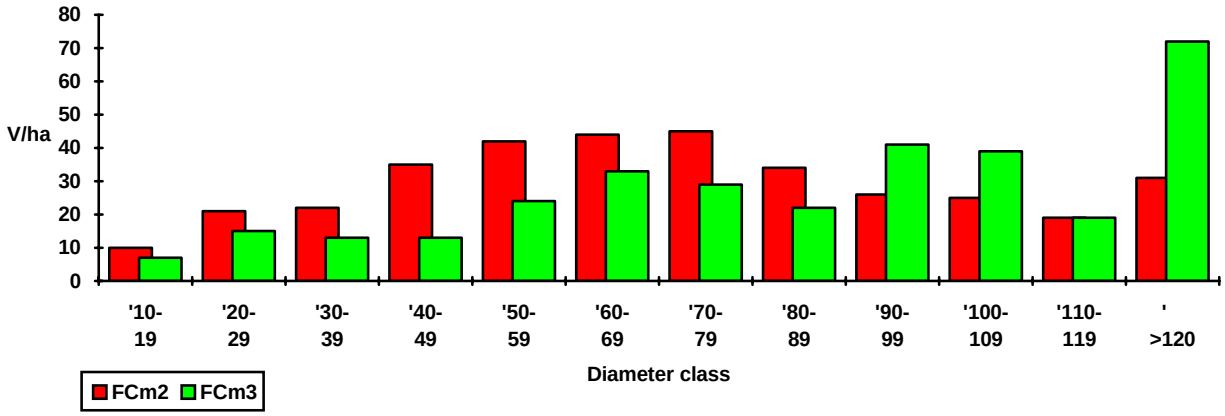

Figure 6: Diameter distribution of average gross volume for mixed conifer forest

The annual increment (see Annex 3.4) of FCm2 for conifers is with 2.6 m^3/ha considerably higher than that of FCm3 (1.6 m^3/ha).

In case of mixed conifer forest the different density classes do not reflect the development stage of the forest like it is the case in fir or broadleaf forests. It seems, that mixed conifer forests have in general a more uneven-aged structure, as all the diameter classes are well represented.

3.2.2.3 Bluepine Forest FCb

LUPP Definition:

"Bluepine forest (*Pinus wallichiana*), which generally occurs between altitudes of 1500 and 3000 m, and often exists as pure stands. However, areas mapped as bluepine also define zones where bluepine clearly dominate within a stand of mixed conifers and broadleaf species."

Inventory data were available for FCb2 from the following FMU´s: Nahi, Khotoka, Paro-Zonglela, Haa East and Karshong. For FCb3 only data from Nahi and Khotoka did exist.

In particular, mixed conifer forest (FCm) was frequently interpreted by LUPP as bluepine forest (19%) which was especially the case in Karshong, where 31 plots (37%) out of 89 plots were identified by FRDS as TSUD (hemlock). At Nahi also 69% of the plots were classified as UPHI (broadleaf) instead of FCb3. It has also been observed during field investigation at Gogona, that the area mapped as bluepine by LUPP consists out of mixed conifer and fir forest. In altogether 57% of the cases the LUPP interpretation matches with the identified FRDS land use codes.

FRDS Land Use Code	corresp. LUPP land use	FCb2 (Plots)	FCb3 (Plots)
PINW, Pb	**FCb**	**85**	**7**
PINW, mixed with QUER	**FCb/FBc**	**20**	
PINW, Pb mixed with conifers	**FCb/FCm**	**44**	
PICS, mixed with PINW	**FCb/FCm**	**4**	
He-Pb	**FCm/FCb**	**3**	
PICS, TSUD, MCON, He,Fi,Ju	FCm	44	12
ABID mixed	FCm	1	
ABID	FCf	3	1
ASHR	FS	1	
QUES,UPHI,CST?	FB	11	40
AGRI, Cu	-	12	
Total		228	60

Table 7.3: FRDS land use codes identified in Bluepine Forest FCb

The tree species distribution in figure 7 indicates clearly that in case of FCb3 misinterpretation of LUPP was considerable. Bluepine represents only 1% of the total gross volume (see Annex 3.3). Other conifers (55%) and broadleaf species (44%) clearly dominate. For FCb2 the situation is better. The percentage of bluepine is 31% and the total percentage of all conifers is 72%.

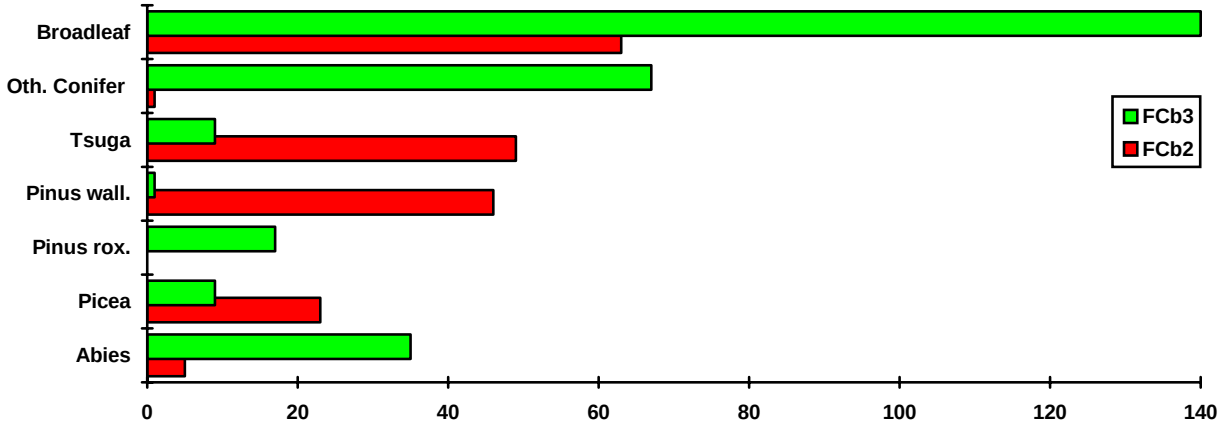

Figure 7: Species distribution of gross volume for bluepine forest

The average gross volume is in FCb3 with about 278 m^3/ha considerably higher than in FCb2 (186 m^3/ha). For both, FCb2 and FCb3, the gross volume is quite evenly distributed over all the diameter classes. The annual increment (see Annex 3.4) for conifers is, due to the high percentage of broadleaf species, in FBc3 with 0.7 m^3/ha much lower than in FCb2 (2.3 m^3/ha).

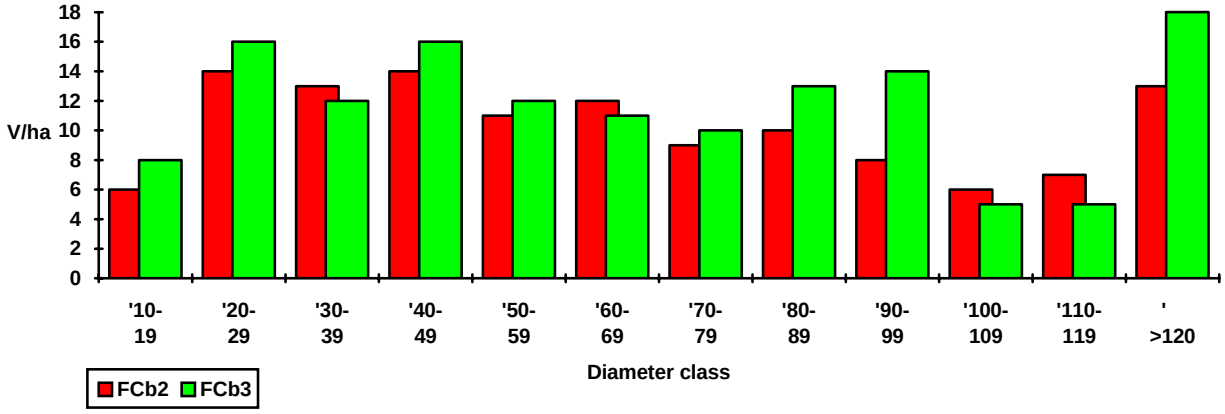

Figure 8: Diameter distribution of average gross volume for bluepine forest

3.2.2.4 Chirpine Forest FCc

LUPP Definition:

"Chirpine forest (*Pinus roxburghii*) are generally found between 700 and 2000 m and usually occur as pure stands. In some locations such as in depressions and along drainage lines, the chirpine may often be mixed with broadleaf species, such as oak."

Chirpine forests were classified by LUPP in Nahi, Kamichhu and Shengana FMU. However. there were no chirpine forest of density class 3 identified in all of the FMU´s. It seems, that dense chirpine forests do hardly occur. According to the GIS interpretation there is no potential (slope < 76) FCc3 in Punakha and only 38 ha of FCc3 exist in Wangdue-Phodrang Dzongkhag (see also table 6). Broadleaf forests were frequently interpreted as chirpine by LUPP. In altogether 60% of the cases the LUPP interpretation matches with the identified FRDS land use codes.

FRDS Land Use Code	corresp. LUPP land use	FCc2 (Plots)	FCc3 (Plots)
PINR, Pc	**FCc**	**50**	
Pc mixed	**FCc/FBc**	**11**	
PINW	FCb	1	
MONT,UPHI,QUES,CST?,FTHI,Nb	FB	34	
BARR,SHRU,.GRI	-	5	
Total		101	

Table 7.4: FRDS land use codes identified in Chirpine Forest FCf

Chirpine forests FCc2 were not considered as potential forest management areas as they are main management objective is cattle grazing (silvo-pastural management system). They also occur generally more on poor and shallow sites and their timber production capacity is quite low. The average gross volume of chirpine forest FCc2 is only about 100 m^3/ha (see Annex 3.3) and the annual conifer increment is just 1 m^3/ha (see Annex 3.4). The percentage of broadleaf species is with 56% fairly high.

3.2.2.5 Hardwood & Conifer Forest FBc

LUPP did not classify any hardwood & conifer forests in all of the 9 FMUs. It seems also that this land use class is not very common at least in the project region (see table 6). Altogether only 2% of the potential area in Wangdue-Phodrang Dzongkhag are classified as FBc, while in Punakha hardwood & conifer forests hardly exist (altogether only 57 ha). For the calculation of the production potential of a particular area, the area of FBc is added by FRPACALC.XLS to that of the mixed conifer forests (FCm).

3.2.2.6 Broadleaf Forest FB

LUPP Definition:

High altitude hardwood forests occur above 2600 m. They include evergreen oak (*Quercus semecarpifolia*), maple (*Acer* spp.) and birch (*Betula* spp.) and may include some coniferous species. Upland hardwoods occur generally between 1800 and 2600 m and may also include some coniferous species, but broadleaf species will clearly dominate. Lowland hardwoods appear below 1800 m (i.e. the sub-tropical area).

Broadleaf forests FB were classified by LUPP in many FMUs. FB2 was identified at Khotoka, Wangduegang and Chapleykhola, FB3 at Nahi, Kamichhu, Khotoka, Shengana and Chapleykhola. For broadleaf forest, in 78% of the cases LUPP´s land use classification matches with the identified FRDS land use codes. Chirpine and bluepine forests were the forest types which have been apparently misinterpreted by LUPP as broadleaf forest (11%).

FRDS Land Use Code	corresp. LUPP land use	FB2 (Plots)	FB3 (Plots)
UPHI,FTHI,CST?,MONT,Nb	**FB**	**55**	**235**
QUE?,Qu,Bl,Ch	**FB**		**10**
Pc mixed	FCc/FBc		6
Pb mixed	FCb/FBc		7
PINR, Pc	FCc		25
PINW, Pb	FCb		18
mixed conifer	FCm	14	6
AGRI, BARR, SHRU, PLAN	-		7
Total		69	314

Table 7.5: FRDS land use codes identified in Broadleaf Forest FB

The average gross volume (see Annex 3.3) of FB2 is with about 446 m^3/ha the highest of all forest types. The percentage of conifers is with 25% quite high, remarkable too is the high percentage of fir (12%) and hemlock (9%). This is due to the fact, that mixed conifer forests (mainly at Kothoka FMU) were misinterpreted as FB2. For FB3 the average gross volume is 275 m^3/ha and the percentage of conifers is reduced to 15%.

