



Forestry Field Manual for Bhutan

Silviculture and Other Forestry Operations

Second Edition, 2016



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Social Forestry and Extension Division
Department of Forests and Park Services
Ministry of Agriculture and Forests
Royal Government of Bhutan
Thimphu



Forward



Bhutan has been endowed with a rich heritage of renewable natural resources. The Royal Government of Bhutan has successfully protected this heritage through enabling policies and practices. With the establishment of Department of Forests in 1952 and the inception of 1st Five Year Plan in 1961, Silviculture was given high priority and many silvicultural systems were applied to Bhutan's forests, mostly in Forest Management Units (FMUs). But there was no published silviculture manual suitable for different forest types of Bhutan to be followed by foresters and the private forest owners.

In 2004, Social Forestry and Extension Division (SFED) produced a set of manuals of which part III was the "Silvicultural Options for Community Forestry". This manual provided technical support and assistance for preparation of a Community Forest Management Plan with the main focus on selection of various silvicultural options suitable for managing Community Forests.

In 2012, SFED with support from Participatory Forest Management Project (PFMP) funded by the Swiss Agency for Development and Cooperation (SDC) produced a manual titled "Silviculture and Other Forestry Operations" which covered all forest management regimes in Bhutan. However, this manual was not finalized due to revision of Forest and Nature Conservation Rules, 2006.

This edition of "Silviculture and Other Forestry Operations" results from an extensive revision of previous manual which has been restructured in such a manner that the silvicultural principles can be applied to all types of forest management regimes in Bhutan (Community Forests, Forest Management Units, Protected Areas, Local Forest Management Areas or to any forest types that do not fall into any specific forest management regimes). This is made possible again with financial support from the PFMP funded by the Swiss Agency for Development and Cooperation (SDC).

I deeply appreciate and thank the Silviculture Expert Group members comprising of officials from Ugyen Wangchuck Institute for Environment and Conservation, College of Natural Resources, Natural Resources Development Corporation and officials of Department of Forests and Park Services, who were actively involved in bringing out this edition. In particular, I would like to thank Social Forestry & Extension Division for timely initiation of this edition of manual which will go a long way in fulfilling the silvicultural needs of different forest types of Bhutan.

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Acronym

AAC	Annual Allowable Cut
AHL	Annual Harvesting Limit
BA	Basal Area
CFMGs	Community Forest Management Groups
CFs	Community Forests
cm	Centimetre
CNR	College of Natural Resources
dbh	Diameter at Breast Height
DoFPS	Department of Forests and Park Services
FMUs	Forest Management Units
GS	Growing Stock
ha	Hectare
LFMAs	Local Forest Management Areas
m	meter
MoAF	Ministry of Agriculture and Forests
NWFPs	Non-Wood Forest Products
PAs	Protected Areas
PFMP	Participatory Forest Management Project
RGoB	Royal Government of Bhutan
SDC	Swiss Agency for Development Cooperation
SFED	Social Forestry and Extension Division
UWICE	Ugyen Wangchuck Institute for Conservation and Environment

Acknowledgement

The first edition of Silviculture and Other Forestry Operations was published in 2012. It was based on Part III of the Community Forestry Manual that was produced in 2004. This is the second edition of Forestry Field Manual for Bhutan. It has been extensively revised and restructured to produce useful field manual covering silviculture and other forestry operations applicable for all forest management regimes in Bhutan (Community Forests, Forest Management Units, Protected Areas and Local Forest Management Areas, that do not fall into any specific forest management regimes). This revision and restructuring process was coordinated in August 2016 by Social Forestry and Extension Division (SFED) with support from the Participatory Forest Management Project (PFMP) funded by the Swiss Agency for Development and Cooperation (SDC). It involved a process of consultation workshop with participants from all related stakeholders and some of the Silvicultural Expert Group members formed in 2009. Finalization of this edition was convened by forming a separate “Task Force” group.

This edition process was able to draw on the extensive and wide-ranging literature on Bhutanese silviculture. Some of this has already been published and is now available on the internet whilst other documents can only be found in the form of printed project reports and academic studies. Annex 5 of this manual consists of a bibliography, listing the major current sources of information.

A number of people were involved at different stages of the preparation of this manual. Particular mention goes to the officials of Department of Forests and Park Services (DoFPS), Ugyen Wangchuck Institute for Environment and Conservation (UWICE), College of Natural Resources (CNR) and Natural Resources Development Corporation Limited (NRDCL) who attended the two days’ consultative workshop in Tsirang and another two days’ Task Force workshop in Thimphu in August 2016. The second edition of this manual reflect ideas and suggestions from participants at these workshops. These are based on practical experiences and reflections of this experienced group of participants. The great contributions of Silviculture Experts and Task Force Members in terms of their professional knowledge, experience, time and effort are hereby deeply acknowledged.

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1. Introduction

1.1 About this Manual

This manual is developed for field foresters working in Bhutan. It could also be used by Community Forest Management Groups (CFMGs) and any other people who are involved in making field-level silviculture and forest management decisions or who may be providing such advice to others. The manual applies equally to forests in Forest Management Units (FMUs), Community Forests (CFs), Protected Areas (PAs) as well as Local Forest Management Areas (LFMAs) that do not fall into any specific forest management regimes. Consequently, this manual on Silviculture and Other Forestry Operations forms a useful resource for all field foresters working in Bhutan.

This manual can also be used as a reference for training to develop silviculture skills and techniques in training institutions such as the College of Natural Resources (CNR) and Ugyen Wangchuck Institute for Conservation and Environment (UWICE).

1.2 How to Use This Manual

The manual begins by defining silviculture and its underlying principles that make silviculture different under various forest management regimes in Bhutan: Forest Management Units (FMUs), Community Forests (CFs), Protected Areas (PAs) and Local Forest Management Areas (LFMAs).

The manual includes the following steps:

Step 1: Identifying Forest Types

Step 2: Assessing Forest Stand Condition

Step 3: Selecting Forest Management Objectives

Step 4: Identifying Silvicultural Options

The manual guides how to implement different silvicultural systems and other forest management activities in different forest conditions.

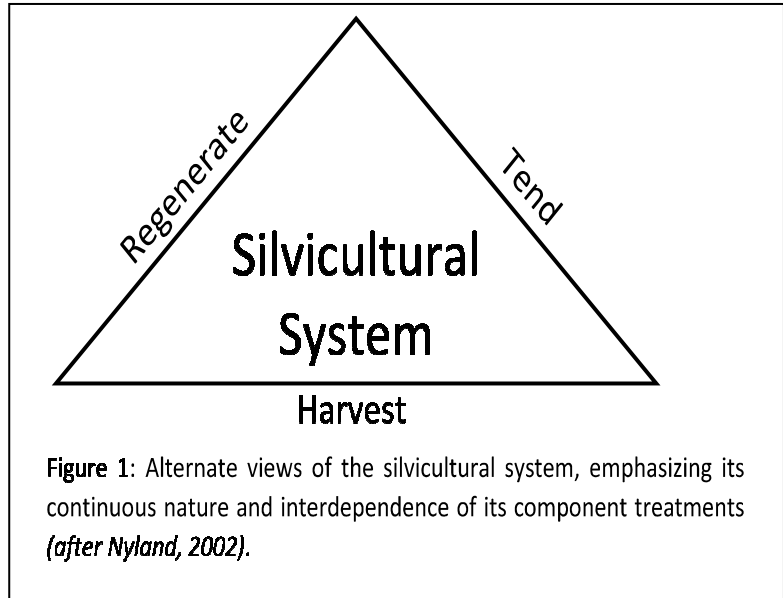
The manual includes a number of important Annexes. These provide supplementary and background information that will assist in following the above steps. Use the formats annexed according to different forest management regimes.

2. Silviculture Definitions and Principles

Silviculture can be defined as: *'The art and science of controlling the establishment, growth, composition, health and quality of forests and woodlands to meet the targeted diverse needs and values of landowners and society on a sustainable basis'* (IUFRO, 2000). It includes implementation of all forest operations from establishment to harvesting (figure 1) aimed at utilising, improving and protecting the forests.

Silviculture covers:

- The method of regeneration of individual trees and other plants making up the forest i.e. how the long-term future of the forest can be assured.
- The form of the forest crop i.e. the size, species mixture, density, shape and age of the trees and plants in the forests.
- The spatial arrangement of trees and other plants in the forests. The yield of forest products over time.
- The mixture and characteristics of forest products being generated.



2.1 General Silvicultural Principles

In Bhutan, certain general principles determine the choice of silvicultural system and their implementation for all forest management regimes whether in Forest Management Units (FMUs), Community Forests (CFs), Protected Areas (PAs) or in Local Forest Management Areas (LFMAs). These principles are largely determined by National Forest Policy of Bhutan, 2011. This means that silviculture as applied to Bhutan's forest needs to ensure:

- i. Sustainable production of economic and environmental goods and services
- ii. Sustainable supply of timber and other forest products
- iii. Sustainable biodiversity, ecosystem services and cultural heritage
- iv. Integrated watershed management and provision of watershed services
- v. Contribution to sustainable socio-economic benefits and poverty reduction
- vi. Ecological, social and economic benefits through raising forest crops
- vii. Support for an economically viable forest based industry

- viii. Establishment of a dynamic organisational set up

Although these principles apply to all forests in Bhutan, their priorities and emphasis vary according to the forest management regimes. These are described separately below.

2.2 Silviculture in Forest Management Units (FMUs)

The primary purpose of FMU is production of timber through sustainable harvesting. Therefore, silviculture practices in FMUs needs to emphasise on:

- Sustainable and low impact tree harvesting. Silviculture is usually carried out on a broad scale, to improve efficiency and lower costs,
- Production of forest products which can sustain a viable forest-based industry and meet market demands,
- Silvicultural systems including regeneration to replace harvested trees (through natural or artificial regeneration),
- Improvement of the forest stands and maximisation of crop growth to meet future demands for forest products,
- Maintenance of forest health and protection of the forest crops from pest and diseases, other types of damage: illegal harvesting, encroachment, fire, storm and misuse.

Other important principles such as biodiversity conservation, sustainable ecosystem services and meeting local people's needs for forest products also need to be ensured through the application of silvicultural systems in FMUs.

2.3 Silviculture in Community Forests (CFs)

The primary purpose of Community Forests is to meet local needs for forest products and to contribute to socio-economic benefits and rural poverty reduction. Silviculture in Community Forests therefore, needs to consider the following distinctive features compared with other forest management regimes¹:

Participatory: As with all aspects of community forestry, silvicultural decisions need to involve CFMG members.

Multiple objectives & products: Having multiple stakeholder means that a CF is managed with multiple objectives and for range of products to meet the diverse needs of CFMG members. Silvicultural systems need to reflect this.

Compressed geographical focus: Silviculture systems and interventions can be carried out on a small scale in individual forest stand.

¹ Adapted from Campbell (1995)

Multiple time horizons: CFMG members cannot afford to have long intervals between harvests of forest products. Most products will be needed in regular, annual and ad hoc quantities to meet local needs.

Indigenous technologies and knowledge: CFMG members can have local knowledge and understanding about forest resources which can be used in their silvicultural decision-making.

2.4 Silviculture in Protected Areas (PAs)

The primary purpose of Protected Areas is to conserve and enhance biodiversity. This needs to be reflected in the choice of silvicultural systems which should emphasise on:

- Silviculture that will enhance and conserve biodiversity e.g. improving species diversity and mitigating potential negative environmental impacts like controlling invasive species or biotic damage (fires, grazing, illicit harvesting, etc.),
- Avoidance of disturbance to natural ecosystems to maintain 'naturalness' – in certain situations silvicultural interventions may be used to mimic natural disturbance e.g. using fire as a tool to stimulate natural regeneration,
- Focus on limited harvesting of non-timber rather than timber products (only in buffer and multiple use zones),
- Meeting local rather than commercial needs (only in buffer and multiple use zones),
- Maintaining environmental and ecological services (especially water and soil conservation),
- Study and research forest ecosystems.

2.5 Silviculture in Local Forest Management Areas

Local Forest Management Areas (forest areas not covered by FMUs, CFs and PAs) are often subject to unsystematic or unplanned exploitation in the absence of a forest management plan. As a result they may often be degraded and not fulfilling their productive potential. In some cases, a local forest management plan may be in place according to the planning guidelines. Silviculture of these areas therefore, needs to emphasise on:

- Interventions to improve the forest condition (growing stock, regeneration status, species composition),
- Conservation of the ecological services (particularly for water and soil conservation),
- Sustainable harvesting for timber and other forest products without compromising the need to maintain, improve and conserve these areas for future productive use.

As with FMUs, other important principles such as biodiversity conservation, sustainable ecosystem services and meeting local people's needs for forest products also need to be ensured through the application of appropriate silvicultural systems although these are not usually the primary factors.

2.6 Forest Stand Concepts

During forest management planning, larger forest areas are normally divided into smaller management units. For example, FMUs and LFMA are divided into compartments (sometimes also into sub-compartments). Community forests are usually divided into blocks. These units (compartments or blocks) can vary in size. The boundaries of blocks and compartments are usually fixed based on the physical features such as ridges, valleys, streams, roads, etc. Management prescriptions in a forest management plan are usually based on a whole block/compartment e.g. in CFs the management plan may prescribe Annual Harvesting Limit (AAC equivalent) expressed in number of trees, whereas in FMU the management plan prescribes Annual Allowable Cut (AAC) in volume/basal area.

However, even within a single compartment or block, forest is usually quite variable. A single compartment/block may contain smaller patches of different types of forest or forest conditions. For this reason the concept of a **forest stand** has been developed to assist in selecting and implementing silvicultural options.

A stand is a smaller forest area within a larger compartment or block where conditions are more or less uniform. A forest stand can therefore, be treated as a single unit for applying silvicultural prescriptions. Stand boundaries are not usually permanent or mapped and over time they may change. Stand areas can be highly variable. A stand is therefore, the basic unit for silvicultural planning, implementing and monitoring. A stand is more or less uniform and it is usually possible to apply a single set of silvicultural prescriptions, which are guided by the actual condition of the stand and also by its function (function map in FMU) and objective in CF management plan. The table below shows the main differences between a forest compartment/block and forest stand.

Table 2.1 Differences between Compartment/Block and Stand

Compartment/Block	Stand
Larger area (up to several hundred ha)	Smaller area (usually less than 50 ha)
Fixed boundaries (often demarcated)	Boundaries not fixed or demarcated
Boundaries defined by recognisable natural features (ridges, roads, rivers, etc.)	Boundaries are defined uniform condition of the forest
Diverse forest condition/type	Uniform forest condition/type
Diverse silvicultural and forest management prescriptions	Uniform (single set) of silviculture and forest management prescriptions

3. Step 1: Identify the Forest Type

Objective: *To identify the forest type in different forest management unit or areas.*

Why Identify forest type?

Different forest types require different silvicultural systems to regenerate and manage them.

Bhutan is ecologically diverse with great variations in topography, altitude, aspect, rainfall and other environmental characteristics due to which there are different type of forests. For identifying forest types, one may follow the classification developed by Grierson and Long in the Flora of Bhutan (Grierson & Long, 1983). An illustration of forest classification is shown in the Figure 2 and a description of each of the main forest types is included in Annex 1.

Boundaries between different forest types are not always clearly defined. There is usually a gradual transition from one type to another with variations depending on changes in slope or aspect. Normally, the forest types are broadly identified in the forest management plan for a particular forest with the forest type assigned to each compartment or block e.g. in a FMU or in CF. However, within this larger area (compartment/block) which could be defined as having a single forest type there are often smaller areas (forest stands) which have different forest types.

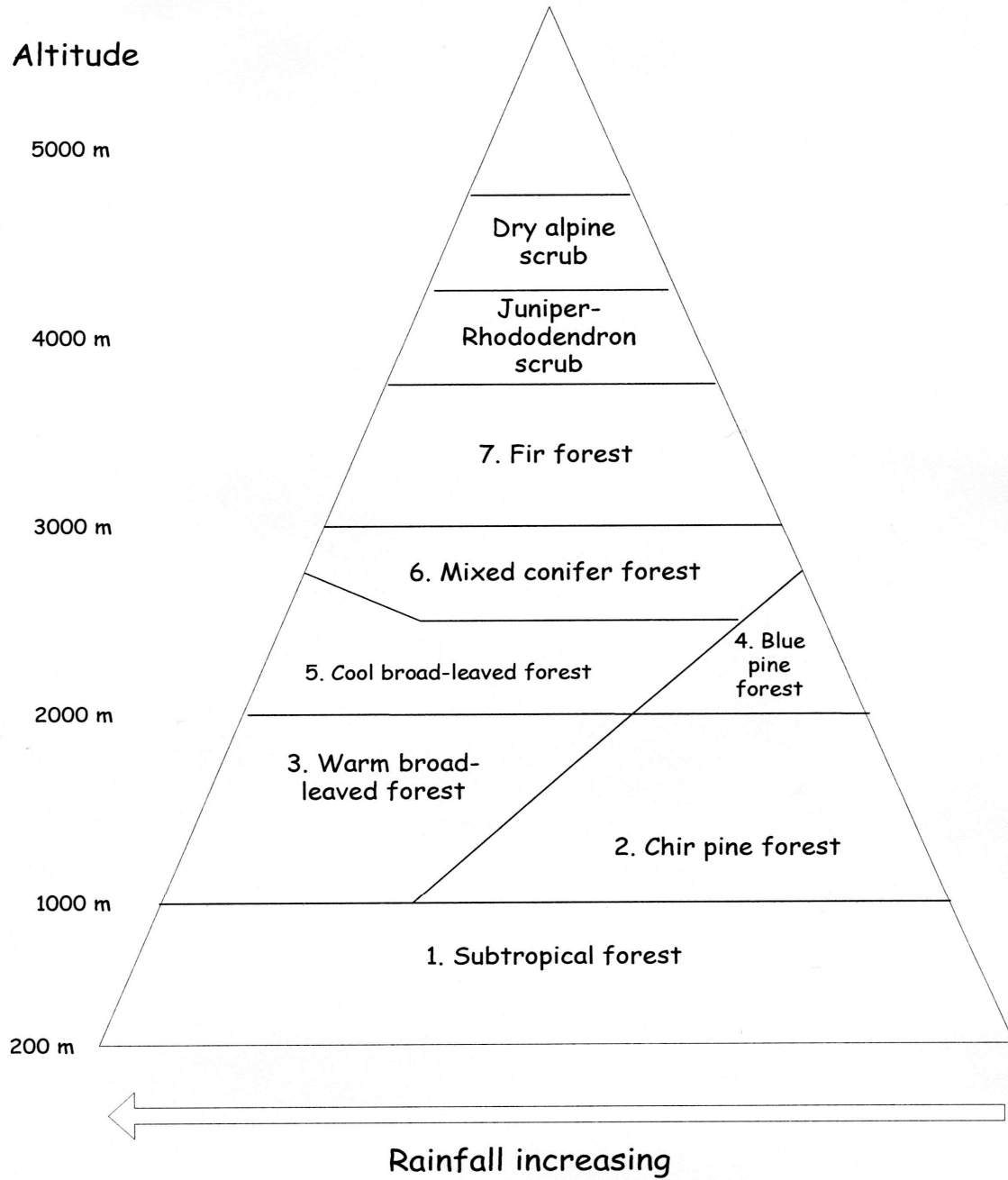
Table 3.1 shows a simple classification system for Bhutan's main forest types. The main types are easily identified by the occurrence of the key species listed in the table. These forest types will be used for the identification and implementation of possible silvicultural options. Figure 2 shows how these forest types vary according to elevation and rainfall.

How to identify forest types

1. Use the management plan to find out the broad forest types.
2. Visit the stand and make an assessment on the ground. In a larger compartment or block there may be several stands with different forest types. Make sure that you visit all parts of the stand.
3. Identify the forest type in each stand by looking for the key tree species listed in Table 3.1. Remember that you may also find mixtures and transitional types.
4. Record the forest type on the stand condition format (Step 2 and Annex 6 to 8 depending on different forest management regimes). Include any notes that may explain your identification e.g. referring to any transitional features, unusual species or past harvesting history, since these will all affect the present forest type.
5. If you cannot assign a particular forest type to the stand, you may need to consider dividing the stand into smaller units and assessing each one separately.

Table 3.1: Main Forest Types of Bhutan			
Forest Type	Altitude Range (m)	Key Tree Species	Dzongkha Name (or Lhotshampkha)
1. Subtropical forest	200-1,000	<i>Duabanga grandiflora</i> <i>Terminalia spp.</i> <i>Tetrameles nudiflora</i> <i>Acrocarpus fraxinifolius</i> <i>Dillenia pentagyna</i>	Patangshing Alashing Kadonshing Chashing
2. Chir Pine forest	900-1,800	<i>Pinus roxburghii</i>	Thhetongphu
3. Warm broadleaved forest	1,000-2,000	<i>Castanopsis indica</i> <i>Engelhardia spicata</i> <i>Macaranga pustulata</i> <i>Schima wallichii</i> <i>Alnus nepalensis</i>	Sokey Mauwa (Lhotshampkha) Malata (Lhotshampkha) Puyamshing Gamashing
4. Cool broadleaved forest	2,100-2,900	<i>Quercus spp.</i> <i>Acer campbellii</i> <i>Betula alnoides</i>	Sisishing; bangkashing; Jeshing Chalam Taap
5. Blue Pine forest	2,100-3,000	<i>Pinus wallichiana</i>	Tongphu
6. Mixed conifer forest	2,500-3,100	<i>Tsuga dumosa</i> <i>Picea spinulosa</i> <i>Taxus baccata</i> <i>Larix griffithiana</i>	Seshing Bashing Keranshing Zashi
7. Fir forest	3,000-3,800	<i>Abies densa</i>	Dungshing

Figure 2: Forest Types of Bhutan According to Elevation and Rainfall



Based on Grierson & Long (1983) and Statz and Wyrsh (1993)

4. Step 2: Assess Forest Stand Condition

Objective: To assess forest stand condition in selecting appropriate silvicultural options.

The following criteria can be used to assess forest condition.

- i. Number of forest storeys
- ii. Canopy density
- iii. Basal area
- iv. Estimation of growing stock
- v. Diameter class distribution
- vi. Stability
- vii. Regeneration status of desired species
- viii. Density of seed trees
- ix. Ground vegetation

Why assess forest stand condition?

Forests of the same type but in different condition require different silvicultural systems to regenerate and manage them.

E.g. a dense pole-stage blue pine forest could be thinned, and mature trees could be managed by the group selection, single tree selection or strip clear felling system.

How to assess forest condition

1. For each stand, complete a Stand Assessments Format (Annex 6 to 8 depending on different forest management regimes). Table 4.1 gives some explanations for the various criteria that are used.
2. Stand assessment should be done quickly and largely based on visual assessment or estimation. It does not need to be statistically accurate.
3. Figures 3-7 gives some thumb rules for assessing these forest stand criteria.
4. For each of the stand criteria, record the current status and also what you expect the status to be after about 10 years. For example, if you expect the canopy density to increase, decrease or stay the same, you should write this down.

Table 4.1: Criteria for Assessing Forest Stand Condition

Criteria	Definition/calculation	Input into format (Annex 6 to 8)
i. Number of storeys	Count the storeys. Upper story (1), middle story (2), under-storey (3)	Write 1, 2 or 3
ii. Canopy density %	Make a visual estimation and apply the following definition: > 40% = dense; < 40% = open. For more accurate estimation, use of Densio-meter and "Fish-Eye Lens" camera, if available.	Estimated %
iii. Basal area (m ² /ha)	Measure the basal area of the stand either by using a wedge prism, Relascope or by measuring fixed area plots.	Ensure that you take enough measurements to get an accurate figure for

	> 18 m ² /ha = good; 12-18 m ² /ha = moderate; 6-12 m ² /ha = degraded; < 6 m ² /ha = open	the whole stand i.e. take at least 4 to 5 measurements /ha
iv. Estimated growing stock (m ³ /ha)	Use the thumb rule to calculate this e.g. GS = basal area x ½ mean tree height. Tree height can be estimated or measured	Estimated GS in m ³ /ha (refer figure 5 &6)
v. Dbh-class distribution number/ha	Count the trees in each dbh-class in 10 x 10 m plots e.g. No. in 2 plots x 50 = no./ha, No. in 4 plots x 25 = no./ha	No./ha
vi. Stability (only for conifer forests)	Stability factor: Tree ht. (m) / mean dbh (m). Example: 10 m ht. / 0.1 m dbh = factor 100. Chir pine factor < 100 = stable tree. Blue pine factor < 80 = stable tree.	Stable/unstable (majority of trees)
vii. Established regeneration of desired species (only required if regeneration is needed)	Definition for established regeneration is 30 cm height and/or 9.9 cm diameter. Abundant = > 1,600 established plants/ha > 30 cm. Scattered = < 1,600 established plants/ha > 30 cm. None = no established regeneration.	Indication in words e.g. abundant, scattered, none (for the desired species)
viii. Number of seed trees/ha	Seed trees (Plus Tree) defined as able to produce viable seed (usually this is a factor of age or tree size).	Name of the species and estimated number/ha. Indicate whether this is sufficient or not
ix. Seed tree (Plus tree) quality	Clean/straight bole, free from pests and diseases, smaller branches, not over matured, etc.	Name of species, estimated number and quality per ha. Mark it as plus tree.
x. Ground vegetation	Describe e.g. , competitive weeds, invasive species, etc.	Describe if there are any problems such as grazing, fires, evidence of soil erosion and regeneration competition from ground vegetation.

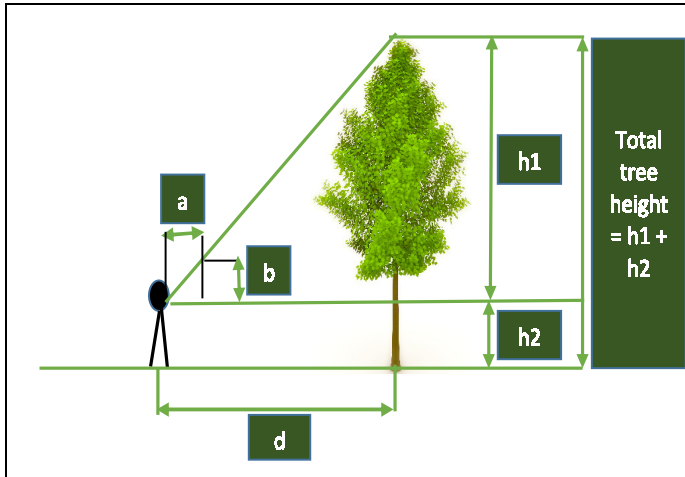


Figure 3 (a): Estimating tree height on horizontal ground.