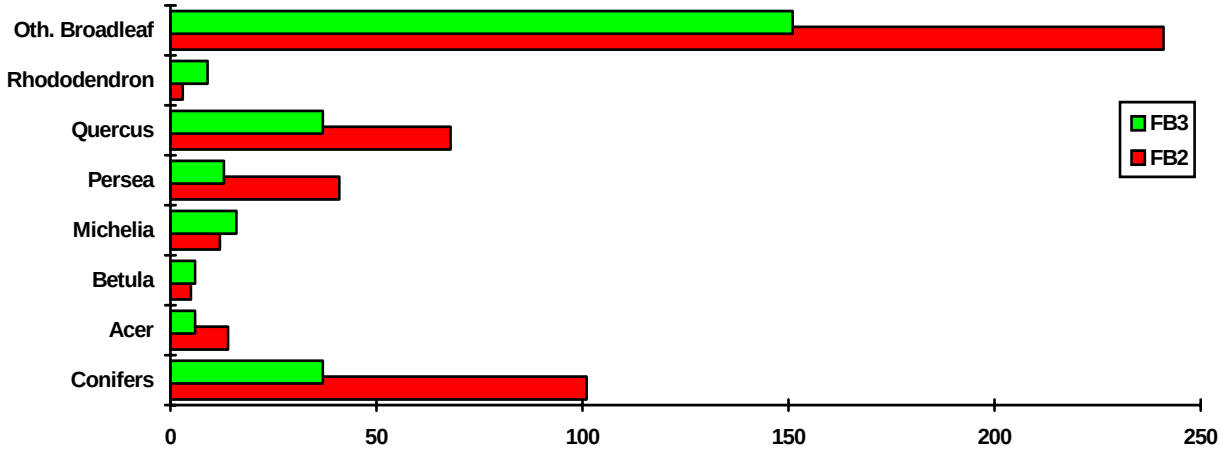

Figure 9: Species distribution of gross volume for broadleaf forest

All the diameter classes are quite well represented indicating that broadleaf forests have in general an uneven-aged structure. In FB2 the percentage of large trees (dbh > 120 cm) is quite high, altogether 30% of the gross volume falls into this category. This may indicate, that FB2 have an overmature top canopy and are rather in the fragmentation phase than in the old-age phase like it is the case with the FB3 forests. For broadleaf species no annual increment could be calculated, due to the lack of increment functions. The annual increment of conifers (see Annex 3.4) in broadleaf forests cannot be used as indicator for the production capability.

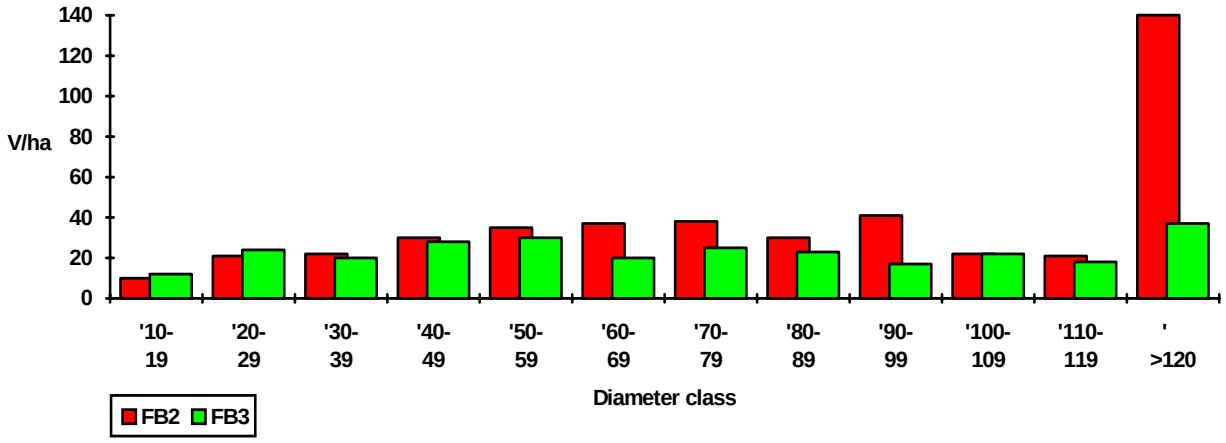

Figure 10: Diameter distribution of average gross volume for broadleaf forest

3.3.3 Conclusions and Recommendations

Inventory data were available for the most common forest types. For fir forests, however, the calculation of the attributes could only be based on the results of Paro-Zonglela. For hardwood & conifer forests FBc and for chirpine forest FCc3 no or not enough data were available. For FCb3 misinterpretation of the forest type was considerable.

It is therefore proposed, that the attribute calculation (FRPACALC.XLS) should be updated with the results of every new inventory conducted for management planning or reconnaissance survey. To do this update is however quite difficult, as it requires a lot of adjustments and recalculations. It is therefore advised to do the update with technical assistance of BG-IFMP only for several inventories at once. Also, the results would become more reliable and precise, if in future the inventory plot locations could be identified with GPS (or at least if the grid could be adjusted with GPS at every 4th plot). It is also recommended that the inventory base-maps are generally digitized and the geographic location of the inventory plots are linked with the GIS-system.

With more and more data available from forest inventories, the forest types could be further devided according to topographical features such as altitude zones (ecobotanical zones) and aspect etc., and separate attributes could be calculated for these subcategories.

The LUWP contain misinterpretations in terms of forest land use. This has been realized when joining and edgematching the digital land use coverage of LUPP. Also during field work, it was experienced that there are misinterpretations in the land use. However, considering the fact that the LUWP have been prepared for training purposes the land use classification did correspond quite well (see table 8) below:

LUPP Land use	Plots (No)	correct interpretation (%)

Fir Forest FCf	27	89
Mixed Conifer Forest FCm	533	52
Bluepine Forest FCb	228	57
Chirpine Forest FCc	101	60
Broadleaf Forest FB	383	78
All forest types	1272	64

Table 8: Conformity of LUPP/FRDS land use interpretation

As previously described there are also some other reasons if LUPP and FRDS land use classes do not correspond (unit size of interpretation, wrong location of inventory plots).

In the long run, the LUWM should be updated. For this purpose a lot of field truthing exercise could be saved if the interpreters would first refer to forest management maps or the PIS-Map.

Additionally, based on already existing inventory data, criteria for a plausibility test for the different forest types could be elaborated. This could be done by analysis of the PLOT.DBF files of the different inventories in the following way:

1. Convert FRDS land use code to LUPP land use code (use transformation code of LAUMANS, 1995)
2. Analyze LUPP land use codes in relation to altitude, aspect, region etc.
3. Define limits for every LUPP land use class.

By incorporating these limiting factors as a plausibility test into the GIS-system misinterpretation could also be minimized.

3.4 Calculation of Results based on GIS and FRPACALC.XLS

The results of the attribute calculation for the different potential forest types were saved as spreadsheet in an EXCEL file called FRPACALC.XLS. This spreadsheet can be used for the calculation of the total and average standing stock and increment of any selected potential area of a reasonable size. For this purpose, however, the area distribution of the various potential forest types have to be known. A printout of FRPACALC.XLS is attached in Annex 3 of this report. The EXCEL file itself is available at FRDS and BG-IFMP.

It has to be kept in mind, that the results of this calculation are fairly broad estimates, especially if smaller size areas (<20.000 ha) are concerned. This is due to the fact, that the landuse was sometimes misinterpreted by LUPP and that the attributes were calculated based on the average forest condition of a much larger region (central and eastern Bhutan). Therefore, the calculation of standing stock and growth by the FRPACALC.XLS program cannot replace the results obtained from a reconnaissance inventory. The results of FRPACALC.XLS should only be used as a criteria for the decision, whether an area can be considered as potential and reconnaissance survey should be undertaken!

The GIS-Cell of FRDS has stored the FRPA results (FINALXX coverage) on their computers. By digitizing the boundary of the defined potential area the GIS-Cell could do a printout of the area statistics without much effort.

3.5 Criteria for the Selection of FMU

One objective of the FRPA is "to identify potential areas for the establishment of self sustainable forest management units (FMUs)".

Several criteria for selection of a FMU have been set up by K.J. Subba and M. Pushparajah in RGOB/MOA/FSD/FRDS; 1994 (c), and by SCHINDELE, 1995 (a). While most of these criteria have to be checked on the ground during the reconnaissance survey, the following criteria can be used for the preselection of suitable areas:

Forest Condition

"The area should be well stocked and should consist of a high percentage of valuable (commercial) species. The estimated potential sustainable yield in the concerned area should allow a long term management of the unit." Especially areas with a high percentage of conifer forests are well suited for the establishment of a FMU.

The results of the FRPA, namely the area statistics and the calculation of the total gross volume and increment based on FRPACALC.XLS will allow a fairly rough estimate of a potential sustainable AAC. A more precise and quantitative assessment including social, economical, ecological and environmental aspects will be subject of the reconnaissance survey.

Accessibility

"The area must be accessible and/or road construction must be economically feasible and environmentally sound."

The FRPA-Map will provide rough information on the length and approximate alignment of the required road network. Detailed cost calculations have to be subject of the reconnaissance survey.

Size

"The area of the unit should be of reasonable size i.e. 4000-5000 ha, otherwise permanent and long term management would not be possible and the unit would not be self sustainable."

This will be a direct result of the GIS-analysis.

Boundary

"The boundaries of the proposed FMU should form a part of sub-catchment of the main watersheds. The proposed unit should encompass all barren and degraded areas adjacent and within the unit so that these areas can be rehabilitated."

The preliminary boundary will be defined by visual assessment of the FRPA-Map.

Part II FRPA: Results for Project Region

1 General Description of Project Region

The Kingdom of Bhutan lies in the eastern Himalayas between China (Tibet) and India. Gasa, Punakha and Wangdue-Phodrang Dzonkhag are located in Central Bhutan (see Figure 2: Administrative Map of Bhutan) and comprise with a total area of approximately 94000 km^2 25% of Bhutan.

Drainage and Aspect

The project area is entirely mountainous with main ranges following the general north-south direction. The main ranges branch off in a maze of spurs running in all directions with the result that all aspects are represented. However southern aspect appears to be more preponderant (GOI/MOA 1980).

Altitude

Altitudes vary considerably within the project region from the mainly alpine areas of Gasa with it's mountain peaks (up to 7000 m a.s.l.) and high altitude pastures down to the lower elevations of the southern part of Wangdue-Phodrang (600 m a.s.l. at Tsang Chhu Valley).

Slope

As aspect and elevation, the slope varies considerably, too. Steep and precipitous slopes dominate in Athang Gewog and at the junction of Khazi, Dangchhu and Nyisho Gewog of Wangdue-Phodrang and Toewang Gewog (Gasa). Moderate to gentle slopes are found in the center (i.e. Phobjikha, Gogona and Kothoka watersheds) and in the northern part (Sephu and Kazhi Gewog) of Wangdue-Phodrang . Also the slopes of the alpine pastures of Gasa are often moderate to gentle.

Geology

The main geological formations in Central and Eastern Bhutan are Chekha, Thimphu and Shumar which all are of pre-Cambrian origin. The Chekha formation is represented by a thick pile of meta sediments comprising crystalline limestone, mica schists, graphitic schists, quartzite, phyllite and intrusions of acidic and basic igneous rocks. Thimphu formation comprises of biotic gneisses interbedded with quartzite, quartz-mica-schists, crystalline limestone and garnetiferous schists intruded by basic sills, aplites, quartz veins and pegmatites. Shumar formation comprises of

Figure 2: Figure 2: Administrative Map of Bhutan

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phyllites and phyllitic slates containing gypsum and underlain by limestone, flaggy quartzites, phyllits and massive quartzites (GOI/MOA 1980).

Soil

The soil in the project region varies from sandy loam to clay loam depending upon the geological formation. Shallow soils are found under degraded forests of low density due to water and wind erosion and are commonly found under chirpine. Slightly acidic soils dominate. Podzolisation is quite common especially on degraded forest lands and pastures due to wash out of humus layer. Organic carbon and total nitrogen levels are mostly low, occasionally rising to medium. Under dense hardwood forest the soils usually have a quite thick layer of humus on the top and are quite fertile.

Climate

Climatic conditions are very diverse due to variations in altitude and aspect. At lower elevation in the south of Wangdue-Phodrang especially along the banks of Tsang Chhu, Hangra Chhu and Kisana Chhu the climate is subtropical to warm temperate, characterized by very hot month of May and June. With rising elevation the climate becomes more temperate and above 4000 m even subarctic to arctic. Seasons are well defined. Winter is most severe from mid December to mid march when snow falls in higher altitudes and the lower areas get rain. At higher altitudes, specially in northern aspect and sheltered places, snow does not melt easily and may stay till end of April. The change from winter to summer is rather gradual. Temperature continues to rise from mid March and rains often start in lower areas during April, otherwise March to May is a dry period in higher areas. The project region is influenced by the south-west monsoon which accounts for 90% of the annual precipitation. Rainfall varies with exposure to the monsoon winds. Regular monsoon break sometime during mid June and continue right up to end of September particularly in lower areas. The period from mid September to mid December is generally clear, rather cold and dry. Temperature decreases with increase in altitude at a lapse rate of about 0.5° to 0.6 ° C per 100 m (EGUCHI 1987). On the high mountains, exposure to the sun determines the temperatures. Fog and frost are frequent particularly in winter. In lower areas during the summer months the temperature can be quite high.