Use an angle of 45 degrees (e.g. protractor). When the top of the tree corresponds with the angle your distance from the tree (d) is equal to h_1 . Measure the distance (d). If $a = b$ then $d = h_1$ and total tree height = $h_1 + h_2$. Note that d must be horizontal. (Other equipment used to measure tree height are Clinometer, explained below and Hypsometer).

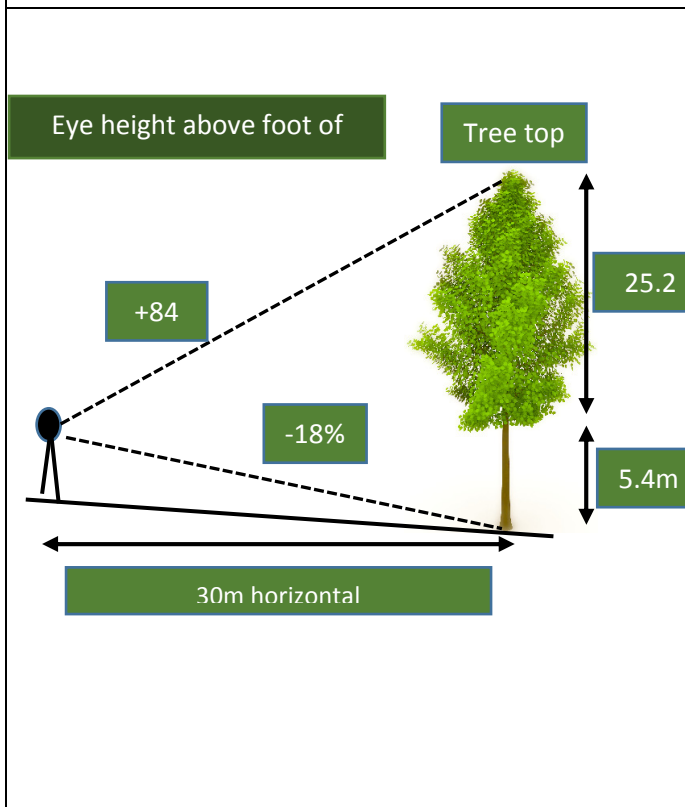


Figure 3 (b): In case the observer's eye-height is above the base of the tree, you should **add** the two clinometer readings:

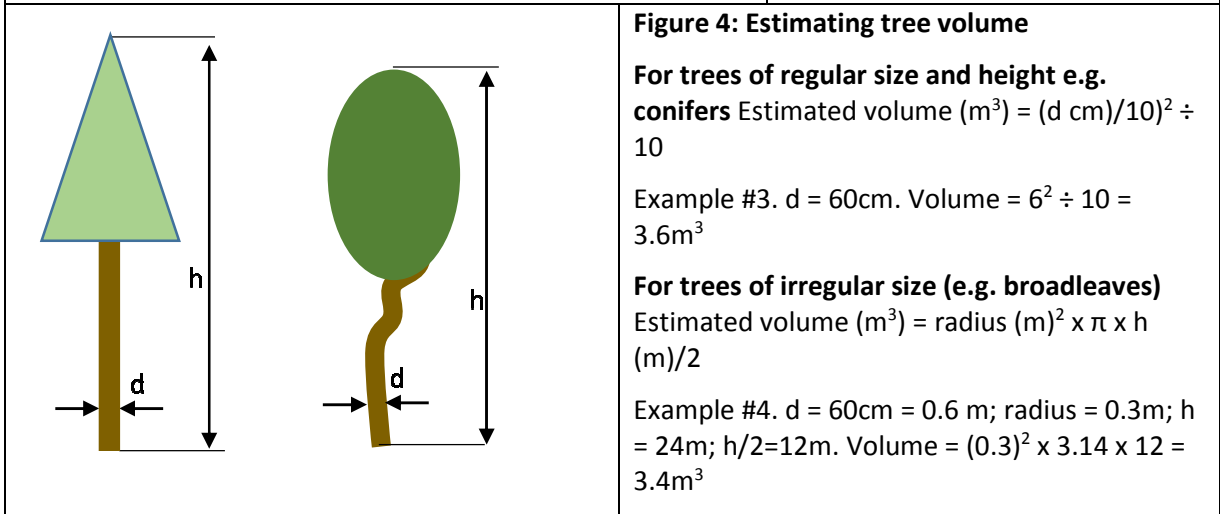
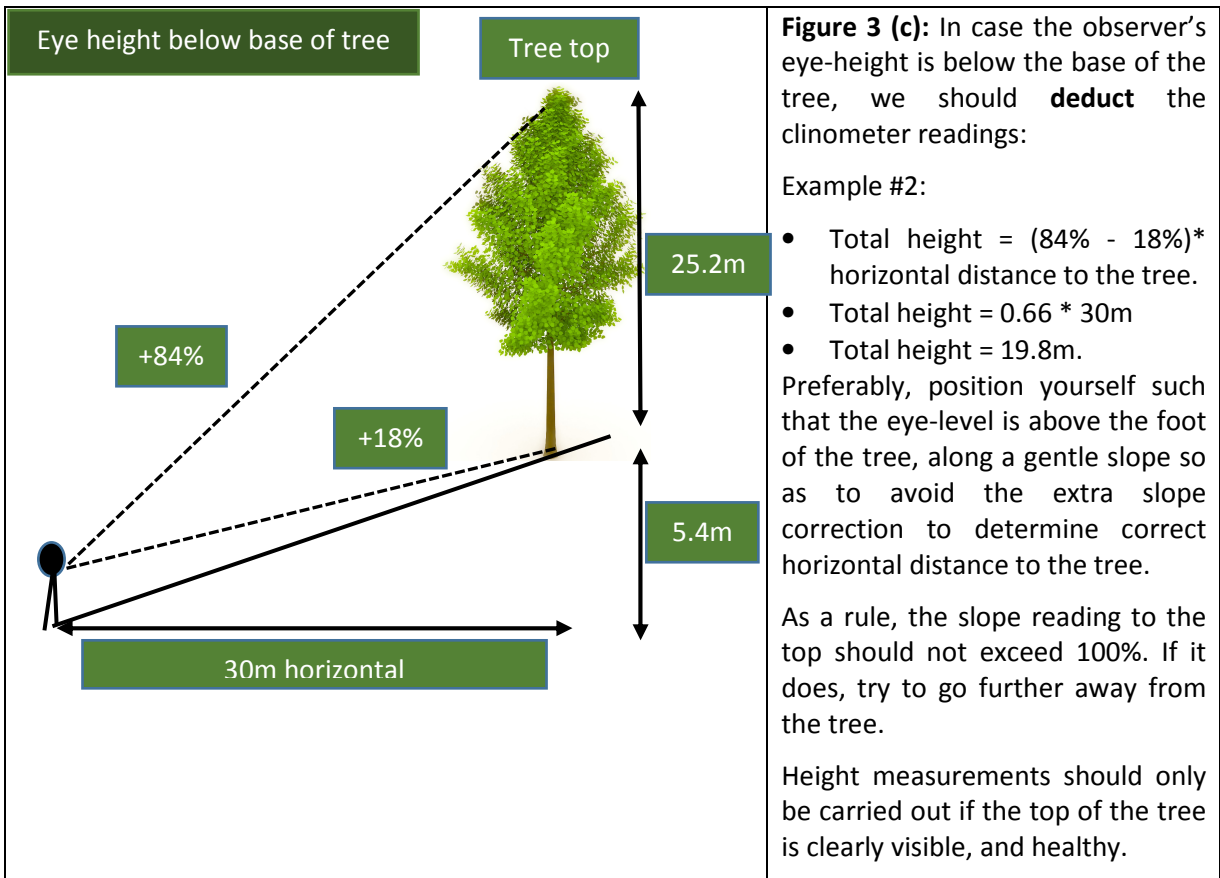
Example #1:

- Total height = $(84\% + 18\%) * \text{horizontal distance to the tree}$.
- Total height = $1.02 * 30\text{m}$
- Total height = 30.6m .

Preferably, position yourself such that the eye-level is above the base of the tree, along a gentle slope so as to avoid the extra slope correction to determine correct horizontal distance to the tree.

As a rule, the slope reading to the top should not exceed 100%. If it does, try to go further away from the tree.

Height measurements should only be carried out if the top of the tree is clearly visible, and healthy.



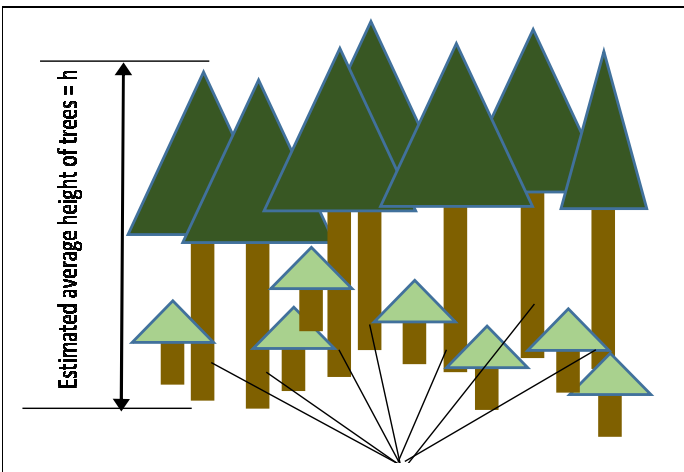


Figure 5: Estimating growing stock in even-aged forests

Growing stock = basal area (m²) x ½ h
 Note: Basal area is estimated by wedge prism. Under-storey trees are not considered.

Example #5.

b = 22m²;

h = 36 m

Growing stock = 22 x ½ x 36 = 400 m³

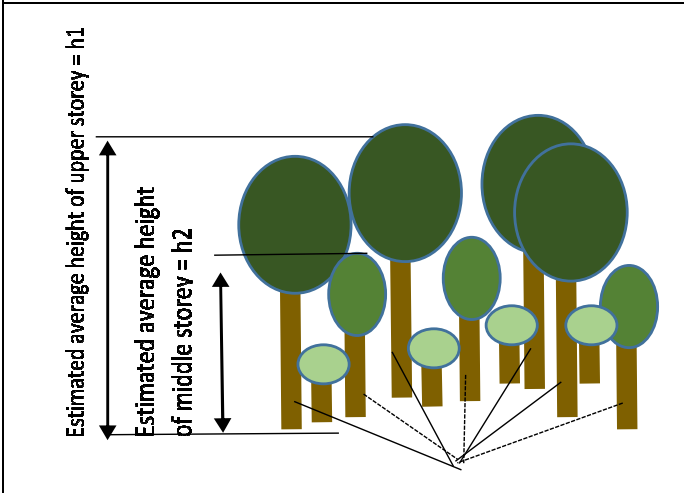


Figure 6: Estimating growing stock in uneven-aged forests

Growing stock = basal area (m²) x ½ h for upper -storey trees plus basal area (m²) x ½ h for middle -storey trees. Under-storey trees are not considered.

Example #6. b1 = 16m²; h1 = 26 m and b² = 12m²; h2 = 14m.

Growing stock = (16 x 13) + (12 x 7) = 290 m³/ha.

This doesn't give accurate results in multi-storey forests

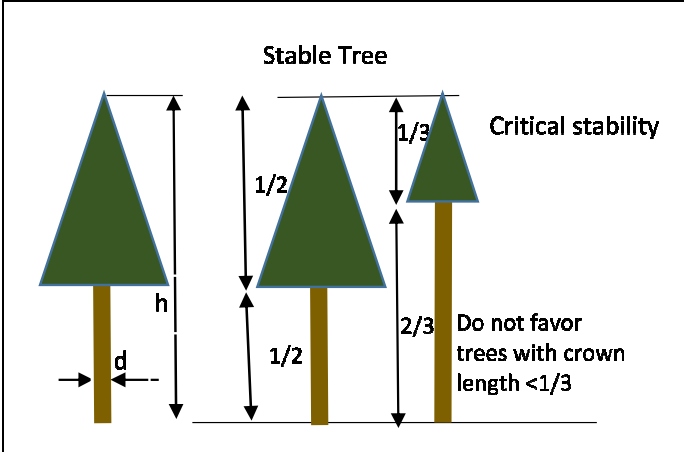


Figure 7: Assessing stability of trees (conifers only)

Stability factor = height (m) / dbh (m).

Example #7. h = 27m, dbh = 0.3m.

Stability factor 27/0.3 = 90

A tree is considered stable when height to diameter ratio is: Chir pine h: d < 100.

Blue pine h: d < 80. Trees that have a crown length < 1/3rd of tree height are also critically unstable.

5. Step 3: Select Forest Management Objectives

Objective: *To identify the main management objectives for the stand in order to choose appropriate silvicultural options.*

There are three (broad) main types of forest management objective:

- 1. Utilisation:** This means using the forest to provide products in a sustainable way. This includes wood (timber) and non-wood forest products (NWFPs).
- 2. Improvement:** This means altering the present forest condition – especially by improvement of degraded or young forest so that it can supply forest products sustainably in future. It also includes changing the species mixture or the size-class distribution of a forest e.g. from single-aged to multi-aged or single species to mixed species and also it includes improving forest biodiversity.
- 3. Protection:** This means protecting the forest from fire, grazing, illicit harvesting, pests and diseases, etc. so that its ability to supply goods and ecological services will be improved. Protection is most critical in forests which is already degraded, but all forests need some protection, even if they are in good condition, so they do not deteriorate further.