Vegetation

Because of its climatic and topographic situation the project region has a large diversity of plant communities. Altogether 47% of the project region is covered by forests. This - compared to the total forest cover of 72% for whole of Bhutan - comparatively low percentage, is due to the large share of areas above the timberline in Gasa and in the northern part of Wangdue-Phodrang Dzongkhag.

Table 9: Forest cover percent per dzongkhag

Dzongkhag	area (km^2)	forest cover percent (%)
Gasa	4038	19%
Punakha	974	84%
Wangdue-Phodrang	4409	65%
Total	9421	47%

Source: LUPP Dzongkhag and Gewog Data Sheets (LUPP 1995 a,b,c)

More detailed information on forest type and forest type distribution is provided in chap. II 2 of this document.

Taking into consideration the above mentioned topographic, climatic and physical factors for most parts of the project region forestry is the only alternative land use (LUPP, 1995 d). Land suitable for sustaining agriculture and horticulture is very limited and most of it is already under cultivation.

Population

The population density within the project area is with about 4 persons per km2 fairly low. Punakha has the highest population density of all three districts and also the highest percentage of urban population (11%), while Gasa is very sparsely populated due to its topographic and climatic condition.

Table 10: Population within project region

Dzonkhag	rural		urban		population
	household.	popul.	household.	popul.	per km^2
Gasa	412	2474	62	366	0
Punakha	2057	13532	294	1763	15
Wangdue-Phodrang	2809	21524	253	1516	5
Total	5278	37530	609	3645	4

Source: LUPP Dzongkhag and Gewog Data Sheets (LUPP 1995 a,b,c)

The average annual population growth rate within the period of 1986 to 2006 was estimated at 2.3% (CSO 1988/89:Statistical Yearbook of Bhutan).

Human Impacts on Vegetation and Fauna

Most of the forest areas are subject to grazing by cattle and/or yaks. The intensity of grazing is dependent upon the proximity to settlements and cleared pasture land. Grazing has considerable impact on the structure of the top soil which lead to lower infiltration rates. It also increases surface erosion and lead in the long run to degradation of the soil. Another negative effect of grazing is the suppression of natural regeneration of trees, which disturbs in the long run the structure and stability of the natural forests. Girdling of trees to open up forest areas for browsing and burning of undergrowth are other negative impacts correlated with browsing.

Table 11: Number of cattle in the project region

Dzonkhag	No of. cattle	cattle per km^2 land area	cattle per km^2 forest area
Gasa	4034	0.9	4.9
Punakha	10176	10.5	11.2
Wangdue-Phodrang	20820	5.2	7.9
Total	35030	3.7	9.2

Source: LUPP Dzongkhag and Gewog Data Sheets (LUPP 1995 a, b, c)

The collection of leaf litter as manure for agricultural production has also considerable effects on the forest soils. By removal of the leaf layer nutrients are removed and the top soil is exposed to rainfall, wind and high temperature and thus erosion is promoted.

The local demand for construction wood and fuelwood is usually collected from forests in the vicinity of the settlement or village or along the roadside. The average domestic wood consumption in the project region was estimated by SCHINDELE (1995 a) at 2.72 m^3/capita which was equal to a total consumption of about 110000 m^3 in 1993. In relation to the total forest area of about 445100 ha, the average exploitation rate for domestic wood is about 0.25 cbm/ha. This figure is definitely lower than the average annual increment of the total forest area. But, if the actual area where the wood is collected is taken into account the exploitation rate per ha definitely exceeds the annual increment. The effect can be observed everywhere in the project region: along roadsides and in the vicinity of settlements forests are already heavily degraded. More details on wood consumption and production are provided in chap. 5 of this document and in SCHINDELE (1995 a).

2 Analysis of Results for Project Region

General Remarks

The GIS-based analysis of the FRPA was only conducted for Punakha and Wangdue-Phodrang, as Gasa Dzongkhag lies completely within Jigme Dorji National Park. As mentioned before, it is the policy of the RGOB to exclude protected areas from commercial forest management.

A copy of the FRPA-maps at a scale 1:250.000 is attached in Annex 4 of this document. As mentioned in chap. II 3.2.1 as potential areas only those on slopes below 76% were considered. Areas on slopes of 76-100% are listed as "limited potential" but they are not included into the potential areas. It is assumed, that the amount of inoperable areas within slope class < 76% is approximately of the same size as the operable areas within slope class 76-100%.

Increment figures can only be given for conifers (see chap. I 3.3).

2.1 Project Region (Excluding Gasa)

The total area covered by the GIS-analysis was 501.250 ha, which is the area of Punakha and Wangdue-Phodrang dzonkhags, of which 29% are protected or otherwise restricted areas (31% if 10000 ha of Rimchhu FMU are included, see chap. II 2.2.1). Another 9% are already managed by FSD either as FMU, CF or WMU (see table 12).

Management Status	Non-Forest (ha)	Non-Potential (ha)	Forest Area Limited Pot. (ha)	Potential (ha)	Total Area (ha)
FMU, CF, WMU	3608	10327	2191	30887	47013
Protected Areas	11956	28005	20107	84481	144549
Unmanaged	139664	23917	22684	123423	309688
Total	**155228**	**62249**	**44982**	**238791**	**501250**

Table 12: Area distribution in project region excluding Gasa

Reminder:

High Potential:	slope <76%:	FCf2, FCm2, FCb3, FBc2, FB2
Potential:	slope < 76%:	FCf3, FCm3, FCb2, FCc3, FBc3, FB3
Limited Potential:	slope 76-100%:	FCf2, FCf3, FCm2, FCm3, FCb2, FCb3, FCc3, FBc2, FBc3, FB2, FB3

2.1.1 Potential Area Distribution

3460 km^2 or 69% of the project region (47% including Gasa, see table 9) is covered by forests, of which altogether about 2387 km^2 are considered as potential forest areas (47% of total area, 69% of forest area).

1154 km^2 are already under some type of management of which 309 km^2 are managed by FSD as FMU, CF or WMU and 845 km^2 are protected or otherwise restricted areas. It has to be mentioned here, that about 100 km^2 of Rimchhu FMU is located within JDNP, thus the total "protected" area is about 945 km^2. Altogether 1234 km^2 (52%) are unmanaged so far and have a good potential for forest management (see table 12, figure 11 and figure 12). Further detailed statistics on potential areas and their distribution according to altitude and slope can be derived from Annex 5.1.1.

Potential Class	FMU etc.		Protected		Unmanaged		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
high potential	11893	5	32879	14	54437	23	99209	42
potential	18994	8	51602	21	68986	29	139582	58
total potential	**30887**	**13**	**84481**	**35**	**123423**	**52**	**238791**	**100**
limited potential	2191	5	20107	45	22684	50	44982	100

Table 13: Potential areas of project region excluding Gasa

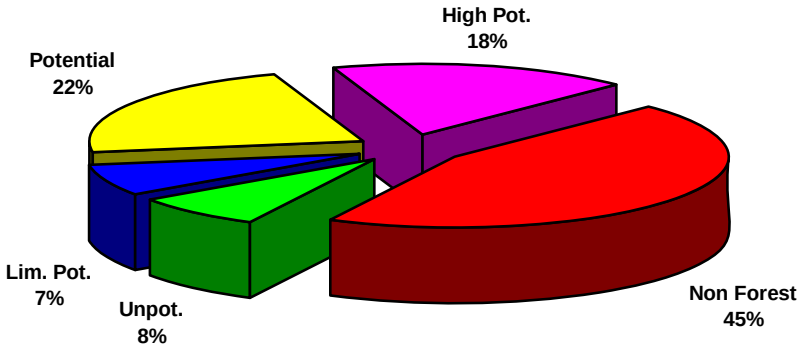

Figure 11: Potential area distribution in unmanaged areas of project region excluding Gasa

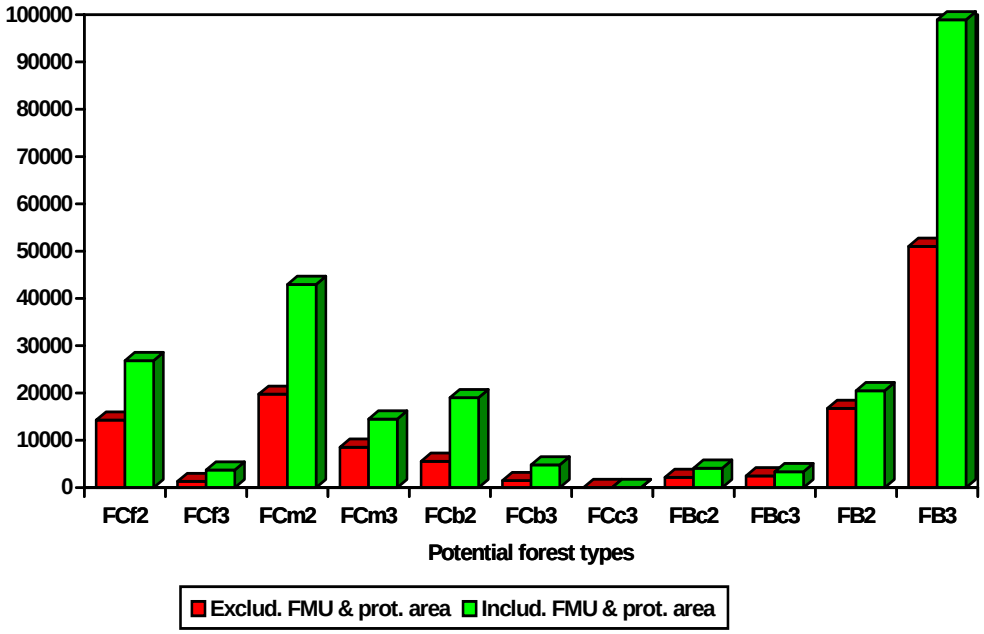

Figure 12: Distribution of potential forest types in project region excluding Gasa

Broadleaf forests FB dominate in the project region, especially FB3. Mixed conifer forest FCm and fir forests FCf2 are the next frequent forest types. There is no significant difference if the forest type distribution with or without FMUs and protected areas is compared.

The potential of the project region for forest management is quite good. From the 1234 km^2 of potential areas 44% can be considered as high potential. If broadleaf forests are excluded, the remaining area of high potential conifer forest is still 377 km^2.

2.1.2 Growing Stock and Growth

For the potential areas (excl. FMUs and protected areas) detailed statistics on average and total gross volume and on the increment of conifer species are listed in Annex 5.1.2.

The average gross volume of the potential forest area is about 330 m^3/ha that is equal to a total of about **40.5 mio m^3**. Figure 13 shows the distribution of the volume according to species and figure 14 according to diameter classes.

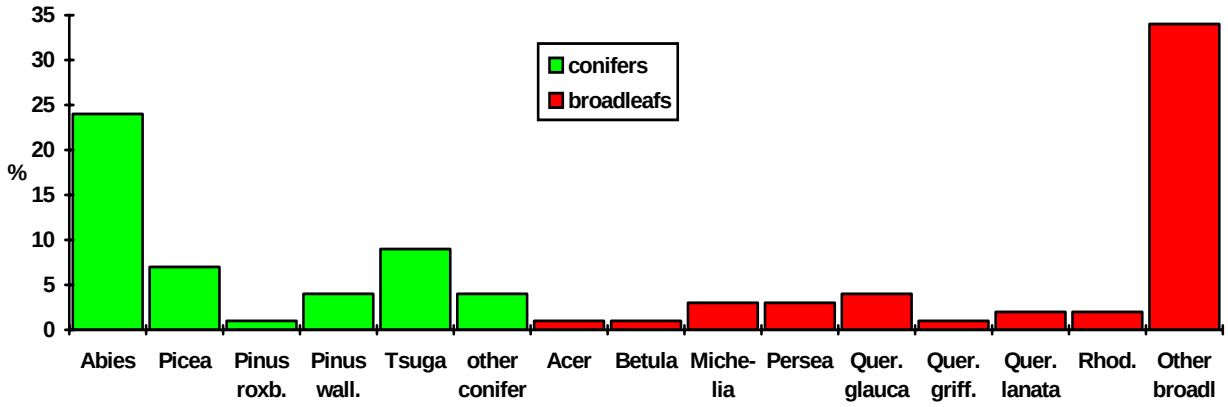

Figure 13: Species distribution of gross volume in project region excluding Gasa

The share of broadleaf species is 52% and that of conifers is 48% on the total gross volume. Fir is the species that is most common (24%) within the potential areas followed by hemlock (9%) and spruce (7). Oaks altogether have a share of 7%.

The diameter distribution of the gross volume shows for conifers the typical distribution of natural forests with a peak in the middle diameter classes, while for broadleafs the gross volume is quite evenly distributed. This might, however, be rather a result of the tree species distribution (i.e. the maximum dbh of Rhododendron will be around 30 cm) than of age distribution. It is particularly noticeable, that 15% of the average gross volume is covered by very large trees of dbh > 120 cm. Altogether 44% of the volume is covered by harvestable trees of dbh > 80 cm which is equal to about **17.9 mio m^3**. For a harvesting limit of 60 cm dbh the total exploitable volume would increase to 26.0 mio m^3.

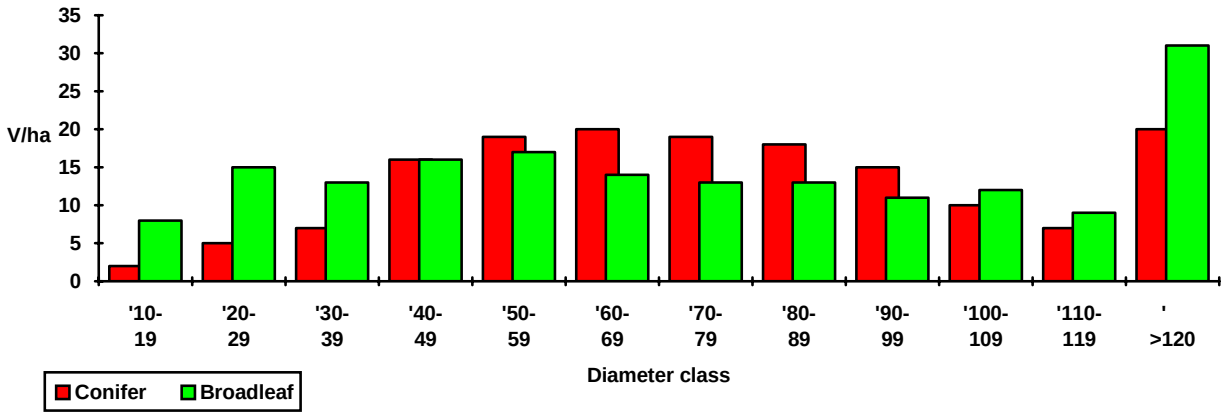

Figure 14: Diameter distribution of gross volume for project region excluding Gasa

The annual increment for conifers is about 1.35 m^3/ha. For broadleaf species no increment could be calculated. An estimate of the total increment is given in the following:

assumption: increment of broadleaf species is about 70% of that of conifers
annual increment of conifers (see Annex 5.1.272): 1.35 m^3/ha
percentage of conifer species: 48%
percentage of broadleaf species: 52%
total annual increment = 1.35 + 1.35*.7*0.52/0.48 = 2.37 m^3/ha

The total annual increment of the potential forest areas (excl. FMUs and protected areas) is about **0.29 mio m^3.**

2.2 Punakha Dzonkhag

Table 14 below shows the distribution of the dzonkhag area according to management status, land use and potential category. The area figures are derived from the GIS-analysis.

The total area of Punakha Dzongkhag is 97430 ha, of which 51% belong to Jigme Dorji National Park (JDNP). As already mentioned in chap. II 2.1.1 about 10000 ha of Rimchhu FMU is located within JDNP, thus the total "protected" area is about 59300 ha (61%). 20% of the dzonkhag area is already managed by FSD either as FMU, CF or WMU and only 29% are "unmanaged" areas.

Table 14: Area distribution of Punakha Dzonkhag

Management Status	Non-Forest	Forest Area			Total Area
		Non-Potential	Limited Pot.	Potential	
	(ha)	(ha)	(ha)	(ha)	(ha)
Dawakha CF	149	56	1	871	1077
Jilegang CF	191	627	3	219	1040
Rimchhu FMU	286	3032	485	6957	10760
Shengana WMU	1005	765	266	4826	6862
Total FMU	**1631**	**4480**	**755**	**12873**	**19739**
Jigme Dorji NP[*1]	4674	10212	6218	28193	49297
Total Protected	**4674**	**10212**	**6218**	**28193**	**49297**
Unmanaged Areas	**9175**	**2038**	**741**	**16440**	**28394**
Total Punakha	**15480**	**16730**	**7714**	**57506**	**97430**

[*1]: about 10000 ha of Rimchhu FMU are located in JDNP. The real area of JDNP in Punakha Dzonkhag is therefore about 59300 ha

2.2.1 Potential Area Distribution

Punakha has with 84% one of the highest forest cover percentages in Bhutan. From the total forest cover of 81950 ha altogether 70% are considered as potential for future forest management. 44% of the potential forest area is located within JDNP and 22% are already managed as FMU, CF or WMU. Altogether about 16440 ha of potential areas are available for future forest management, which mainly consist out of broadleaf forests. Table 15 show the management status of the potential areas (see also figure 15).

Potential Class	FMU etc.		Protected		Unmanaged		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
high potential	5619	10	12056	21	499	1	18174	32
potential	7254	12	16137	28	15941	28	39332	68
total potential	**12873**	**22**	**28193**	**44**	**16440**	**34**	**57506**	**100**
limited potential	755	10	6218	81	741	9	7714	100

Table 15: Potential forest areas of Punakha Dzongkhag

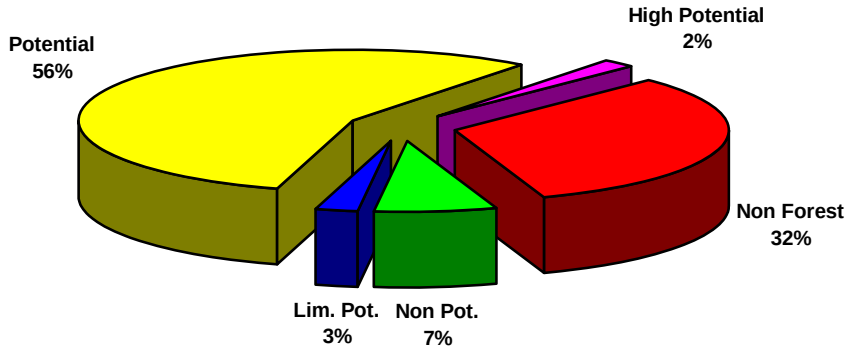

Figure 15: Potential area distribution in unmanaged areas of Punakha Dzonkhag

The potential forest area distribution according to altitude and slope is attached in Annex 5.2.1. It is noticeable, that the percentage of conifer forest in Punakha is only 3%, if FMUs and protected areas are excluded, while it is 34%, if FMUs and protected areas are included. This is an indication, that in Punakha all well suitable forest blocks for the establishment of FMUs are already managed in one or the other ways (refer to chap. 3.5). Therefore no potential FMU area could be identified in Punakha Dzonkhag.

As already mentioned the potential forest area consists almost entirely of broadleaf forest. Only at Rimchhu FMU, Shengana WMU and in JDNP there are some conifer forests.

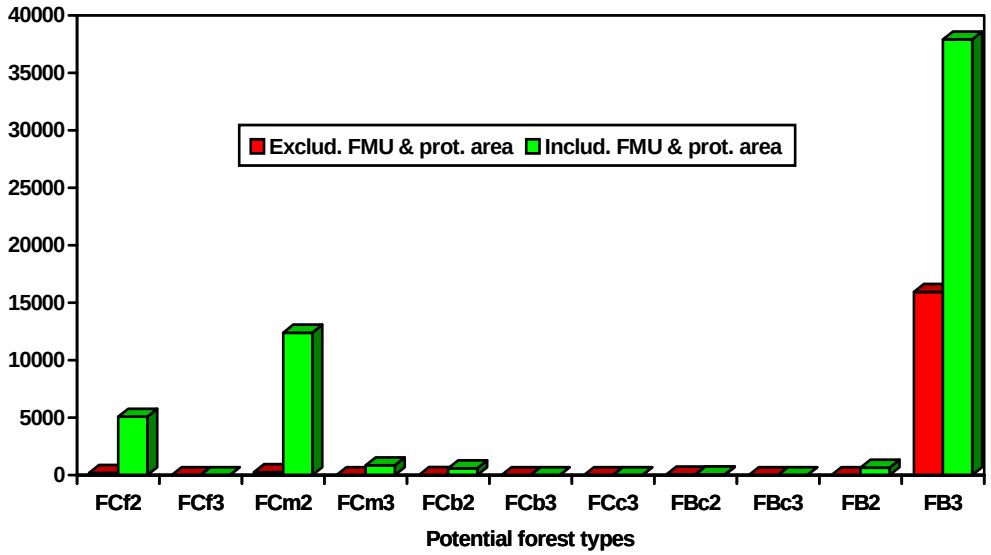

Figure 16: Distribution of potential forest areas in Punakha Dzonkhag

The distribution of potential forest types per gewog is attached in Annex 5.2.1. The Annexes 5.2.3/1-10 contain per gewog statistics of the distribution of the potential forest areas according to slope and altitude.

2.2.2 Growing Stock and Growth

The gross volume and the increment for conifers are listed for different species and diameter classes in Annex 5.2.2

The average gross volume of the potential forest areas is about 330 m^3/ha which is equal to a total of about **4.6 mio m^3**. Figure 17 shows the distribution of the volume according to species and figure 18 according to diameter classes.

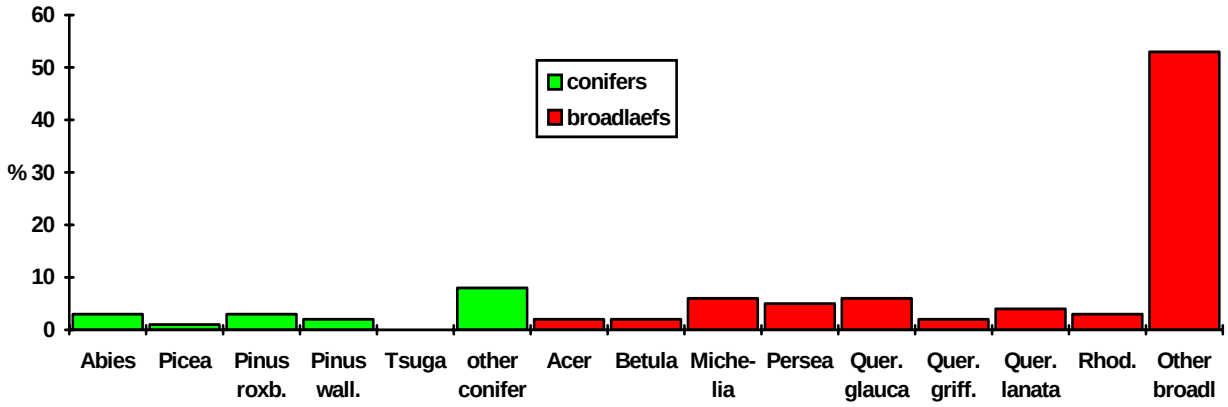

Figure 17: Species distribution of gross volume in Punakha Dzongkhag

Broad-leaved species have with 83% the main share of the gross volume, while conifers have only 17%. No particular coniferous species dominates. For broad-leaved species, the genus *oak* dominates clearly with altogether 12% of the gross volume.

The diameter distribution of the gross volume shows no particular trend, neither for coniferous, nor for broad-leaved species. Altogether 41% of the volume is covered by harvestable trees of dbh > 80 cm which is equal to about **1.9 mio m^3**. For a harvesting limit of 60 cm dbh, the total exploitable volume would increase to 58% or 2.7 mio m^3.