How to select forest management objectives

1. In the Forest Stand Assessment Formats (Annex 6 and 8) complete all parts of its step. E.g. in Community Forests, there are 2 main parts to be completed.
2. First, complete the section about the long-term vision. This will come from the forest management plan for the forest. Write down how you would expect the stand to appear after about 30 years – assuming that all the proposed silvicultural and management activities have taken place.
3. Next, record under each of the 3 main objectives (utilisation, improvement and protection) how the stand will be managed. For example for ‘utilisation’ you could write ‘harvesting ‘Cham-sized’ trees for timber or under ‘protection’ you could write ‘protection of regeneration from grazing and fire’.

Objectives are not mutually exclusive i.e. more than one broad management objective can be applied to a single stand. Depending on the forest management regimes (FMUs, CFs, PAs or LFMA) these broad management objectives will have different priorities. For example in FMUs, utilisation will be the first priority. In Protected Areas, protection will be the priority objective.

In FMUs the forest function mapping that has been carried out during preparation of the FMU management plan will indicate which of these broad management objectives will be given priority for each forest stand.

In community forests the CF management planning process will have identified the main management objectives for each block. This has been discussed and agreed by the CFMG members and is recorded in the CF management plan.

In protected areas the priority management objective is always protection and there are legal restrictions on utilisation (especially timber) in core areas.

In local forest management areas, utilisation is often considered the main management objective although in practice many of these forest areas are already somewhat degraded. Therefore, protection or improvement could also be the priority management objectives or should be combined with utilisation.

6. Step 4: Identify Silvicultural Options

Objective: *To identify appropriate silvicultural options for the forest stand based on its type, condition and management objectives.*

How to identify silvicultural options

1. This is the critical part of the stand assessment. You now know the forest type, the stand condition and the management objectives. Based on these you can select the best silvicultural option(s).
2. First, use table 6.1. This gives you the silvicultural systems that can be applied for different forest types. This is based on practical experience and research studies in Bhutan.
3. Use the stand assessment format to see what the stand condition is (Step 2). Based on this, use Table 6.2 and select the part of the table that best describes the stand condition (column 1). This will then indicate a number of possible management activities depending on the management objectives.
4. If harvesting (timber or poles) is a possible activity (under the utilisation objective), then you will need to select the best silvicultural option for timber and/or pole harvesting – again using Table 6.2
5. Depending on the broad management objectives (utilisation, improvement or protection), select and record the possible silvicultural options from the table 6.2. You might choose to select silvicultural options from more than one box in the table 6.2 if the forest condition in the block is variable. Note that as forest condition becomes more degraded, there are fewer silvicultural options available for utilisation, and more for protection and improvement.
6. Note that not all the options listed in Table 6.1 will be available for all stands. For example, bamboo harvesting can only take place if bamboo is available. Resin tapping can only take place in Chir pine forest. Timber harvesting will not be permitted in core zone of protected areas regardless of the forest condition or timber availability. You need to carefully apply your judgement, visual observations and knowledge of the forests.
7. From the combination of Table 6.1 and 6.2 you will be able to suggest the most appropriate silvicultural options. These should be written on the stand assessment format. Use the comments box on the stand assessment format to explain why you have selected a particular option.
8. After you have selected a silvicultural system, the next chapter will describe how to implement this in different forest types.

Table 6.1: Silvicultural Systems for Utilisation of Forests in Bhutan		
Forest type	Altitude range	Appropriate Silvicultural System
1. Subtropical forest	200-1,000	<ul style="list-style-type: none"> • Single tree selection system or • Patch felling with either natural or artificial regeneration or • Coppice system
2. Chir pine forest	900-1,800	<ul style="list-style-type: none"> • Single tree selection system or • Group selection
3. Warm broadleaved forest	1,000-2,000	<ul style="list-style-type: none"> • Patch felling with either natural or artificial regeneration or • Single tree selection or • Coppice system
4. Blue pine forest	2,100-3,000	<ul style="list-style-type: none"> • Single tree selection system or • Strip clearcut system or • Group selection
5. Cool broadleaved forest	2,000-2,900	<ul style="list-style-type: none"> • Patch felling with either natural or artificial regeneration or • Single tree selection system or • Coppice system
6. Mixed conifer forest	2,500-3,100	<ul style="list-style-type: none"> • Group selection or • Strip clearcut system
7. Fir forest	3,000-3,800	<ul style="list-style-type: none"> • Single tree selection or • Group selection

Note:

1. Select only the appropriate silviculture system applicable for a particular forest type.
2. Single tree selection system may be applied in all forest types depending upon the forest condition and management objectives.

	Stand Condition	Utilisation	Improvement	Protection
Canopy density & Basal Area	Dense canopy > 40% BA > 18m ² /ha (good) & 12-18 m ² /ha (moderate)	<ul style="list-style-type: none"> • Timber harvesting • Pole harvesting • Fuelwood harvesting • Bamboo & cane harvesting • Fodder collection • NWFP collection • Leaf litter collection 	<ul style="list-style-type: none"> • Thinning • Cleaning and weeding • Singling • Pruning 	<ul style="list-style-type: none"> • Awareness on forest fire prevention • Law enforcement • Construction of fire line/fire breaks • Regular monitoring • Sanitary felling • Fencing regeneration, water source, plantation, etc.
	Open canopy < 40% BA 6-12 m ² /ha (degraded) & < 6 m ² /ha (open)	<ul style="list-style-type: none"> • Fuelwood harvesting • Fodder collection • Bamboo & cane harvesting • NWFP harvesting • Leaf litter collection 	<ul style="list-style-type: none"> • Facilitate or induce (soil disturbance) for natural regeneration • Sowing of seeds and planting of seedling (artificial regeneration) • Cleaning and weeding • Singling • Pruning • Soil conservation 	<ul style="list-style-type: none"> • Prescribed burning • Law enforcement, controlled or restricted grazing • Fencing of regeneration, water source, plantation, etc.
Regeneration status	Abundant (More than 1,600 established plants per ha > 30cm ht.)	<ul style="list-style-type: none"> • Pole harvesting • Fodder collection • NWFP harvesting 	<ul style="list-style-type: none"> • Singling • Cleaning and weeding • Fencing 	<ul style="list-style-type: none"> • Protection of regeneration • Prescribed burning • Law enforcement
	Scattered (less than 1,600 established plants per ha >30cm ht.)	<ul style="list-style-type: none"> • Fodder collection • NWFP harvesting 	<ul style="list-style-type: none"> • Fencing • Soil conservation • Enrichment planting 	<ul style="list-style-type: none"> • Awareness on forest fire prevention • Law enforcement • Construction of fire line/fire breaks • Regular monitoring • Fencing of regeneration, water source, plantation, etc.

None (which do not fall in any of the stand conditions mentioned above)	<ul style="list-style-type: none"> • Fodder collection 	<ul style="list-style-type: none"> • Fencing • Plantation establishment • Soil conservation 	<ul style="list-style-type: none"> • Awareness on forest fire prevention • Law enforcement • Construction of fire line/fire breaks • Regular monitoring • Fencing of regeneration, water source, plantation, etc.
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One of the characteristics of silviculture as practiced in Bhutan is that as far as possible it mimics nature and natural ecosystems. When considering the silvicultural system (especially for timber harvesting) it helps to consider how the stand would naturally become disturbed and regenerated again and as far as possible to try to replicate this through artificial interventions. The silvicultural systems for different forest types should try, as far as possible, to reflect the natural disturbance for the forest ecosystem.

Three categories of natural forest in Bhutan can be identified based on the type and frequency of natural disturbances:

1. Disturbance - maintained forest e.g. Chir pine forest,
2. Disturbance - driven forest e.g. blue pine forest,
3. Gap driven - forest e.g. broadleaved forests, mixed conifer forest and fir forest.

Table 6.3: Mimicking Disturbance in Natural Forests	
Disturbance - maintained forest	Regular periodic disturbances e.g. fires, create a forest that is a patchwork of areas of different ages. Fires are needed for regeneration but should not be too frequent or too infrequent.
Disturbance - driven	Occasional catastrophic disturbances e.g. fires, climatic events or defoliating insects create a forest which is largely even-aged (and often single storied). Cycles of disturbance are long – maybe 100-150 years.
Gap driven forest	Disturbances are created when individual trees die and fall leaving canopy gaps in which young trees regenerate. This takes place on a small scale but continuously, creating a forest which is uneven-aged and multi-storied.

Source: Dick and Yonten (1996)

7. Implementing Activities under different Silvicultural Systems

As a forest manager you need to apply your knowledge and skills to select and implement the most appropriate silvicultural system. Different silvicultural systems have been recommended for the main forest types in Bhutan (Table 6.1). However, it is important to remember that silvicultural system to be applied depends on forest condition as well as forest type and also on the management objectives for the forest stand.

In FMUs, CFs and LFMA, you may need to carry out timber harvesting for local or commercial use. This means you may need to fell mature timber-sized trees and need to select a silvicultural system.

This chapter describes the 4 main silvicultural systems you may need to select:

- i. Single tree selection
- ii. Group selection
- iii. Strip Clearcut Felling System
- iv. Patch felling with natural or artificial regeneration

There are other possible silvicultural systems but they are not used much in Bhutan e.g. coppice system or shelterwood system. However, modifications of all these 4 suggested systems are possible depending on the actual stand conditions.

Marking and felling are the critical operations when carrying out all silvicultural systems involving timber harvesting. Under no circumstances should the marking officer mark good quality, healthy trees in the stand if this is not consistent with good silvicultural practice.

7.1 Single Tree Selection

In Bhutan, this silvicultural system can be used for all forest types.

Description

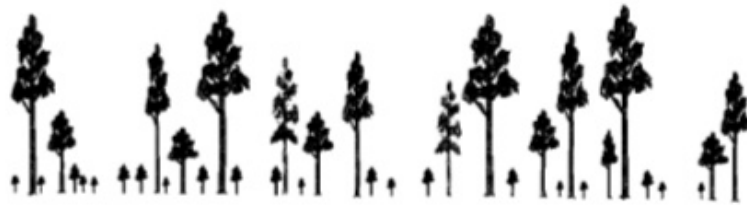
Single tree selection is a silvicultural system where individual trees are selected for harvesting in all size classes more or less uniformly throughout the stand. Individual trees are harvested with the intention of maintaining a continuous canopy without significant gaps. This system is most suitable for shade-bearing species because gaps created by removal of single trees are too small for regeneration of strong light demanders. It is a silvicultural system that most closely mimics nature in gap driven forest types (Table 6.3) and it results in a stand that is uneven-aged i.e. not dominated by a single size-class or age class.

Single tree selection is used to harvest timber and to develop and improve mixed forest stands (with mixed species and age-classes). It allows further growth to be concentrated on the best individual trees of the most desirable species whilst improving the vitality and health of the stand.

It avoids too much forest disturbance and provides suitable conditions for natural regeneration of shade bearing species in the selected forest types.



Single-tree selection system -- before cut



Single-tree selection system -- after cut

Figure 8: Single tree selection

Note that only a few trees have been removed (about 15%) of all sizes and evenly across the stand so that no large gaps are created.

Priority is to remove less desirable species or trees that are over-mature and poor quality.

Implementing single tree selection requires considerable skill by forest managers. It requires a good knowledge of the silvicultural and growth requirements of different species (especially in broadleaved forests) and it requires careful monitoring over time. However, it does allow for timber to be harvested 'on demand' i.e. if only small quantities are required at one time, although usually it is better to apply single tree selection system for the entire stand at one time to avoid excessive disturbance.