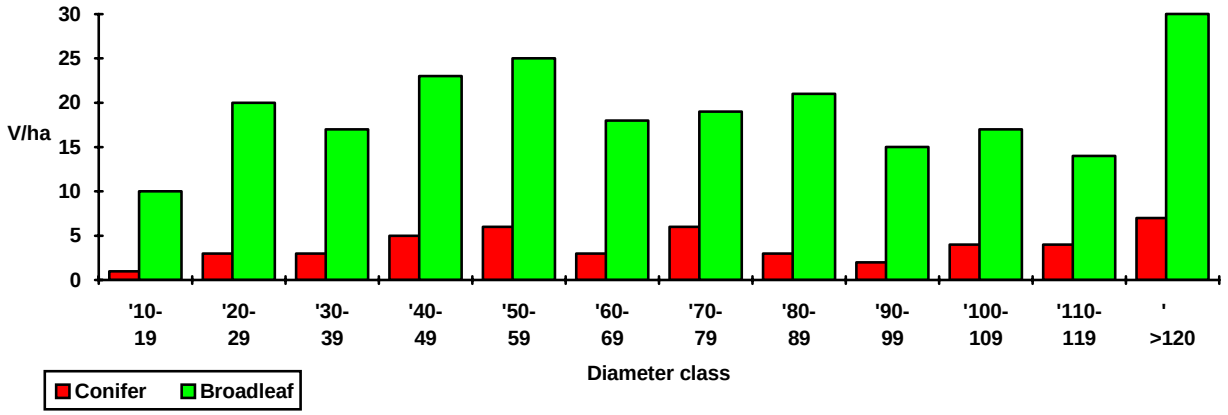

Figure 18: Diameter distribution of gross volume for Punakha Dzongkhag

Due to the very high percentage of broad-leaved species the annual increment can only be very roughly estimated as follows:

assumption: increment of broadleaf species is about 70% of that of conifers
annual increment of conifers (see Annex 5.2.2/2): 0.45 m^3/ha
percentage of conifer species: 17%
percentage of broadleaf species: 83%

total annual increment = 0.45 + 0.45*.7*0.83/0.17 = 1.99 m^3/ha

The total annual increment of the potential forest areas (excl. FMUs and protected areas) is about **32600 m^3.**

The volume and increment data of the potential forest areas of each gewog are listed in the Annexes 5.2.3/1-10.

2.2.3 Already Managed and Protected Areas

The following areas in Punakha are already designated as forest management units, community forests or watershed management areas. Because of the comparatively small size of the units, no results on standing stock and growth were calculated (see chap. I 3.4).

Rimchhu Forest Management Unit:

Rimchhu is the only forest management unit with the objective of commercial wood exploitation in Punakha. It comprises according to the GIS-analysis of an area of altogether 10760 ha, of which 6957 ha has been identified as potential area (see table 14). It belongs to Kabjisa Gewog and is located to a large extent (roughly 10000 ha) within the Jigme Dorji National Park. This is due to the fact, that exploitation of Rimchu has started in 1992 before the National Park was established in 1993.

Of the potential area 56% has been classified as mixed conifer forest FCm2, 16% as fir forest FCf2 and 28% as broadleaf forest FB3 (see Annex 5.2.5). Rimchhu is with altogether 5000 ha high potential forest area and the high percentage of conifer forest the only large forest block in Punakha which is suitable to be managed as a self sustainable FMU.

A forest management inventory has recently been completed, field truthing is going on. No management plan has been prepared so far. Based on a two years working scheme (operation plan) harvesting operations and other management activities are going on under the control of the DFO Wangdue.

Shengana Watershed Management Unit

Shengana has been officially declared as a watershed management unit. It is under the control and management of the Social Forestry and Extension Section (SFES) of FSD.

Shengana is located entirely at She'nganang Gewog and comprises the whole watershed of the Shenga Rong Chhu.

The total area of Shengana WMU is 6862 ha of which 4826 ha (70%) were classified as potential forest. Most of the potential area consists of broadleaf forest FB3 (88%) and only 18% were classified by LUPP as bluepine forest FCb2.

Dawakha Community Forest

Dawakha was identified as community forest in 1994. It is located at Toewang Gewog and comprises an area of 1077 ha of which 871 ha were classified as potential broadleaf forest FB3 by the GIS-analysis (see table 14).

A forest inventory was implemented in 1993-94 and a "Community Forestry Management Plan" has been compiled in November 1995 by SFES of FSD.

Dawakha is managed by the user group "Drong Yul Medey Negtshel" which consists of 72 households. The main management objectives are: to manage the forest area for a sustainable supply of timber and non-timber forest products and to maintain the ecological and environmental functions of the forest. For further details (see RGOB/MOA/FSD/SFES; 1995 b).

Jilegang Community Forest

Located at Toewang Gewog, Jilegang CF covers an area 1040 ha. Most of the area (60%) has been classified as non-potential for commercial forestry, 8% is comprised by non-forest land uses and only 22 % or 219 ha were classified as potential broadleaf forest FB3 (see table 14).

Jilegang was declared as community forest in 1994. A inventory design has been developed by FRDS, but due to lack of funds and manpower, the inventory was not implemented yet. However, land use mapping is completed, also boundary demarcation. Altogether three user groups were identified and for one user group a RRA was conducted.

Jigme Dorji National Park

Jigme Dorji National Park was declared in 1993. It's total area is 4200 km^2 out of which 593 km^2 are located at the Toewang, Goenshari, Chhubu and Kabjisa Gewog in Punakha Dzongkhag. Of the total forest area of about 550 km^2 only about 290 km^2 were classified as potential area, mainly FB3, FCm2 and FCf2. It is managed by the Nature Conservation Section (NCS) of FSD.

Jigme Dorji consists of only the western end of an former enormous wildlife sanctuary, but the border has been brought considerably further south to increase the range of habitats through conifer forests to upper broadleaf formations. This was one of the reasons, why about 10.000 ha of Rimchhu FMU was included into the park area. For more details on JDNP see RGOB/MOA/FSD; 1993.

2.2.4 Identification of Potential FMUs

A reconnaissance survey has already been undertaken at an area near Tame Damchhu for creating a new forest management unit in the area. The results have been presented in a report which found the set up of a FMU "economically and technically (scientifically) justifiable and feasible" (see ANON, 1996). According to personnel communication with responsible FRDS staff, this report is far too optimistic. Tame Damchhu is not considered as of high potential for forest management due to difficult accessibility, it's terrain features and forest condition. The cost for road construction (many rivers, narrow valleys) would be too high in relation to the actual forest area which could be taken under management. Also the area is quite densely populated.
According to the GIS-analysis Tame Damchhu consists mainly of broadleaf forest FB3 with a high percentage of inoperable areas.

Considering the selection criteria for the establishment of self sustainable FMU (see chap. I 3.5), the assessment of the FRPA-Map and the GIS-analysis comes to the result, that in Punakha Dzonkhag no suitable forest blocks exist which fulfill these conditions. However, due to the different objectives of CF and WMU there might be some suitable areas for the set-up of such units. However, within the context of this FRPA, those areas cannot be specified.

2.3 Wangdue-Phodrang Dzongkhag

Table 16 below shows the distribution of the dzonkhag area according to management status, land use and potential category. The area figures are derived from the GIS-analysis.

The total area of Wangdue-Phodrang Dzongkhag is 4038 km^2 ha, of which 581 km^2 are within Black Mountain National Park (BMNP) and 123 km^2 belong to Phobjika Protected Area. For the establishment of a Hydroelectric Power Station the watershed of Basechhu (248 km^2) was reserved. The total forest area excluded from commercial logging is altogether 880 km^2 (23%) of the total forest area.

Four forest areas are already managed as FMUs: Kothoka, Nahi, Kamichhu and Chendebjie (only a small part is located within Wangdue-Phodrang District) with a total area of 273 km^2 or 7% of the dzonkhag area. In relation to the total forest area, about 10% are already declared as FMU and are - or will be in future - managed sustainable for commercial purpose.

Table 16: Area distribution of Wangdue-Phodrang Dzonkhag

Management Status	Non-Forest (ha)	Non-Potential (ha)	Forest Area Limited Pot. (ha)	Potential (ha)	Total Area (ha)
Nahi FMU	888	1079	283	5386	7636
Kothoka FMU	701	1161	90	7427	9379
Kamichhu FMU	388	3568	1013	3716	8685
Chendebjie FMU	0	39	50	1485	1574
Total FMU	**1977**	**5847**	**1436**	**18014**	**27274**
Black Mountains NP	1772	14139	12292	29920	58123
Phobjika Protected Area	4075	1768	166	6334	12343
Basechhu Hydel	1435	1886	1431	20034	24786
Total Protected	**7282**	**17793**	**13889**	**56288**	**95252**
Unmanaged Areas	**130489**	**21879**	**21943**	**106983**	**281294**
Total Dzonkhag	**139748**	**45519**	**37268**	**181285**	**403820**

2.3.1 Potential Area Distribution

65% of Wangdue-Phodrang (see table 9) are covered by forest. From the total forest 1813 km^2 or 67% were classified as potential and another 455 km^2 (17%) as limited potential forest areas. Table 17 show the management status of the potential areas (see also figure 19).

Potential Class	FMU etc.		Protected		Unmanaged		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
high potential	6274	3	20823	12	53938	30	81035	45
potential	11740	6	35465	20	53045	29	100250	55
total potential	**18014**	**9**	**56288**	**32**	**106983**	**59**	**181285**	**100**
limited potential	1436	4	13889	37	21943	59	37268	100

Table 17: Potential areas of Wangdue-Phodrang Dzongkhag

From the potential areas 9% are already managed as FMU and 32% are protected or reserved for other uses. Still 59% are yet unmanaged and available for future management.

Altogether 373 km^2 were classified as limited potential, that means, that potential forest types are located on slopes between 76% and 100%. These areas have a high percentage of inoperable areas, and because of the high costs for the establishment of forest infrastructure and timber harvesting, they should not be considered per se as potential. Only if these areas are intermixed with potential areas on slopes below 76% they would be of limited potential (see chap I 3.3.2). Most of these "limited potential" areas are located at Athang Gewog south of Kothoka and Gogona area and at the junction of Kazhi, Dangchhu and Nyisho Gewog.

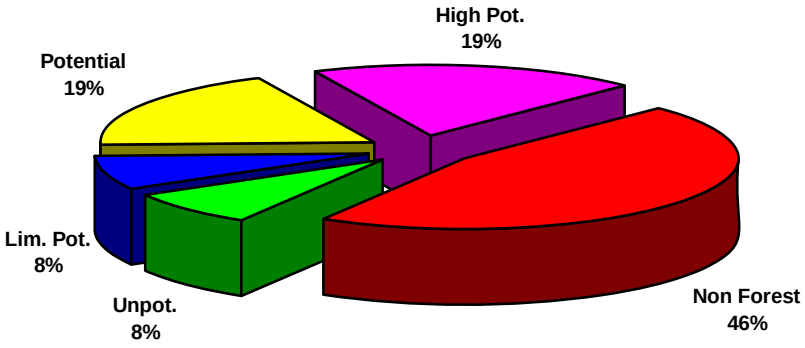

Figure 19: Potential area distribution in unmanaged areas of Wangdue-Phodrang Dzongkhag

The potential forest area distribution according to altitude and slope is attached in Annex 5.3.1. It contains also the distribution of the potential areas per gewog.

The following discussion of the potential forest area distribution always refers to potential areas on slopes < 76% and excludes already existing FMUs, protected and otherwise reserved areas.

47% are conifer forests, 49% are broadleaf forests and 4% are mixed hardwood & conifer forests (see figure 20). Broadleaf forests dominate at the lower elevations and are quite common at Daga, Athang and Nyisho Gewog. High potential broadleaf forests FB2 are less common than FB3. Mixed conifer forests, in particular high potential FCm2, are dominating with 55% among the conifer forests, followed by fir forest of density class 2 with 28%. Fir forests are only found at higher elevations and are quite common at Sephu, Kazhi and Phobji Gewog. Bluepine forests FCb have a share of 14% of the conifer forests and are found in larger blocks at Bjena, Athang and Phobji Gewog.