Implementation (general)

1. Visit all parts of the stand to be harvested so that a good overall impression is obtained. Then complete the stand assessment format including the estimate of the growing stock.
2. Plan how much timber can be harvested from the stand. This should be no more than 10-20% of the standing volume for single tree selection.
3. Follow these marking guidelines for single tree selection:
 - Where ever possible, mark trees evenly distributed throughout the stand,
 - Mark up to 25% of the stand volume,
 - Mark trees that are malformed, dead, diseased and dying as a priority including those that are less than 50 cm dbh,
 - Mark larger trees for timber (above 50 cm dbh) that will promote the growth of nearby saplings of desired species when they are removed and that have utilisation value,
 - Ensure that no large openings are created in the stand,

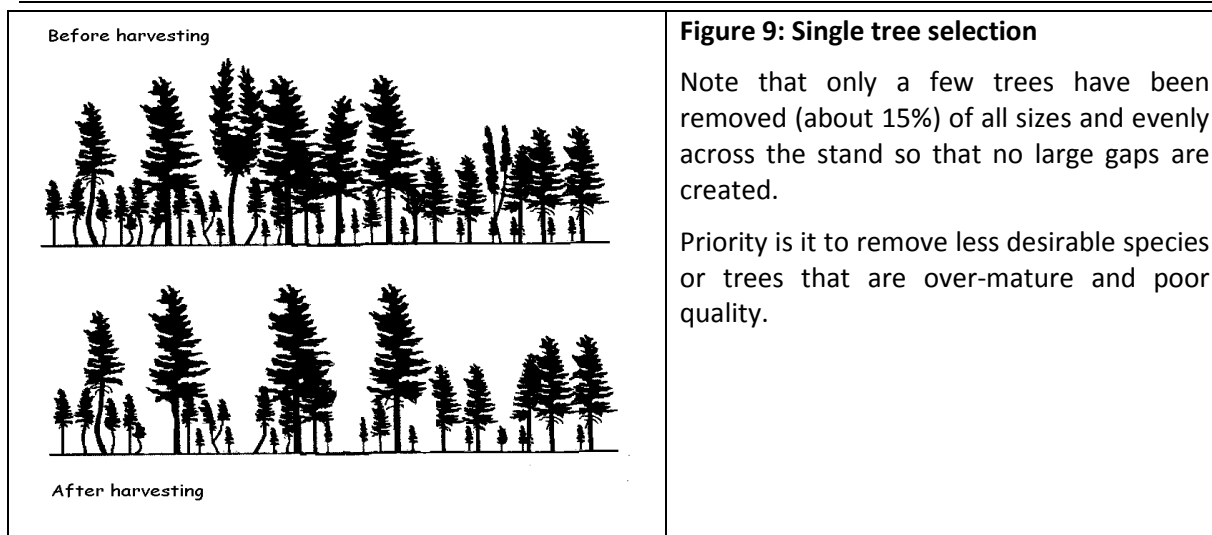
- Ensure that an even distribution of suitable species remains after harvesting,
 - If using cable cranes, the extraction lines should be as narrow as possible (not wider than 3-5 m).
4. Do not mark trees if they are:
 - On steep slopes with more than 45 degree (100%),
 - Closer than 30 m to a water course or water source,
 - In and around the sacred places (consult local people).
 5. Harvesting operations shall start only after marking has been completed for the particular stand. This will give you an opportunity to check whether the right volume has been marked.
 6. During harvesting, trees should be carefully felled to avoid damaging neighbouring trees and regeneration. Trees should be felled across the slope if possible.
 7. Marking and harvesting should normally be carried out between October and March.
 8. All marked trees should be harvested and extracted within 2 years of marking.
 9. After harvesting, the stand should not be visited for harvesting again for at least 10 years. This will allow the stand to recover and to allow the regeneration to develop and grow.

Implementation (fir forest)

The single tree selection system is particularly suited to slow-growing fir forests that are usually uneven-aged and that often comprise larger over-mature trees. In these forests, fir is the major timber species but individual large trees may not produce good timber because they may be unsound (rotten inside). Through careful selection of trees to be harvested, these older trees can gradually be removed to favour the growth of younger, more vigorous trees and to allow regeneration to develop without opening the canopy too much. This prevents invasion and domination by under-storey species such as rhododendrons (*Rhododendron hodgsonii*) and bamboos (*Arundinaria racemosa* & *Yushania microphylla*) that will restrict regeneration of fir.

Implementation (broadleaved forest)

In broadleaved forest types, single tree selection can be used to increase the stocking of the most valuable timber species such as *Michelia*, *Nyassa*, *Alnus*, *Castanopsis* and *Juglans*. Stems of less preferred species or with poor form adjacent to good quality individual stems of the preferred timber species can be marked for harvesting so that these remaining trees continue to grow and the overall quality of the stand improves. However, harvesting operations must be carried out carefully so that these valuable stems are not damaged.



7.2 Group Selection

In Bhutan, group selection is most frequently applied in mixed conifer forests, although it can also be used in fir forests (TableTable 6.1). The method of implementation can be either manual i.e. where trees are harvested and extracted by hand (usually in CFs) and mechanised i.e. where trees are harvested and then extracted by cable systems (in FMUs).

Description

In group selection, natural regeneration is initially encouraged by creating small canopy gaps (less than 2 tree lengths in diameter) by harvesting timber-sized trees. These gaps are gradually increased in size with further felling as regeneration becomes established. Groups are normally started by felling large and mature (or over-mature) trees and using the gaps created as the basis for a new group. The aim is to create a range of light and environmental conditions suitable for seedlings of different species and ages thus producing a forest which is uneven aged and has high increment.

One disadvantage of group selection is that marking of trees to be felled in the groups is a skilled operation. It requires good knowledge of regeneration of a range of conifer species. Also, because of the uneven-aged structure of the forest that is created with group selection, there is a high risk of damage to younger trees when older trees are harvested. Therefore, good harvesting skills are required to minimise such damage (see section 7.7 on timber harvesting). However, the level of skill and attention to carry out a group selection makes it very suitable for use in community forests where greater attention to detail is possible. It is also commonly used in FMUs where timber extraction is by cable crane. This means that groups need to be aligned so that timber can be harvested and extracted efficiently and with minimal damage.

Implementation (general)

1. Firstly, visit the whole stand to be harvested so that a good overall impression is obtained. This will enable you to select the best groups. Then complete the stand assessment format including the estimate of the growing stock.
2. Plan how much timber can be harvested from the stand. This should be based on the Annual Harvesting Limit in CFs and Annual Allowable Cut in FMUs.
3. Within the stand, identify and select suitable groups. These groups may be based on existing openings, existing regeneration (if present); suitability for timber extraction e.g. accessible to the cable line or the availability of trees of harvestable size. Groups are not normally marked although it may be helpful to put temporary pegs around the group boundary.
4. Groups are roughly circular in shape (or oval-shaped with the long axis running approximately east-west).
5. Group size depends on the characteristics of the species that are expected to regenerate in the group (see the section 7.5 on regeneration) and on the presence of competing weeds. Group diameter should not exceed 2 times average tree height (usually 0.1 - 0.25 ha). Typically groups might be 30 m in diameter (or slightly larger if there are no competing species such as bamboos and rhododendrons).
6. Distance between groups should not be less than 50 m. The total area covered by groups should not be more than 30% of the whole stand.
7. If there are existing openings that are already larger than this, 1-2 mature mother trees (seed/plus tree) should be retained within these to serve as a seed source and to ensure suitable regeneration conditions within the group (otherwise groups will be susceptible to reduced moisture conditions, excessive sunlight and/or invasion by unwanted under-storey species).
8. Follow these marking guidelines for harvesting trees under the group selection system:
 - Mark trees for harvesting inside these groups only (see separate implementation guidelines for mixed conifer forest and fir forest below),
 - Mark all timber sized trees in the groups and also any damaged or deformed trees that have not yet reached timber size,
 - Over matured, hollow, dead and dying, trees can be left unmarked (for biodiversity conservation),
 - Mark tree only if they are more than 10 cm dbh,
 - Smaller pole-staged trees within the group may be marked for thinning (if required),
 - Around the edge of the group try to ensure that unmarked edge trees are stable (wind-firm) and able to produce seed.
9. Do not select groups or mark trees if they are:
 - Outside the selected groups,
 - On very steep slopes with more than 45 degrees (100%),

- Closer than 30 m to a water course or water source,
 - 200m uphill and 100m downhill of a highway (road buffer),
 - In and around the sacred places (consult local people).
10. Start harvesting operations only after the whole stand has been marked. This will give you an opportunity to check whether the right volume has been marked and if the selection of groups has been satisfactory i.e. not too much area has been covered.
 11. During harvesting, trees should be carefully felled to avoid damaging established regeneration. Trees should be felled across the slope if possible.
 12. Any damaged trees (logs) can be left on the ground within the groups to provide seed beds for further regeneration (for hemlock-dominated stands approximately 10 m³/ha of dead wood should be retained on the ground and for spruce-dominated stands approximately 7 m³/ha of dead wood should be retained on the ground inside the opening).
 13. Marking and harvesting should normally be carried out between October and March.
 14. After harvesting, carry out any other required silvicultural operations including thinning pole-stage stands, tending and weeding existing regeneration and cutting back rhododendrons and bamboos to create better conditions for further regeneration.
 15. All marked trees in groups should be harvested and extracted within 2 years of marking.
 16. The stand will not be visited for harvesting again for about 20 years. This will allow it to recover and will allow regeneration in the harvested groups to develop and grow.

Implementation (mixed conifer forest)

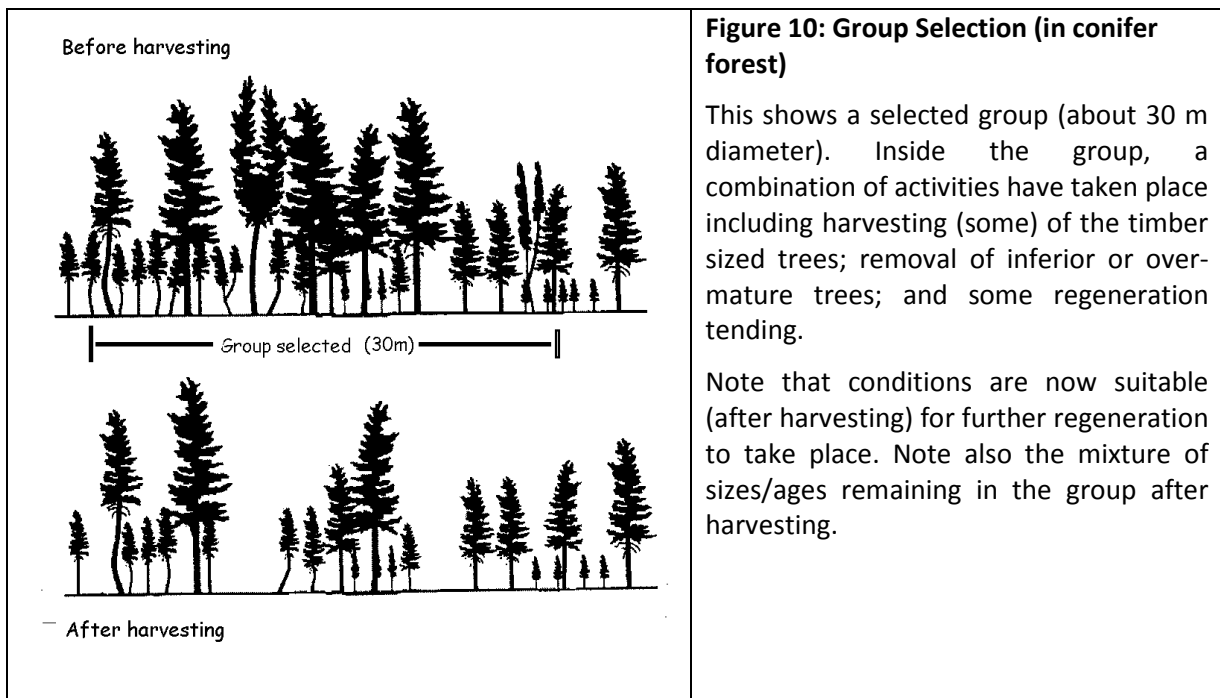
In mixed conifer forests the aim of group selection is to create suitable conditions for a range of conifer species to regenerate and develop. Over a larger area there may be different stands that are dominated by different conifer species depending on the site conditions. When selecting groups and their sizes, it is necessary to consider what species are expected to regenerate on the site and then create the best conditions for this to take place. Looking at existing regeneration will give a good indication of what species are likely to regenerate.

Make sure that protection systems are in place for the stand before starting any harvesting. Grazing and trampling can be a problem for regeneration in mixed conifer forests. Where canopy cover is continuous, new openings can be created by marking and harvesting one or two large and mature trees which are close together. Dense areas of pole-sized trees can also be marked for thinning.

In mixed conifer forest all large, timber-sized trees in the group can be marked including any over-mature or deformed trees even if these may not be particularly useful for timber so that the forest is gradually improved. Such unwanted trees need not be extracted – they can be left within the forest to provide micro-sites suitable for regeneration. After harvesting, always carry out necessary silvicultural activities such as weeding, establish regeneration and cutting back unwanted shrubs so that conditions within the group are ideal for maximising regeneration. It may be necessary to return to the harvested groups in subsequent years to carry out such activities again.

In FMUs, cable extraction systems will be used to harvest timber from group selection. The guidelines for implementing group selection using cable crane systems are similar to those above with the addition of some extra conditions:

- The distance between extraction lines should not be less than 60 m,
- Groups should be identified along the extraction lines (or accessible to them),
- Trees can also be marked for harvesting along the extraction corridors which must be as narrow as possible (less than 4 m),
- Felling should be oriented towards the cable corridor to reduce damage – although due consideration is also needed to avoid damaging existing regeneration.



Implementation (fir forest)

Group selection may occasionally be used in fir forests although in most situations single tree selection is likely to be more appropriate.

In fir forest, if applying group selection, the maximum diameter of a group should be less than one tree length (less than 0.1 ha). Groups should not be selected in wet spots. Normally, in group selection, the groups consist of gaps with no standing mature trees left. However, in fir forests it is safer to remove only a few mature trees in each group (but not heavily rotten trees). As a result, a 'small shelter' of sound, immature and some very old and rotten trees is left within the group. This creates ideal conditions for fir regeneration. If gaps are too large, fir will not be able to compete with the broadleaved species which will also start to regenerate. Old rotten trees may later fall down or break up naturally, so further felling will not be required until the younger trees have reached timber size. This avoids too much felling at a later stage which can damage regeneration

(see Figure 1010). If the shade is too dense, more light-demanding species e.g. Larch cannot survive and also rhododendron will benefit creating a dense understorey which is not suitable for fir regeneration.

In fir forests, a few large trees which shade the group can be kept because fir requires more shade and moisture to develop and grow than spruce. These trees are also important for biodiversity conservation.