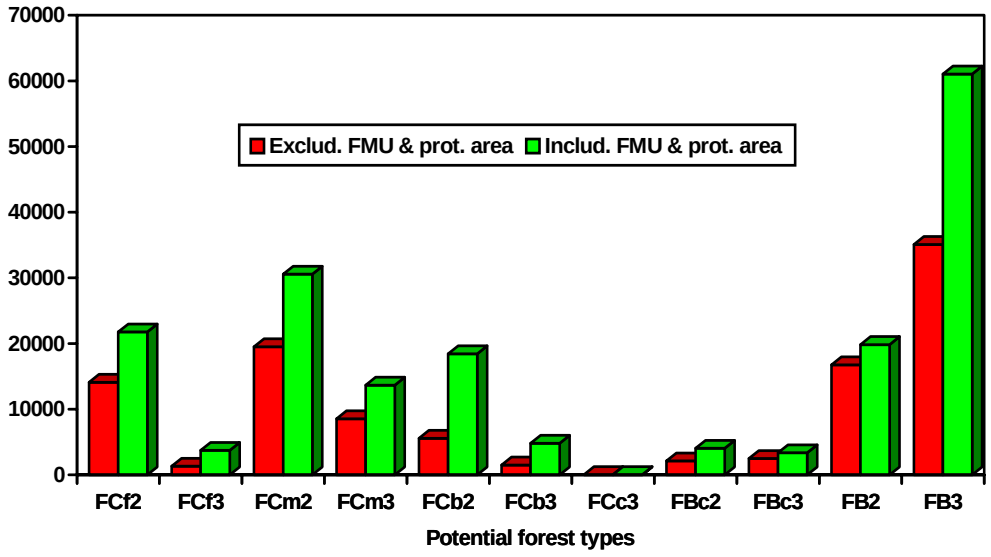

Figure 20: Distribution of potential forest areas in Wangdue-Phodrang Dzonkhag

The Annexes 5.2.3/1-10 contain per gewog statistics of the distribution of the potential forest areas according to slope and altitude.

2.3.2 Growing Stock and Growth

The gross volume and the increment for conifers are listed for different species and diameter classes in Annex 5.3.2 and per gewog in Annex 5.3.3.

The average gross volume of the potential forest area is about 335 m^3/ha, that is equal to a total of about **35.9 mio m^3**. Figure 21 shows the distribution of the volume according to species and figure 22 according to diameter classes.

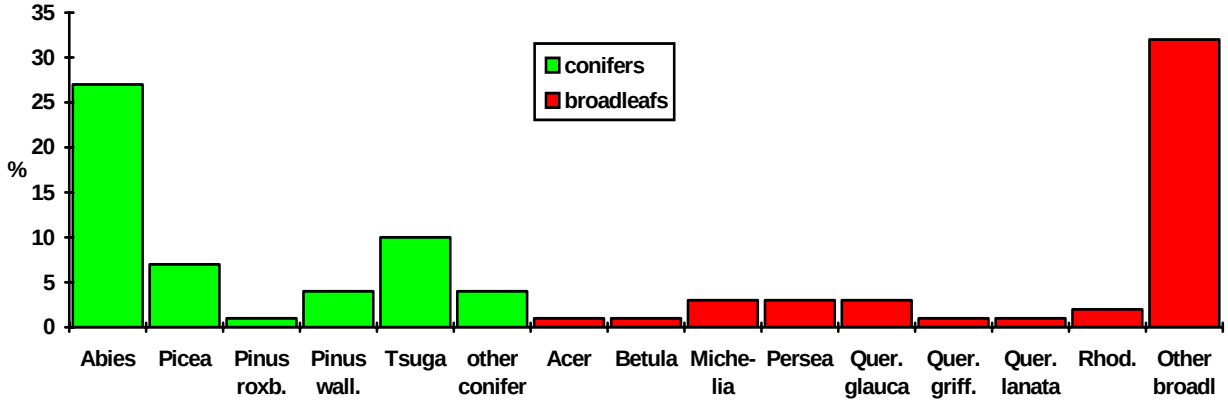

Figure 21: Species distribution of gross volume in Wangdue-Phodrang Dzongkhag

Neither conifer species (52%), nor broadleaf species (48%) dominate. The most common tree species is fir due to the large area of fir forests at higher elevations and the high percentage of fir (30%) in FCm2. Hemlock (10%) and spruce (7%) have a considerable share on the gross volume, too. Because of the high amount of different broadleaf species which are common in the project region, "other broadleaf" species have a share of 32% on the gross volume.

Especially conifers are of interest for commercial timber production. However, fir has a considerable high percent of decay, and the log recovery rate is thus quite low. The total gross volume of other conifers except fir is estimated at about 9 mio m^3/ha.

The diameter distribution of the gross volume shows for conifers the typical distribution of natural forests with a peak in the middle diameter classes, while for broadleaf species the gross volume is quite evenly distributed. This might be, however, rather a result of the tree species distribution (i.e. the maximum dbh of Rhododendron will be around 30 cm) than of age distribution. It is particularly noticeable, that 16% of the average gross volume is covered by very large trees of dbh > 120 cm. Altogether 46% of the volume is covered by harvestable trees of dbh > 80 cm which is equal to about **16.0 mio m^3**. For a harvesting limit of 60 cm dbh the total exploitable volume would increase to 23.3 mio m^3.

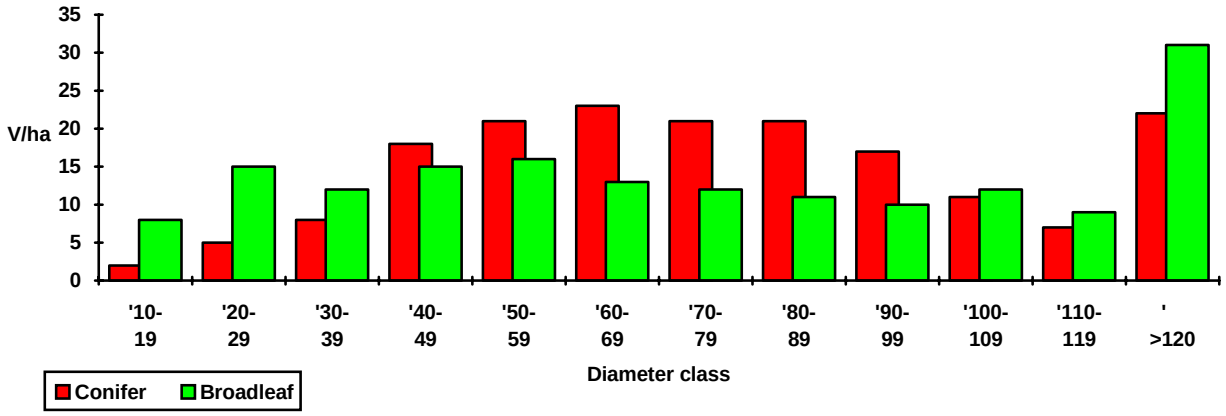

Figure 22: Diameter distribution of gross volume for Wangdue-Phodrang Dzongkhag

The annual increment for conifers is about 1.49 m^3/ha. For broadleaf species no increment could be calculated. An estimate of the total increment is given in the following:

assumption: increment of broadleaf species is about 70% of that of conifers
annual increment of conifers (see Annex 5.3.2/2): 1.49 m^3/ha
percentage of conifer species: 52%
percentage of broadleaf species: 48%

total annual increment = 1.49 + 1.49*.7*0.48/0.52 = 2.45 m^3/ha

The total annual increment of the potential forest areas (excl. FMUs and protected areas) is about **0.26 mio m^3.**

The volume and the increment of the potential forest areas of each gewog is attached in the Annexes 5.3.3/1-10.

2.3.3 Already Managed and Protected Areas

Potential area statistics for the FMUs are attached in Annex 5.3.5 and for protected or otherwise restricted areas in Annex 5.3.4.

Kothoka Forest Management Unit

Kothoka FMU was already established in 1983 and consists of two sub units: Pazechu and Kekephu. The Bhutan Logging Corporation (BLC) started forest management in 1984 based on a 10-years management plan for a period of April 1984 to April 1994 (see RGOB/MOA; 1983). The FMU area was extended in 1994 towards southwest leading to an increase of area from 4908 ha to 9379 ha.
Kothoka is located at an altitude from 2500 m to 3600 m a.s.l. in the south of Bjena and in the east of Ruepaisa Gewog. According to the GIS-analysis most of the area is covered by mixed conifer FCm and

bluepine forests Fcb (see Annex 5.3.5). The identified broadleaf forests by LUPP are obvious misinterpretations.

Kothoka is not accessible by road, but by Tashila ropeway, which was especially constructed for the management of the FMU.

The management plan of 1984 has calculated the annual yield at 6900 m^3. Unfortunately no data about the real harvested volume or the log recovery are available for the whole past planning period.

Timber conversion is done by two sawmills inside the FMU and the products are transported down to the market via the privatized Tashiling ropeway, which turned out to be the "bottleneck" of the timber production capacity. A study on the forestry operations within Kothoka with special consideration on it's economy was conducted by BG-IFMP in 1996 (see RIEGER 1996).

A new management plan is at present under preparation by FRDS based on the results of a forest management inventory which was conducted in 1995.

Nahi Forest Management Unit

In 1993 the whole of Nahi Gewog was declared as a FMU. It comprises a whole watershed and includes Nahi village with it's agricultural areas. It is located at an average altitude of 2400 m a.s.l. ranging from 1200 to 3600 m.

Already in 1991 a management inventory was conducted which estimated the total growing stock of the accessible area (about 5000 ha) at 1.23 mio m^3 of which only 12% are conifers. In 1993 a management plan prepared by FRDS was approved which is valid from 1993 to 2002. The annual allowable cut (AAC) was fixed by the plan at 10000 m^3 and the revenue for the 10 years period was estimated at Nu 27.6 millions (see RGOB/MOA/DOF/FRMD; 1993 b). According to the opinion of BG-IFMP the AAC estimate is too high (SCHINDELE, 1995 a). MAIER (1995) criticized the missing holistic approach in the management plan. KLEINE (1996) developed some guidelines for the silvicultural treatment of the broadleaf and chirpine forests based on studies in Nahi FMU.

Harvesting or management operations have not yet been started.

Kamichhu Forest Management Unit

An total area of 8685 ha at Daga Gewog has been identified as Kamichhu FMU. It consists out of the northeast facing slope towards the Tsang Chhu and ranges from 800 m in the south up to 2800 m a.s.l. in it's northwest corner. According to the GIS-analysis only about 3700 ha are considered as potential, of which most of it are broadleaf forests (see Annex 5.3.5).

A management inventory has already been conducted, but no results are available up to now. Field truthing for aerial photo interpretation (preparation of land use map) is currently on. Harvesting or management operations have not yet been started.

Chendebjie Forest Management Unit

Only a minor part (1574 ha) of Chendebjie FMU is located in Sephu Gewog. The main part belongs to the administration of Tongsa Dzonkhag. The management of Chendebjie is controlled by the DFO Tongsa.

For Chendebjie a management plan is available for the period of 1996 to 2005.

Black Mountain National Park

The Black Mountain area was declared as a national park in 1995. It comprises a total of 1400 km^2 of which about one third (581 km^2) is located in Athang and Phobji Gewog. It constitutes the largest and richest temperate forest nature reserve in the entire Himalayas (RGOB/MOA/FSD; 1993). The park contains almost no permanent residents.

The relief of BMNP within the project area is characterised by steep slopes and narrow valleys. Only 53% of the park's forest area was classified as potential (almost all forest types exist) and 25% as limited potential (slopes 76-100%). In the remaining 22% of the area slopes above 100% dominate.

The BMNP is managed by NCS of FSD.

Phobjikha Conservation Area for Black Neck Crane Wintering

The area around Phobjikha valley, Phobji Gewog, was declared in 1992 as a conservation area for the wintering of the Black Neck Crane. The total conserved area is 123 km^2. Almost 50% of it has been classified as high potential mixed conifer FCm2 (see Annex 5.3.5) and potential bluepine forests (FCb). Although it is not legally specified, it is the policy not to establish a FMU in a conservation area. Conservation areas are multiple use areas and as such do not need to be under the management of the Nature Conservation Division (RGOB/MOA/FSD; 1993).

Basechhu Hydel

The watershed of Hetsho Chhu in Gase Tsho Aom and Daga Gewog was reserved for the establishment of a hydroelectric power station. The whole area included in the hydel scheme is about 248 km^2. The percentage of potential forest areas is with 81% fairly high. The area of Basechhu hydel contains all type of forests except chirpine.

Unfortunately, no more information on Basechhu hydel could be obtained.

2.3.4 Identification of Potential FMUs

As already mentioned Wangdue-Phodrang Dzonkhag has a large area of forest with a good potential for forest management. However, the criteria set (see chap. I 3.5) for the selection of areas suitable for the establishment of a FMU is only fulfilled by three forest blocks which are briefly described in the following:

Gogona potential FMU area

The potential FMU area is located between Kothoka FMU in the west and Phobjikha Conservation Area in the east and belongs to Bjena and Athang Gewog. The southern boundary is formed by the transition from the gentle slopes of Gogona valley to the steep slopes facing towards the south. The total area calculated by the GIS-analysis is about 8203 ha of which 7062 ha were classified as potential. It has to be mentioned at this place, that the classified bluepine forest have been misinterpreted by LUPP and are in most cases mixed conifer forests FCm.