7.3 Strip Clearcut System

Description

Strip clearcuts are used to harvest a stand over a period of three to seven years by removing several strips rather than harvesting the entire stand at once. Strip clearcutting was developed to take advantage of natural seeding from the leave-strips. In a pure sense, strip clearcut systems have mostly been used on a few site types with blue pine, spruce and hemlock species of mixed conifer forests.

Implementation (general)

A major concern associated with strip clearcuts is wind damage because the leave-strips expose much more edge for a short period than does one large clearcut. To avoid excessive windthrow, leave-strips should be at least 40 m wide, open only at one end, and harvested as soon as adjacent cleared strips are regenerated, thus minimizing exposure time. Also, boundaries of strips should be carefully located in healthy stands on deep, well-drained soils. Strip clearcuts can be designed in an alternate strip clearcut or progressive strip clearcut. These are further explained below:

Alternate Strip Clearcut

In alternate strip clearcut systems the cutting unit is cut in two stages. The initial cut produces long narrow clearcuts with leave-strips in between. Often leave-strips are narrower than first-pass strips because the leave-strips are cut once the regeneration is established in first-pass strips. The second-pass cuts will therefore need planting, but this requirement can be minimized.

Strip clearcuts, alternate or otherwise, are best oriented at right angles to prevailing winds. The width of the strips will depend on seedfall distances for the preferred species, wind hazard and other factors (figure 11).

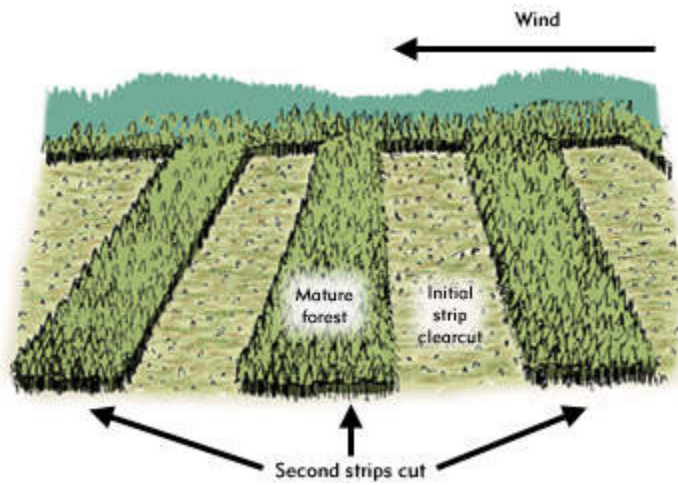


Figure 11: Alternate Strip Clearcut
 (Source: <https://www.for.gov.bc.ca/hfp/training/00014/varclear.htm#clear>)
 In alternate strip clearcut systems the cutting unit is cut in two stages. The initial cut produces long narrow clearcuts with leave-strips in between. To avoid excessive windthrow, leave-strips should be at least 40m wide. Open only at one end, and harvest as soon as adjacent clear strips are regenerated.

Progressive Strip Clearcut

The progressive strip clearcut system accomplishes the same objectives, in essentially the same manner, as the alternate strip clearcut but in three or more passes rather than in two (figure 12).

Progressive strip clearcuts have two advantages over alternate strip clearcuts:

1. The strips are progressively cut into the prevailing wind, reducing the exposed edge and windthrow.
2. Less area in the final pass needs planting.

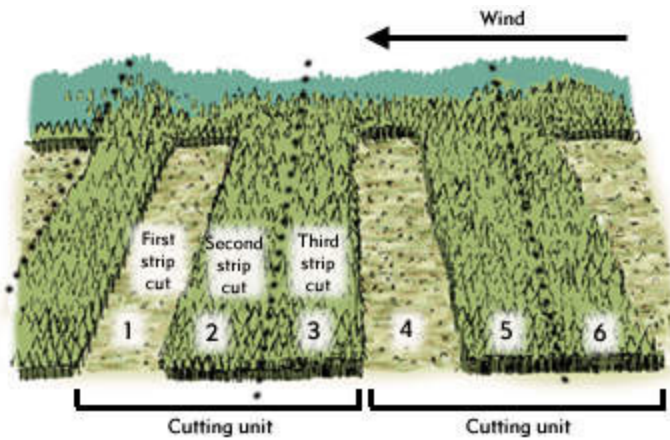


Figure 12: Progressive Strip Clearcut
 (source: <https://www.for.gov.bc.ca/hfp/training/00014/varclear.htm#clear>).
 Progressive strip clearcuts have two advantages over alternate strip clearcuts:
 1. The strips are progressively cut into the prevailing wind, reducing the exposed edge and windthrow.
 2. Less area in the final pass needs planting.

7.4 Patch Felling with Natural or Artificial Regeneration

The patch felling with natural or artificial regeneration system is normally used in subtropical forest and both warm and cool broadleaved forest types in Bhutan (Table).

Description

There is still some uncertainty about the best harvesting system for broadleaved forests and subtropical forests in Bhutan. Patch felling has been tried in these forest types with moderate success especially in cool broadleaved forests. Normally, additional planting of preferred species (artificial regeneration) is needed to supplement natural regeneration to ensure best results under the patch felling system.

In patch felling, small patches of forests are clear-felled in the stand creating openings in the canopy. These openings are kept weed-free and are protected from grazing. This creates growing conditions suitable for regeneration – including natural regeneration. The result is an uneven-aged and mixed species stand.

Implementation (subtropical and warm and cool broadleaved forest)

1. Firstly visit the whole stand to be harvested so that a good overall impression is obtained. This will better enable you to select the best patches for canopy opening. Then complete the stand assessment format including the estimate of the growing stock.
2. Plan how much timber can be harvested from the stand. This should be based on the AHL specified in the management plan for CFs and ACC in FMUs.
3. Within the stand, identify and select suitable patches for canopy opening. These may be based on existing openings, existing regeneration (if present) or the availability of trees of harvestable size. Openings are not normally marked although it may be helpful to put temporary pegs around the boundary.
4. The size of the openings (patches) should be small because they will need to be kept free of grazing and weeds. Smaller openings will also create a range of light conditions suitable for different species to regenerate. Opening sizes may be up to 30 x 30m (0.1 ha) but should not less than 20 x 20 m. Patches should include some harvestable trees (> 30cm dbh) and should be more or less circular. It may be possible to create new patches by enlarging existing canopy gaps.
5. Make sure that protection measures are in place for the stand before starting any harvesting. Grazing is a major problem for regenerating broadleaved and sub-tropical forests and it must be controlled in the harvested patch otherwise the regeneration will fail.
6. Inside the opening (patch) identify all the tree species (of all sizes) particularly those that are most important for timber.
7. Follow these marking guidelines for harvesting trees under the patch felling system:
 - All sizes of trees can be marked (not just large timber trees),

- Marking should depend on the light requirements of each species. The aim is to create the best conditions for the regeneration of preferred species,
- Mark (a) mature trees of preferred timber species, (b) immature trees that need to be felled for forest improvement purposes and (c) trees that are obstructing the growth of preferred regenerating species – including smaller trees,
- Do not mark two or more large trees that are directly adjacent to each other,
- Mark trees with the aim of creating an uneven-aged forest structure (multi-storey),
- Dead trees can be left standing for biodiversity conservation,
- Ensure that the forest areas adjacent to the patch (opening) contains seed trees of the required timber species.

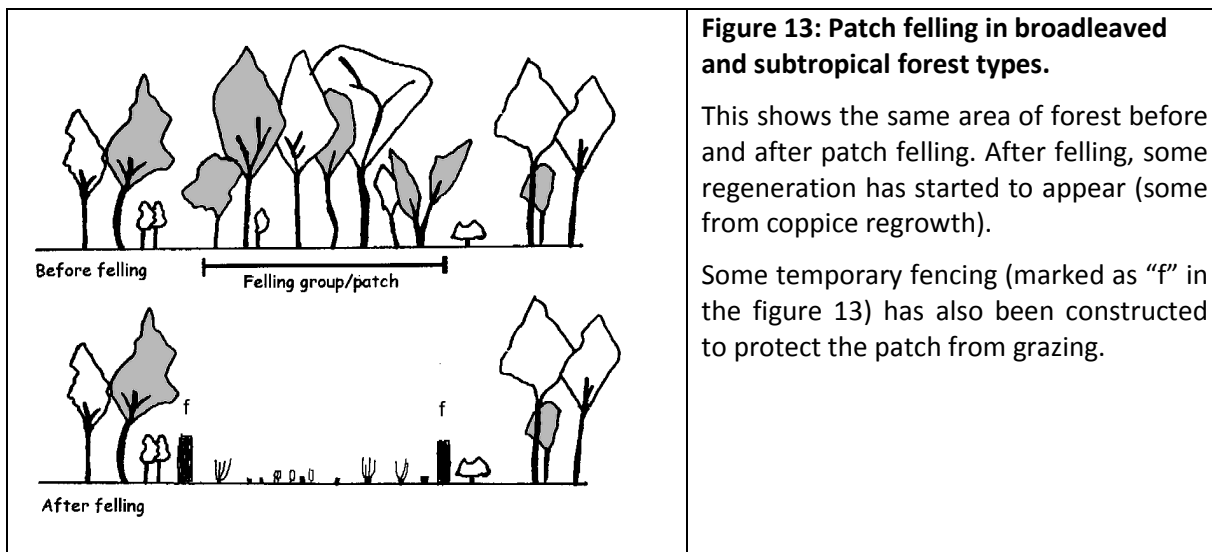


Figure 13: Patch felling in broadleaved and subtropical forest types.

This shows the same area of forest before and after patch felling. After felling, some regeneration has started to appear (some from coppice regrowth).

Some temporary fencing (marked as “f” in the figure 13) has also been constructed to protect the patch from grazing.

8. Do not select patches for felling or mark trees within patches if they are:
 - Outside the selected patches (openings),
 - On very steep slopes, more than 45 degree or 100% (on moderately steep slopes marking is possible provided that harvested trees can be removed),
 - Closer than 15 m to a water course or water source,
 - 200m uphill or 100 m downhill of a road (road buffer),
 - Close to sacred places (consult local people).
9. Carry out the felling in a way which avoids damage to regeneration. Clear away any remaining shrubs or understorey vegetation from the opening after harvesting.
10. After harvesting, strict protection (especially from grazing) is needed to encourage natural regeneration from seed. Fencing may be necessary.
11. Some regeneration will also come from coppice shoots sprouting from the cut stems as well as from seed.

12. Establish a regeneration monitoring plot in the felled area. Monitor the progress of regeneration in the plot.
13. If natural regeneration is insufficient, supplementary planting is needed. This should be of preferred native timber species (refer Table 7.1).
14. Select and harvest new patches annually making sure that new areas are not within 50 m of existing harvested patches.
15. Keep the patch free of weeds and any unwanted shrubs. Annual cleaning will be required.
16. Patch felling will produce a range of trees of different species, sizes and timber quality. Use of these products needs to be carefully controlled to avoid waste. It is not advisable to harvest a whole patch simply to get a single large tree of a valuable timber species.

Table 7.1: Recommended tree species for planting in patch felling in subtropical forest and both cool and warm broadleaved forest types

Subtropical forest	Warm broadleaved forest	Cool broadleaved forest
<i>Acrocarpus fraxinifolius</i>	<i>Alnus nepalensis</i>	<i>Acer campbellii</i>
<i>Chukrasia tabularis</i>	<i>Bischofia javanica</i>	<i>Betula utilis</i>
<i>Dalbergia sissoo</i>	<i>Exbucklandia populnea</i>	<i>Cupressus corneyana</i>
<i>Duabanga grandiflora</i>	<i>Morus alba</i>	<i>Juglans regia</i>
<i>Gmelina arborea</i>	<i>Phoebe altenuata</i>	<i>Michelia doltsopa</i>
<i>Lagerstroemia hirsute</i>	<i>Michelia doltsopa</i>	<i>Nyssa javanica</i>
<i>Michelia champaca</i>	<i>Schima wallichii</i>	<i>Persea fructifera</i>
<i>Tectona grandis</i>		<i>Quercus lamellosa</i>
<i>Terminalia myriocarpa</i>		
<i>Terminalia tomentosa</i>		
<i>Toona ciliate</i>		
<i>Shorea robusta</i>		
<i>Refer to Annex 1 for forest types and Annex 5 for local tree names</i>		

7.5 Managing Regeneration

For sustainable forest management, regeneration is needed to replace harvested trees or to improve forest that is already degraded. Getting regeneration of the desired species and making sure that it survives and grows is an essential part of forest improvement. Forests which have been subject to frequent fires and grazing in the past usually do not have enough regeneration. Fortunately most of the main forest types of Bhutan are easy to regenerate naturally if protection is provided. Natural regeneration is a much cheaper option than plantation establishment (artificial regeneration) and every effort is needed to aim for this before starting to consider planting.

This section covers the options for managing regeneration and also describes the characteristics of the main forest types in Bhutan in terms of their regeneration requirements.

Option 1: Create suitable conditions for regeneration

1. Ensure that there are enough mature trees producing viable seed (of the preferred species). About 25 trees per ha (minimum) of most conifer species are needed. If not, then use direct sowing with collected seed. Otherwise it may be necessary to establish plantations artificially.
2. Improve soil and vegetation conditions for regeneration. This includes removal of competing undergrowth and vegetation e.g. bamboo or other species by slash and cutting. In some forest types e.g. blue pine, seedlings are able to grow through understory bushes.
3. In fir forests, understory shrubs provide some protection for regeneration against frost, snow and cold so these should be cut back with caution.
4. Consider carrying out soil disturbance to expose top soil and provide better conditions for seed to germinate, especially for blue pine and spruce.
5. Remember that many trees do not produce seed every year. It may be necessary to wait for 2-3 years to get enough seed for regeneration to take place.
6. Consider the use of fire in Chir pine forests. Controlled ground fires in open patches of Chir pine forests can lead to abundant regeneration without damaging the older trees. In other forest types, fires are less effective and can be damaging.
7. Ensure that grazing is being controlled. This is particularly important in broadleaved forests where tree seedlings are often highly palatable.