The valley bottom is intensively used for pasture and for agricultural production. Almost all the forest area is intensively browsed and used for yak wintering.

A fairly rough estimate (note: based on LUPP´s land use classification) based on calculation with FRPACALC.XLS resulted in a total gross volume of 2.1 mio m^3 (see Annex 5.3.6/1) and in an average annual increment of about 20300 m^3.

Gogona valley is not accessible yet by motor vehicles. The establishment of a FMU would require the construction of about 20 km forest road starting from Phobjikha. From the technical viewpoint road construction would be quite easy. The total costs for road construction are roughly estimated at Nu 17 Mio (SCHINDELE, 1995 a). A disadvantage, however, is the long transport distance from Phobjikha to the timber market at Lobesa, which takes about 3 hours by car. Also the road has not everywhere been constructed for heavy transport. Due to the dominating gentle relief of the Gogona valley, on the other hand, harvesting operations could be quite easily done by cable crane.

As it was pointed out clearly in chap. I 2.2 the decision whether a FMU should be opened or not cannot be the task of the FRPA, this needs much more detailed investigation. Therefore at present a reconnaissance forest inventory is implemented by FRDS which will provide quite detailed information on the forest condition, standing stock and growth (SCHINDELE 1995 b,c). Additionally a socio-economic study and a preliminary environmental impact assessment have to be carried out as well as an economic feasibility study based on the results of the reconnaissance forest inventory.

Sephu West potential FMU area

Sephu West potential FMU area is located between Nyekha Chhu in the east and the gewog boundary in the west. In the south the boundary is formed by the motorable road and in the north by a small river. It ranges from 2800 m in Nyeka Chhu valley up to 4100 m a.s.l. in the northwestern corner. In the northern part the terrain becomes more rough and the percentage of steep slopes increases. The potential FMU area is located completely within Sephu Gewog.

The total area is approximately 7800 km^2 of which 4872 were classified as potential forest areas. Fir forests of density class 2, characterized by a high gross volume, dominate with 69% of the potential areas. They form the forest zone in the north on altitudes above 3200 m a.s.l.. In the southern part, below the fir zone mixed conifers form the major part of the forest.

The total gross volume calculated with FRPACALC.XLS amounts up to 1.9 mio m^3 (see Annex 5.3.6/2) and the total annual increment is estimated at about 15500 m^3.

A problem for future management, which will affect the economic feasibility of forest management is the high cull percentage of fir.

The area is already accessible by a motorable road to Lobesa. There would be only the need to construct logging roads to the log landings of the cable cranes.

As for Gogona, more detailed investigations in form of a reconnaissance survey are required to finally decide, whether a FMU should be opened in this area or not.

Sephu East potential FMU area

This forest area is located at a southwestern slope between Nyeka Chhu in the west, the dzonkhag boundary to Tongsa in the east and Chendebjie FMU in the south. The altitude ranges from 2800 to 3600 m a.s.l..

In the southwest, the area is accessible by a motorable road. For future management, however, about 7 km of access roads along the Nyeka Chhu would have to be constructed.

The total area is approximately 4000 ha of which only 2850 ha were classified as high potential FCm2 (86%) and hardwood & conifer forest FBc2 (14%). The result of FRPACALC.XLS are listed at Annex 5.3.6/3, which estimates the gross volume at 0.9 mio m^3 and the annual increment at 7800 m^3. Because of the comparatively small area, these results are not much reliable (see chap. I 3.4).

Because of it's comparatively small size, it is questionable whether this area can be managed in future as a self sustainable FMU (see chap. I 3.5). This has to be subject of a detailed reconnaissance survey.

3. Production/Demand Scenario

SCHINDELE 1995 (a) has calculated the timber and wood demand of Gasa, Punakha and Wangdue-Phodrang dzongkhags. The results are listed in Annex 6.

The domestic wood consumption per capita in standing volume equivalent without the consumption of the industry and export was estimated 1993 at 2.72 m^3 (see table 18). Multiplied with the total population of about 41200 capita in 1995 (see table 10) the total domestic demand results in 112000 m^3 standing volume equivalent. It has to be mentioned, that the figures on construction wood for Punakha and Wangdue-Phodrang most probably include wood produced for the construction of the NRTI building and the renovation of Punakha Dzong (SCHINDELE, 1995 a). Therefore, the total wood demand estimate should be considered to be on the upper limit.

	Population (capita)	Firewood. (m^3/cap.)	Construction (m^3/cap.)	Total (m^3/cap.)	(m3)
Gasa	2840	2.24	0.21	2.45	6958
Punakha	15295	1.49	0.88	2.37	36249
Wangdue-Phodrang	23040	1.64	1.35	2.99	68890
Total	41175	1.62	1.10	2.72	112097

Table 18: Wood consumption in the project region

To forecast the per capita consumption of wood in future is very difficult. This depends on too many unpredictable factors such as population development, change of livelihood, industrialization, urbanization, migration, change in house construction, wood demand for public buildings and road construction, etc.. SCHINDELE 1995 (a) came to the conclusion that most probably the factors increasing/decreasing the demand may compensate each other and that the total wood demand per capita will remain at the same level or will even be reduced. (Note: the per capita consumption is quite high compared to other countries).

The demand of timber for the industrial purpose was estimated 1993 at 6800 m^3 and for export at 12000 m^3. It is supposed, that this demand may increase at the same rate as the average population growth rate of 2.3% predicted for the period 1986 to 2006 (CSO 1988/89: Statistical Yearbook of Bhutan).

For 1995 the total amount of wood consumed can be estimated as follows:

Domestic demand	112000 m^3
Industry	7100 m^3
Export	12600 m^3
Total	131700 m^3

The total wood demand per capita including industrial demand and export is 3.2 m^3 per capita.

Depending on the type of wood product (firewood, construction wood, shingleps, etc.) and the user (rural or urban population, industry, export), 73 % of the demand was collected and exploited from "unmanaged" forests, 18% was produced by FMUs and 9% came from imports from other dzongkhags (SCHINDELE 1995 a).

It is expected, that in future the wood required by the rural population will be produced in own community forests or - like right now - by allocation of wood in "unmanaged" forests. Thus the production rate of 73% of the demand by yet "unmanaged" will not change much. The urban and industrial demand and the demand for public purposes will have to be produced in sustainable managed FMUs in the long run.

Production capacity of forest outside FMU (excluding protected areas)

The most important factor for determining the productivity of a forest is the annual increment. It should be kept in mind, that in unmanaged natural forests the increment is much lower than in managed forests.

If it comes to exploitation, especially old trees should be used which have already reached their cumulating point of growth. In Bhutan, depending on the forest type (and of course on the tree species), it is assumed that this is reached at an average diameter of 60 to 80 cm.

For a valuation whether the forest can sustainable supply the required wood demand, the gross volume of harvestable trees and the annual increment are the most important factors (see table 19).

Dzonkhag	Gross Volume (m^3)	(m^3)	(m^3)	Annual Increment (m^3)
Punakha	4.6	2.7	1.9	0.03
Wangdue-Phodrang	35.9	23.3	16	0.26
Total	40.5	26.0	17.9	0.29

Table 19: Production capacity of "unmanaged" potential forest areas

In 1995 a total of 96100 m^3 (131700 m^3 *.73) of wood was exploited for the rural demand that is only 33% of the annual increment. If all the forest area would be equally "used" the rural demand could be easily supplied by the potential "unmanaged" forest area, even if the population growth is taken into consideration. The problem, however, is that most of the required wood is collected in the vicinity of the settlements which has already led to a considerable forest degradation in these areas. To be sustainable in the long run, the required wood has therefore to be exploited at least in one third of the potential area.

Assumed that the harvestable trees with dbh > 80cm would be used over a time span of 20 years, annually about 895000 m^3 would be available. Considering this fact and taking into consideration, that by proper management the annual increment will increase, it can be assumed that about 25% of the "unmanaged" potential forest area could supply in the long run even the total domestic wood demand. While there are enough potential forest areas available in the project region, the problem lies in it´s distribution and accessibility. Not all gewogs - not to talk of villages and settlement - have equal access to potential areas. Gewogs which have less than 30% potential forests within their area are in Punaka Dzonkhag: Dzomma, Guma and Lingmukha (see Annex 5.2.1 page 2) and in Wangdue-Phodrang Dzongkhag: Kazhi, Phobji, Sephu and Thedtsho (see Annex 5.3.1 page 2).
Also, beside the already degraded forests along the existing roads, all other forest areas are hardly accessible.

Production capacity of FMUs

Table 20 gives an estimate of the present production capacity of the FMUs. Unfortunately for Rimchhu and Kamichhu no management plans are available so far. Exploitation in Rimchhu has already started in 1992 and already a considerable area has been harvested. The AAC estimates specified in table 20 are pure estimates, as no information on the harvested area nor on standing stock was available. The production capacity for Kamichhu is estimated based on the results of the management inventory. Chendebji FMU is entirely managed by the forest administration of Tongsa district and the produced timber does not contribute to the supply of the project region.

FMU	AAC acc. to plan (m^3)	Estimated AAC optimistic (m^3)	pessimistic (m^3)
Kothoka	6900	6900	4000
Nahi	10000	10000	7000
Rimchhu	-	4000	1000
Kamichhu	-	6000	4000
Total	-	26900	16000

Table 20: Production capacity estimate of FMUs

As mentioned before, the total amount of timber which should have to be produced in FMUs is about 36000 m^3 (131700 m^3 *0.27) under the assumption, that no timber will be imported from other districts. Even the optimistic AAC assumption of 26900 m^3 could only supply 75% of the demand. For the pessimistic estimate it will drop down to 44%.

Taking into consideration the optimistic case, the already existing FMUs could supply the required urban and industrial demand of altogether 23400 m^3 per year, but could not feed the export market. Under the pessimistic assumption, just the urban demand of about 15500 m^3 per year could be supplied (see Annex 6.1). It is therefore obvious, that in the long run new FMUs have to be opened.

The identified potential FMU areas of Gogona, Sephu East and Sephu West (see chap. 2.3.4 and Annex 5.3.6) could most probably produce together with the already existing FMUs enough timber to supply the whole urban and industrial demand, even if the pessimistic AAC estimate is considered. Furthermore, there would be some surplus timber which could be exported. At this stage it is not possible to give detailed production figures, but the annual increment of the potential FMU areas account altogether for 41600 m^3 (see chap. II 2.3.4).

To get more detailed information on the potential AAC and the technical, social and economical feasibilty, it is therefore proposed to carry out reconnaissance surveys in Sephu East and West in the next future.

Annex 1

References

ANON, 1996: Damchhu Forest Punakha.

BG-IFMP; 1995: Project Document, Phase 1 (1995-1996). Thimphu/Bhutan.

EGUCHI, T.; 1987: Synoptic Analysis of Temperature, Precepitation and moisture Conditions in the Bhutan Himalayas. Life Zone Ecology of the Bhutan Himalaya, Chiba University.

GOI/MOA; 1980: Report on Reinvestment Survey of Forest Resources in Central and Eastern Bhutan. Volume I: Forest Resources. Dehra Dun.

GUPTA P.N.; 1992: Bhutan. Distribution of Land use and Vegetation Type. DANIDA.

KLEINE, M.; 1996: Silvicultural Management of Broad-leaved and Chir Pine Forests in the Punakha and Wangdue-Phodrang Districts of Bhutan. Final Report. BG-IFMP, February 1996.

KOWALCZYK, S.; undated: User's Manual for <PLOT> Sytem. Forest Inventory Data Processing. FAO BHU 91/002.

LAUMANS, P.; 1994 (a): Exchanging LUPP and FRDS Land Cover/Use Classes and Codes for Forestry Purposes.

LAUMANS, P.; 1994 (b): Selected LUPP Forest Cover Statistics for Eastern Bhutan. Third Forestry Development Project. RGOB/MOA/FSD.

LAUMANS, P.; 1995 (a): Selection of Potential Forest Management Areas in Eastern Bhutan based on GIS Techniques. Third Forestry Development Project, RGOB/MOA/FSD.

LAUMANS, P.; 1995 (b): Forest Resources Assessment of Eastern Bhutan: First Results. Third Forestry Development Project, RGOB/MOA/FSD

LUPP; 1994: Area Statistics. Land Cover Figures for Bhutan. RGOB/MOA, Thimphu, Bhutan.

LUPP; 1995 (a): LUPP Dzongkhag and Gewog Data Sheets for Punakha Dzongkhag. RGOB/MOA, Thimphu, Bhutan.

LUPP; 1995 (b): LUPP Dzongkhag and Gewog Data Sheets for Wangdue-Phodrang Dzongkhag. RGOB/MOA, Thimphu, Bhutan.

LUPP; 1995 (c): LUPP Dzongkhag and Gewog Data Sheets for Gasa Dzongkhag. RGOB/MOA, Thimphu, Bhutan.

LUPP; 1995(d): Sustainable Land Use. Guidelines for Bhutan Vol. VII.8. Guidelines on Land Capability Classification and Management Recommendations. October 1995, Thimphu. RGOB/MOA.

MAIER, E.J.; 1995: Assessment of the Holistic Approach of Management Plan for FMU Nahi. BG-IFMP Working Paper No. 1.

MÄÄTTÄ, M.; 1993 (a): Use of Plot System in Forest Inventory Data Processing. A Report of the Training at the Forest Resources Management Division 29. March - 9. April 1993.

MÄÄTTÄ, M.; 1993 (b): Report of Forest Inventories in Forest Resource Management Division, Bhutan 1991-1993. Working Document No. 4 (FO: DP/BHU/91/002).

NAMGYEL, P.; 1996: Beyond Timber - What Value of the Forest? A Rapid Rural Appraisal Study on Non-Timber Forest Products in the Nahi Gewog, Wangdue-Phodrang Dzongkhag, Western Bhutan. FRC/BG-IFMP Occasional Paper No. 1.

RGOB/MOA; 1983: Forest Management Plan - Kothoka Valley.

RGOB; 1995: Forest and Nature Conservation Act of Bhutan, 1995.

RGOB/MOA/DOF 1991 (a): Master Plan for Forest Development. Annex Report No. 2: Assessment of Forest Resources of Bhutan. Prepared by COWIconsult/Jaakko Pöyry for Danida/ADB.

RGOB/MOA/DOF/FRMD; 1993 (b): Management Plan for Nahi Forest Management Unit, Wangdi Phodrang Dzongkhag. Period of the Plan: 1993 - 2002; Prepared by D.B. Dhital, FRMD.

RGOB/MOA/FSD/FRDS; 1994 (c): Implementation of Forest Management Plans. Proceedings of the Fourth Workshop held 31 March to 2 April 1994 in Trashigang.

RGOB/MOA/FSD; 1993: Protected Area Planning in Bhutan. Work Plans for FY 93/94 - 95/96; WWF Bhutan Programme.

RGOB/MOA/FSD/SFES; 1995 (a): Community Forest Management Plan of Dawakhar. Second Draft, Compiled by Kin Gyeltshen and Dennis F. Desmond..

RGOB/MOA/FSD/SFES; 1995 (b): Dawakha - Community Forest Management Plan.

RIEGER, G.; 1996: Study on Forestry Operations within the Kothoka Forest Management Unit, Wangdue-Phodrang District. Report on a Short - Term Consultancy to the Bhutan - German Integrated Forest Management Project. BG-IFMP Working Paper No. 7.

SCHINDELE, W.; 1995 (a): Forest Resources Management in Punakha and Wangdue-Phodrang District. Mission Report on Forest Resources Assessment and Forest Management within the Scope of the Bhutan-German Integrated Forest Management Project. BG-IFMP, Working Paper No. 4.

SCHINDELE, W.; 1995 (b): Guidelines for a Reconnaissance Forest Inventory. Mission Report on Forest Resources Assessment and Forest Management within the Scope of the Bhutan-German Integrated Forest Management Project. BG-IFMP, Working Paper No. 6.

SCHINDELE, W.; 1995 (c): Reconnaissance Forest Inventory Field Manual. Mission Report on Forest Resources Assessment and Forest Management within the Scope of the Bhutan-German Integrated Forest Management Project. BG-IFMP, Technical Paper No. 1.

Annex 2

FRDS Land Use Codes

Translation table between codes used in the field/<PLOT> and map codes.

Field/<PLOT>	***Description***	***Map***
LAKE	Lakes and Rivers	Wa
BARR	Rocky outcrops and barren land	Ro
SETT	Settlements	Se
AGRI	Agriculture	Cu
PLAN	Forest plantation	Pl
TBAM	Tall bamboo	Bt
TUNS	Temporarily unstocked	Bk
AGRA	Alpine grassland	Ga
ASHR	Alpine shrubland	Sa
GRAS	Grassland	Gr
OSHR	Oak shrubland	Qu
SHRU	Shrubland	Sc
LBAM	Low bamboo	Bl
AGRA/ABID	Alpine Grassland with sparse Fir	Ga(Fi)
AGRA/JUN?	Alpine Grassland with sparse Juniper	Ga(Ju)
AGRA/PICS	Alpine Grassland with sparse Spruce	Ga(Sp)
GRAS/PICS	Grassland with sparse Spruce	Gr(Sp)
GRAS/PINR	Grassland with sparse Chirpine	Gr(Pc)
GRAS/PINW	Grassland with sparse Bluepine	Gr(Pb)
GRAS/TREE	Grassland with sparse tree cover	Gr(Nf)
OSHR/PINW	Oak shrubland with sparse Bluepine	Qu(Pb)
OSHR/TREE	Oak shrubland with sparse tree cover	Qu(Nf)
ASHR/ABID	Alpine shrubland with sparse Fir	Sa(Fi)
SHRU/PINR	Shubland with sparse Chirpine	Sc(Pc)
SHRU/PINW	Shrubland with sparse Bluepine	Sc(Pb)
SHRU/TREE	Shrubland with sparse tree cover	Sc(Nf)
LBAM/TREE	Low bamboo with sparse tree cover	Bl(Nf)
LBAM/MCON	Low bamboo with mixed conifers	Bl(Nc)
BARR/PINR	Barren land with sparse Chirpine	Ro(Pc)
BARR/PINW	Barren land with sparse Bluepine	Ro(Pb)
BARR/TREE	Barren land with sparse tree cover	Ro(Nf)
ABID	Fir Fi	
CUP?	Cypress Cy	
JUN?	Juniper Ju	
LARG	Larch La	
PICS	Spruce Sp	
PINR	Chirpine	Pc
PINW	Bluepine	Pb
TAXB	Yew Ye	
TSUD	Hemlock	He
ACE?	Acer sp. Ac	
ACEC	Acer campbellii	Ac
ALNN	Alnus nepalensis	Al
BET?	Betula sp.	Be
EXBP	Exbucklandia populnea	Ex
CST?	Castanopsis sp.	Ka
MAC?	Macaranga sp.	Ma
POPC	Populus ciliata	Oc
POPR	Populus rotundifolia	Or
QUE?	Quercus sp.	Qu
QUEI	Quercus griffithii	Qg
QUES	Quercus semecarpifolia	Qs
RHO?	Rhododendron sp.	Rh
SCHW	Schima wallichii	Ch
ABID/ACEC	Fir/Acer campbellii	Fi-Ac
ABID/BET?	Fir/Betula sp.	Fi-Be

ABID/JUN?	Fir/Juniper	Fi-Ju
ABID/LARG	Fir/Larch	Fi-La
ABID/PICS	Fir/Spruce	Fi-Sp
ABID?/PRU?	Fir/Prunus sp.	Fi-Ar
ABID/RHO?	Fir/Rhododendron sp.	Fi-Rh
ABID/TSUD	Fir/Hemlock	Fi-He
LARG/QUES	Larch/Quercus semecarpifolia	La-Qs
PICS/ACEC	Spruce/Acer campbellii	Sp-Ac
PICS/TSUD	Spruce/Hemlock	Sp-He
PICS/PINW	Spruce/Bluepine	Sp-Pb
PICS/POPC	Spruce/Populus ciliata	Sp-Oc
PICS/QUES	Spruce/Quercus semecarpifolia	Sp-Qs
PINW/POPC	Bluepine/Populus ciliata	Pb-Oc
PINW/POPR	Bluepine/Populus rotundifolia	Pc-Or
PINW/QUE?	Bluepine/Quercus sp.	Pb-Qu
PINW/QUEI	Bluepine/Quercus griffithii	Pb-Qg
PINW/QUES	Bluepine/Quercus semecarpifolia	Pb-Qs
PINW/RHO?	Bluepine/Rhododendron sp.	Pb-Rh
PINW/TSUD	Bluepine/Hemlock	Pb-He
TAXB/POPC	Taxus baccata/Populus ciliata	Ye-Oc
TSUD/ACEC	Hemlock/Acer campbellii	He-Ac
TSUD/BET?	Hemlock/Betula sp.	He-Be
TSUD/PRU?	Hemlock/Prunus sp.	He-Ar
TSUD/QUES	Hemlock/Quercus semecarpifolia	He-Qs
ACEC/BET?	Acer campbellii/Betula sp.	Ac-Be
ACEC/POPC	Acer campbelli/Populus ciliata	Ac-Oc
ACEC/QUES	Acer campbellii/Quercus semecarpifolia	Ac-Qs
CST?/QUE?	Castanopsis sp./Quercus sp.	Ka-Qu
POPC/QUES	Populus ciliata/Quercus semcarpifolia	Oc-Qs
QUEI/QUES	Quercus griffithii/Quercus semecarpifolia	Qg-Qs
QUEI/RHO?	Quercus griffithii/Rhododendron sp.	Qg-Rh

MCON	Mixed coniferous	Nc
MQUE	Quercus spp.	Qu
FTHI	Foothill-broadleaved	Nb
UPHI	Upper hill-broadleaved	Nb
MONT	Montane-broadleaved	Nb
PINR/FTHI	Chirpine/Foothill-broadleaved	Pc-Nb
PINR/UPHI	Chirpine/Upper hill-broadleaved	Pc-Nb
PINW/UPHI	Bluepine/Upper hill-broadleaved	Pb-Nb
PICS/MONT	Spruce/Montane-broadleaved	Sp-Nb
PINW/MONT	Bluepine/Montane-broadleaved	Pb-Nb
POPC/MCON	Populus ciliata/Mixed coniferous	Oc-Nc
QUE?/MCON	Quercus sp./Mixed coniferous	Qu-Nc
QUEI/MCON	Quercus griffithii/Mixed coniferous	Qg-Nc
QUES/MCON	Quercus semecarpifolia/Mixed coniferous	Qs-Nc
MCON/MONT	Mixed coniferous/Montane-broadleaved	Nc-Nb

Appendix 2. Clarification of selected code pairs.

Ro
Exposed rocks, boulders, (riverbed) stones or barren soils with (almost) no tree cover.
Se
Houses, home gardens, buildings etc.
Cu
Fields for crops such as rice, maize, oranges, cardamom, including shifting cultivation
Bt
A vegetation of tall (>= 5 m) bamboo.
Bl
A vegetation of low (< 5 m) bamboo.
Bk
A temporarily unstocked (blank) area within forest land (e.g. recently logged areas).

Annex 3

Calculation of Attributes

Annex 4

FRPA-Map

4.1 FRPA-Map for Punakha Dzonkhag
4.2 FRPA-Map for Wangdue Phodrang Dzonkhag

Annex 5

Statistics on
Potential Areas and Standing Stock

Annex 5.1

Project Region
(Excluding Gasa)

5.1.1 Potential Area Statistics
5.1.2 Gross Volume and Increment

Annex 5.2

Punakha Dzonkhag

Annex 5.2.3

Gewog Statistics

5.2.3/1	Bji'menang
5.2.3/2	Chhubu
5.2.3/3	Dzoma
5.2.3/4	Goenshari
5.2.3/5	Guma
5.2.3/6	Kabjisa
5.2.3/7	Lingmukha
5.2.3/8	She'nganang
5.2.3/9	Talo
5.2.3/10	Toewang

Annex 5.2.4

Protected Area Statistics

Annex 5.2.5

FMU Statistics

Annex 5.3

Wangue-Phodrang Dzonkhag

Annex 5.3.3

Gewog Statistics

5.3.3/1	Athang
5.3.3/2	Bjena
5.3.3/3	Daga
5.3.3/4	Dangchhu
5.3.3/5	Gangte
5.3.3/6	Gase Tsho Aom
5.3.3/7	Gase Tshogom
5.3.3/8	Kazhi
5.3.3/9	Nahi
5.3.3/10	Nyisho
5.3.3/11	Pahng Yue
5.3.3/12	Phobji
5.3.3/13	Ruepaisa
5.3.3/14	Sephu
5.3.3/15	Thedtsho

Annex 5.3.4

Protected Area Statistics

Annex 5.3.5

FMU Statistics

Annex 5.3.6

Potential FMU Statistics

5.3.6/1	Gogona
5.3.6/2	Sephu East
5.3.6/3	Sephu West

Annex 6

Timber and Wood Demand
in
Project Region