What is regeneration management?

Regeneration management means activities that are carried out to improve the establishment, quality and growth of regeneration of trees e.g. tending, singling, cleaning, soil working, etc.

Why manage regeneration?

- To improve site conditions before regeneration starts,
- To improve the growth rate and survival of existing regeneration,
- To improve the species mixture and overall condition of the final crop.

Option 2: Encourage the growth of existing regeneration

1. Carry out weeding to remove competing vegetation (especially grasses and woody shrubs). Weeding can be done three times a year in broadleaved forests and two times in conifer forest.
2. Carry out singling of regeneration to remove multiple stems.
3. For small patches, soil working can be done in circle of 1 meter around the regeneration. This can be effective in weed control and improve soil moisture condition.
4. Open the canopy. If the canopy is too dense (more than 40%), regeneration will not develop. Once it has become established, it is possible to remove the mature trees through timber harvesting, thinning or branch pruning.
5. Ensure that regeneration is protected from grazing, illicit cutting and any unsound silvicultural operations.
6. Protect from fire. Once regeneration has taken place, fire will be very damaging. Strict fire control is needed for 5 years in Chir pine forests and more in other forest types.
7. Carry out re-spacing of regeneration. This is similar to thinning where regeneration is very abundant its density can be reduced to give better survival and growth.

Regeneration of subtropical and broadleaved forests

Although, subtropical and warm and cool broadleaved forests differ in species composition (Annex 1), they can be managed with similar silvicultural systems. Compared with the conifer forests, these forest types have been less researched and there is less information available on the best regeneration management. These are mixed forest types consisting of many species making their regeneration complex.

The main problem with sustainable management of these forest types in Bhutan is achieving successful regeneration of the most desirable species. Often, numbers of saplings and seedlings are too low to replace the larger trees felled and frequently regeneration that does come up after harvesting is not of the preferred timber species e.g. it may consist of fast-growing pioneer species such as *Macaranga* spp. (which have less commercial value) and *Alnus nepalensis*.

Regeneration can be good under certain situations. However, grazing usually inhibits it from becoming properly established and often results in better survival of the least palatable species. Competition with weeds and grasses can also be a problem for regeneration establishment.

Enhancement of regeneration in subtropical and broadleaved forests:

- Restrict grazing after harvesting – this may include fencing around patches/groups, tree-guard or tree shelter.
- Do not rely solely on regeneration counting to monitor progress. It is important to monitor not only the total quantity of regeneration but also the species type coming up. If the desired species are not regenerating then plantation has to be carried out.

- Control weeds and understorey species in harvested groups/patches. This will restrict regeneration. However, be cautious when carrying out weeding or shrub cuttings to avoid damage on regenerations.
- Observe if there are adjacent seed sources of desirable timber species. If not, the regeneration is unlikely even if the site conditions are right. Remember that many species in these forests have large seeds which do not get dispersed far from the mother tree and which do not have long viability e.g. *Quercus*, *Castanopsis*, *Terminalia*, *Lithocarpus*, etc.
- Consider supplementary planting of desirable species in harvested gaps (with protection). Planted seedlings will need weeding. Also consider the possibility of direct sowing of seeds (with protection).
- If planting is necessary, avoid using exotic species.
- Many broadleaved species in these forest types will regenerate through coppice regrowth from cut stems and root systems. This can be encouraged by minimising damage during harvesting.

Regeneration of Chir pine and Blue pine Forests

These forest types can be managed using the group selection and single tree selection systems. Both species are pioneers and are able to colonise bare sites provided that a suitable seed source is available. They require high light conditions for successful germination. Under natural conditions, these species form extensive stands of more or less even-aged trees.

Enhancement of regeneration in Chir pine and Blue pine forests:

- Chir pine can regenerate profusely after a ground fire. Therefore, controlled burning can be used to stimulate natural regeneration. Blue pine seedlings are more sensitive to fire damage than Chir pine. Therefore, fire control in Blue pine forests is essential.
- Areas of bare soil help to provide suitable germination sites for both pine species. Therefore, the opening of canopy may be essential.
- When regeneration takes place, both species will often result in dense stands of saplings and pole-stage trees. Therefore, requires thinning.

Regeneration of mixed conifer forests

In mixed conifer forests, group selection and single tree selection system is usually applied for harvesting and regeneration. During implementation of this silvicultural system, it is necessary to create suitable conditions for different conifer species to regenerate. The requirements for regeneration vary from species to species which will result in stands of pure, mixed, even aged and uneven aged depending on local site conditions.

Enhancement of regeneration in mixed conifer forests:

- **Hemlock** regenerates best on moist sites with low light conditions (it is shade tolerant). Group opening should be kept small (0.1-0.25 ha) on drier sites and where there is competition with bamboo and other understorey species. Hemlock cannot regenerate under bamboo and/or rhododendron species. Groups can be larger on moist sites with fewer competing species especially on northern aspects. Hemlock prefers moist woody material as a substrate for

regeneration i.e. it regenerates on moss on older logs, forest floor, etc. Such materials should be retained on the forest floor.

- **Spruce** is less shade tolerant than hemlock and can regenerate in larger openings although it also prefers moist conditions without much direct sunlight. It is also susceptible to competition with bamboo and woody understorey shrubs. Where these species are present, groups should not be too large (less than 0.35 ha). Spruce stands are vulnerable to damage from bark beetle. To prevent this, avoid damage to the remaining stand and to remove all harvested material from the site as soon as possible.
- **Blue pine** tends to form larger pure stands and is very shade intolerant (it is a pioneer species). For regenerating stands of blue pine within mixed conifer forest groups can be larger (up to 0.35 ha). Blue pine regeneration is vulnerable to fire damage and trees of blue pine are also vulnerable to bark beetle attack. Blue pine regeneration requires re-spacing to improve its stability and reduce its vulnerability to snow damage.
- **Sites dominated by bamboo.** Consider the option of grazing to reduce competition from bamboo.

Regeneration of fir forests

Fir forests are difficult to manage sustainably because of its long rotation age, the difficult terrain, and the high percentage of over-mature and rotten trees that are present in unmanaged old-growth forests.

Enhancement of regeneration in fir forests:

- Fir requires more shade and moisture for regeneration than spruce. Therefore, large canopy openings should be avoided to maintain shady conditions on the forest floor (single tree selection system is the best).
- In fir forests, rhododendron and/or bamboo understorey will hinder regeneration. This can be reduced by controlled grazing to lower its density and create better conditions for fir to regenerate.
- Grazing needs to be restricted or phased out as soon as regeneration gets established to avoid further damage. Alternatively, this understorey of rhododendron and bamboo can be opened up - but only if regeneration is already present.
- Regular monitoring is required – regeneration will take time to establish.

7.6 Establishing Plantations

Plantation establishment should be seen as an option to be considered under certain circumstances only (see box). It is costly and labour intensive and once established, plantations are difficult to protect from fire and grazing. In general, plantations should be avoided unless there is no alternative method of regeneration. Planting of exotic species are restricted.

Figure 14 indicates the required regeneration status and canopy density for selecting plantation establishment as an option. Only if the site is completely open (i.e. with no forest canopy) and if there is no existing natural regeneration should plantations be established. Otherwise natural regeneration is more suitable and effective. Chapter 7.5 covers managing regeneration and this should always be

considered as a priority option before establishing a plantation. Enrichment planting is an intermediate option where planting is done (at lower density) to supplement any natural regeneration already present.

Before establishing a plantation, the following questions need to be answered. Normally the plantation will have been included in the management plan for any forest area.

- Which species will be planted?
- Where will the tree seedlings come from (seedling source)?
- If the plantations are established with seed sowing, seed provenance (seed source) needs to be identified.

What is plantation establishment?

Plantation establishment means artificially establishing trees as an alternative or a supplement to natural regeneration.

Why establish plantations?

- To improve the condition of degraded forest where natural regeneration is inadequate or absent,
- To rapidly establish young trees on barren site,
- To establish tree species that would not otherwise regenerate e.g. if there is a lack of seed trees,
- To establish preferred native species where they do not exist,
- To establish improved varieties of an existing tree species.

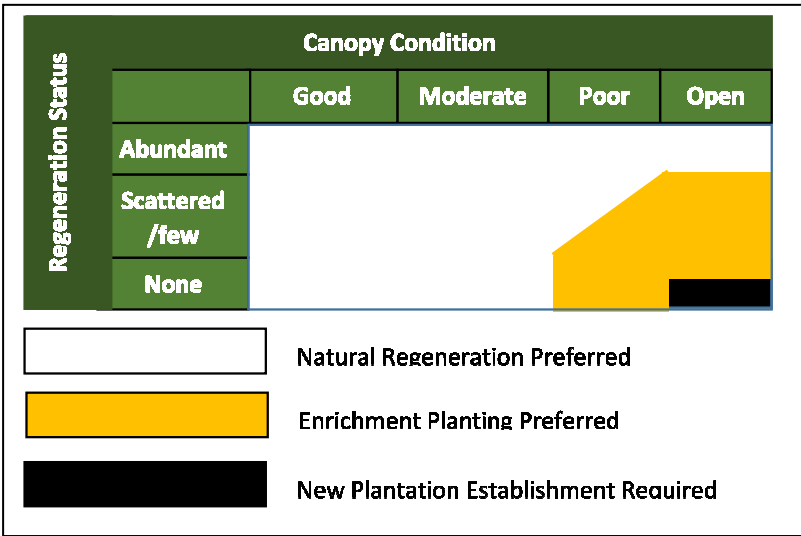


Figure 14: Natural regeneration or plantation establishment

- What is the size of the planting area? Because it is usually easier to protect a small plantation, a larger area can be planted gradually over a period of years.
- How will the plantation be protected? There are a range of options including fencing, caretaker, 'social fencing', etc. A combination of these will sometimes be required.
- Who will arrange the labour for plantation establishment and its maintenance? (Number of labour, source, duration, etc.).
- How will the plantation affect traditional uses of the area e.g. for grazing, fodder collection, NWFP collection, etc.

Choice of plantation species is critical. Unfortunately, some of the most preferred species for timber (especially broadleaved species) are slow-growing and difficult to raise in nurseries. Some do not perform well when planted in open and degraded sites resulting in their poor survival. Grazing is likely to be an important limiting factor too.

If the objective is to improve forest condition, a better option rather than planting species that are unlikely to survive is to first re-establish the forest with hardy and reliably fast growing species (such as pines or alder) and hope that with improved site conditions, natural regeneration of other, more demanding species will take place later. The primary reason for selecting any tree species for planting must be whether or not it will survive and grow on the site. Failed or poorly growing plantations are of no benefit to anyone.

7.7 Harvesting Timber

All the silvicultural options described in this chapter involve harvesting timber. The first requirement is to ensure that the marking is properly carried out. The marking guidelines are described in each of the silvicultural systems separately. The next requirement is to ensure that the marked trees are harvested properly. The following measures should be considered when harvesting timber to avoid damage and minimise wastes:

- Do not start to harvest a stand until the marking is complete to avoid over-harvesting.
- Marked trees should be harvested within two years.
- Control the direction of felling. Upslope or along the slope is best as this reduces the tendency of the harvested tree to break when it falls.
- Pay attention to the safety aspects of harvesting. Harvesting is a dangerous activity – not just for those people felling the trees, but also for bystanders.
- Avoid felling large trees into pole-stage stands or stands of dense regeneration.
- Cut trees as low as possible (20-30 cm) to the ground level - do not leave high stumps.
- Remove felled trees from the forest as soon as possible to avoid spread of pest and diseases.
- Avoid rolling logs down steep slopes. If you have to drag logs, then control them to avoid damage to other trees.
- In fir and hemlock stands, logs that cannot be used for timber (rotten or damaged) can be left on the forest floor to act as a substrate for natural regeneration. Otherwise, trees which are felled but found to be unsuitable for timber can be reallocated for other uses e.g. for fuelwood.

- After harvesting, carry out any subsidiary silvicultural operations e.g. tending, shrub clearing or weeding (in opened patches). These activities should not be delayed as this will affect the success of regeneration establishment.
- To avoid infestation of bark beetles, standard sanitation works (debarking of stumps and logs of Spruce and Blue pine, burning of barks and lops and tops, etc.) has to be carried out.

7.8 Optimising Timber Use

Felled trees should be cross-cut into useable sections before removal in the most economic and efficient way. Making best use of felled trees can increase timber utility thereby, reducing the number of trees to fell. The following points should be followed during cross-cutting:

- Cross-cut large trees into sizes that take into account the different sizes actually needed e.g. for roof structures, planks, door and window frames, etc.
- Before cross-cutting, inspect the cut tree on the ground. Identify the first log – this is the best log with few branch stubs that will produce high quality timber.
- Then identify the second log (usually lower quality or smaller size).
- Use saws (not axes) for cross-cutting to reduce waste.
- Employ skilled sawyers who can avoid damaging and wasting timber and who can work in safety with sawing equipment.
- Avoid conversion of high-quality logs into firewood.

7.9 Tending Operations

Tending operations refer to activities aimed at improving younger stands of trees. They are normally carried out together with silvicultural systems for harvesting timber to produce stands of good quality and young growing stock with vigorous growth.

7.9.1 Weeding & Cleaning

Weeding and cleaning means removing competing vegetation (usually grasses and shrubs) around young trees.

Weeding and cleaning are done:

- To produce better conditions for regeneration to establish and grow,
- To improve access to the forests (along trails and paths),
- To reduce fire hazard and fire spread – especially dry grass,
- To control the spread of weedy or invasive species.

Weeding and cleaning are labour intensive and do not yield much direct benefit in terms of forest products. However, they are essential and it is vital that regeneration areas and plantations do get regular weeding and cleaning to ensure that they get well established.

In young plantations and open areas, weeding is especially important towards the end of the monsoon season (August-September) and again before the start of the fire season (before December). However, weeding time may differ depending on regions and locality. If plantations

and areas being managed for natural regeneration are well protected from grazing and fire, weed growth will be rapid. If not controlled, weeds will compete and reduce the growth and survival of young trees as well as being a fire hazard.

7.9.2 Climber Cutting

This is a specific type of tending operation where climbers are removed from growing trees in both plantations and natural forests. It is normally carried out as part of regular tending operations. The purpose of climber cutting is:

- To remove competing vegetation (from tree crowns) to increase tree growth,
- To improve timber quality by preventing climbers from bending or breaking the leading shoots of young trees,
- To assist in timber harvesting operations (climbers are cut just before harvesting to allow felled trees to fall correctly).

Climber Cutting Procedures:

- Climber cutting should be a regular activities in the plantations which are carried out together with weeding and cleaning,
- While cutting climbers, avoid damage to the tree crops,
- As far as possible uproot or cut the climbers at the initial stage of its growth,
- Cut the climber at the base/ground level. As far as possible, climber cutting may be started during the autumn to avoid its regrowth and repeat the procedure as and when necessary.

7.9.3 Singling

Singling means removing multiple stems from trees (or regeneration) leaving a single stem. Singling activities is applied in Coppice System. It can be carried out in plantations and in natural regeneration to:

- To improve the quality and growth of the remaining uncut stem,
- To reduce stocking density,
- To produce some fuelwood from cut stems.

Singling is a simple operation, but it must be carefully carried out to avoid damage. Use of sharp cutting tools is important. Singling may be carried out at various stages during the growth of a plantation or a naturally regenerated area.

Singling procedures:

- When several stems are produced – single them by selecting the strongest and/or straightest,
- Singling should be done gradually to minimize the stress to the remaining stems,
- With coppice regrowth e.g. after harvesting broadleaved trees multiple new shoots are frequently produced from the cut stump. Select 1 or 2 of these and remove the others,
- After being damaged e.g. by snow, wind, frost or grazing, some young trees may develop a forked stem. Singling is used to select the best stem and remove the other,

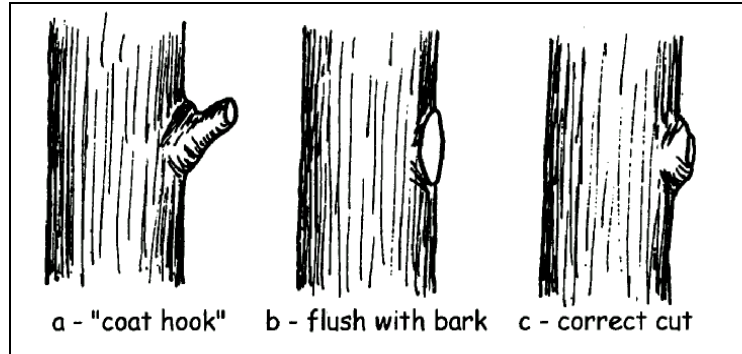
- In degraded forests forked or multiple-stemmed trees have often been left after the better trees have been harvested,
- Singling is an opportunity to improve the growing stock as well as producing some fuelwood and poles.

7.9.4 Pruning

Pruning means removing branches (live or dead) from established trees:

- To improve timber quality by reducing the number of knots which come from branch stubs (see figure 15),
- To reduce canopy density and shading e.g. where an understory of vegetation is required.

Figure 15: Pruning cuts to improve timber quality



Pruning Procedures:

- Do not prune branches to more than 50% of the total tree height or do not remove more than half the crown of mature trees otherwise growth will be affected.
- Pruning can be done for trees measuring more than 10 cm dbh or when attains the pole size.
- Prune live branches during the winter to give trees a chance to recover during the growing season.
- Use sharp tools to avoid breaking branches and damaging tree stems. Dead branches can be removed at any time.

7.9.5 Thinning

Thinning is an important silviculture activities. It is particularly important where there is dense stocking of young trees of similar age and size and is most likely to be needed in forest types which form more or less even-aged stands such as Chir pine, blue pine and mixed conifer forests.

The objective of thinning is primarily for improvement (of stand increment and quality) although poles and fuelwood will also be produced.

Some Effects of Thinning²:

- Shortens the time for individual tree to reach some specified diameter and favours trees with best growth potential.
- Improves the quality and value by focusing the growth on the most valuable trees and the most valuable species.
- Increase product yields by harvesting trees that would otherwise succumb to intense inter-tree competition.
- Provides periodic revenues/income during intermediate stages of stand development.
- Strengthens the bole and branches of remaining trees, making them more resistant to breakage.
- Maintains tree vigour and removes trees susceptible to local insects and diseases.
- Provides early income and help pay in investments and operating costs.
- Maintain trees of good phenotypes as a seed source for the next rotation.

What is thinning?

Thinning is a reduction of stem density at regular intervals in time, involving selection of trees to be retained/removed, based on silvicultural criteria.

Why Thinning?

- To improve the growth rate and diameter of the remaining trees in the forest (by reducing competition).
- To improve the quality of the final timber crop by removing deformed tree stems which will produce timber.
- To produce poles and fuelwood.
- To make the stand more stable.

Implementation (in pole-stage stands)

1. Carry out thinning depending on the silvicultural characteristic of particular stand. However, gap between two thinning should not be more than 10 years,
2. To decide whether thinning is needed, measure the average dbh of trees and the mean, stocking (stems/ha) in the stand. If the number of stems per ha for the average dbh is greater than the stocking indicated in Table 7.2 (for blue pine and Chir pine stands) then thinning is required. You can check this by measuring the basal area with a wedge prism,

² Adapted from Nyland (2002)

3. Use Table 7.2 (column 2) to see what the mean spacing between trees should be for the stocking you wish to achieve (for blue pine and Chir pine forest). Use a cut stick of this length to check if trees are too close.

Table 7.2: Spacing table for Blue pine (*Pinus wallichiana*) and Chir pine (*Pinus roxburghii*)

Average tree dbh (cm)	Average distance between trees (m)	Stocking (trees per ha)	Basal area (m ² /ha)
5	1.7	3,558	7.21
8	2.1	2,197	10.02
10	2.4	1,682	13.64
13	2.7	1,329	16.83
15	3.0	1,076	19.63
18	3.4	890	22.09
20	3.5	814	26.39
23	3.8	689	28.27
25	4.0	637	32.27
28	4.3	549	33.67
30	4.4	512	37.36

4. Use Table 7.3 to decide which of the three situations described best fits the stand to be thinned (A, B or C).
5. Follow the appropriate thinning and marking technique described in Table 7.3
6. Mark up to 25% of volume/stem in a single thinning.
7. Always select trees for marking based on their stem form and quality. Poor quality stems must be removed during thinning well before they reach Cham size (30 cm dbh).
8. All trees affected by parasitic plants (e.g. mistletoe in Blue pine) should be marked and harvested.
9. Do not allow canopy gaps to be created by thinning. The aim is to improve the stand – not encourage regeneration.
10. Harvest the marked trees taking care not to damage adjacent unmarked trees.
11. First thinning is needed as soon as trees start to compete with each other for light and space. If the density of natural regeneration has been high, this can be in forests as young as 5-8 years. After that, thinning can be done every 5 years.
12. Use Table 7.2 with caution since it assumes an even-aged stand. In stands this will not be the case and the crop may be quite irregular (uneven-aged). Stocking and basal area figures are given as a guide only.

Harvesting Poles

In Bhutan there is a high demand for pole-sized stems for flagpoles and fence posts. It is better to think of pole harvesting as a silvicultural operation carried out to improve the forests rather than as one solely for utilisation. When harvesting poles the same steps should be followed for thinning.

Under certain circumstances some suitable stands could be managed just for pole production. In this case, all trees would be cut when they reached pole size.

The best species for flag posts and fence posts are those which produce durable poles and that are slender and branch-free and include blue pine, spruce, hemlock, Dhom shing and alder.

Table 7.3: Thinning Techniques for different Forest Conditions		
Stand Description		
A	B	C
<ul style="list-style-type: none"> • Most trees in the stand are of the same species. • Most trees have good quality stems (potential timber trees). 	<ul style="list-style-type: none"> • Most trees in the stand are of the same species. • Most trees have poor quality stems (not potential timber trees). 	<ul style="list-style-type: none"> • Many different tree species are present in the stand. • Trees are of variable quality.
Thinning and marking technique		
<ul style="list-style-type: none"> • Look for the best tree every 5-10m. This is a plus tree. Mark this tree to be retained (not to fell). • Mark these trees with paint (not blazes). • Remove the trees that compete with this selected best tree. • Remove up to 20% of all trees in one thinning. • Repeat after 5-10 years. 	<ul style="list-style-type: none"> • Select the poorest quality trees and mark these for felling. • Mark trees for felling evenly across the stand. • Remove up to 20% of all trees in one thinning. • Repeat after 5-10 years. 	<ul style="list-style-type: none"> • Decide on the most important tree species to be kept as part of the final timber crop (2 or 3 species). • Look for the best tree of each species every 5-10m and mark this to be retained (not to fell). • Remove all the trees that compete with these selected best trees. • Remove up to 20% of all trees in one thinning. • Repeat after 5-10 years.

8. Implementing Other Forestry Operations

This chapter covers other forest management activities that are not necessarily silvicultural operations. However, they may be important to ensure sustainable forest management and they should be included in forest management plans of all forest management regimes of Bhutan.

8.1 Fuelwood Harvesting

Fuelwood harvesting means collecting and harvesting material suitable for fuelwood from the forests. This includes whole trees, branches, and woody shrubs, lops and tops and woody debris generated from harvesting and other silvicultural operations (see Box). Removing fuelwood is also a way of removing unwanted trees and woody material from the forests.

Fuelwood is an important forest product in Bhutan. Even degraded forests can produce some fuelwood and most silvicultural options for timber utilisation will produce some fuelwood. Some tree species are better for fuelwood than others. Oak, chestnut, and many broadleaved species produce good quality fuelwood which burns with a high temperature and for a long time. Conifer species are also favoured even though they burn more quickly because they are usually easier to light and their wood is easy to split and season.

Often fuelwood collection and harvesting is done unsystematically. If possible it is better to plan and organise fuelwood harvesting as part of an organised felling operation. However, it may be difficult to predict how much fuelwood will be produced. When carrying out silvicultural operations in FMUs, CFs, PAs and LFMA, agreement needs to be reached with the stakeholders concerning:

- How the fuelwood will be harvested (or collected from the forests) – the harvesting system,
- Who will be allowed to collect or harvest the fuelwood,
- From where fuelwood can be harvested (and when),
- How much can be collected or harvested.

Procedures need to be developed to cover these aspects and included in the management plan.

Sources of fuelwood

- Harvested trees unsuitable for timber e.g. crooked or damaged stems.
- Dead and diseased trees unsuitable for timber.
- Branches and other tree parts remaining after harvested trees have been converted into timber.
- Unwanted poles and other stems from thinning operations
- Woody shrubs produced during cleaning and weeding operations
- Branches and stems from pruning and singling operations
- Dead branches and fallen trees that can be collected without doing any harvesting.

8.2 Non-Wood Forest Product Collection

Non-Wood Forest Products (NWFPs) play an important role in the daily lives and overall well-being of the Bhutanese people especially among the rural farming community. NWFPs are a major source of off-farm income and often a safety net for poor people in the off-farm season or whenever

needed as a food security measure. For the sustainable management of NWFPs, guidelines for resource assessment have been developed to guide the field foresters and the collectors. Detailed guidelines for resource assessment for 10 important NWFPs has been developed. They are listed in Table 8.1. Resource inventories may not be necessary when sustainable harvesting has little negative impact on the host plant and its population. The interim framework is valid for 60 NWFP species that can be harvested in a sustainable manner ensuring the survival of the host plant and its population.

Sl. No.	Title	Common name	Dzongkha name	Year
1	Guidelines for resource assessment and management of <i>Borinda grossa</i>	Bamboo	Baa	2008
2	Guidelines for resource assessment and management of <i>Swertia chirayita</i>	Chirata	Chirata	2008
3	Guidelines for resource assessment and management of <i>Illicium griffithii</i>	Star anise	Doomleeshing	2008
4	Guidelines for resource assessment and management of <i>Cymbopogon</i> spp.	Lemon grass	Humchu Tsa	2008
5	Guidelines for resource assessment and management of Pipla (<i>Piper pedicellatum</i>)	Pepper	Pipla	2008
6	Guidelines for resource assessment and management of Yula (<i>Neomicrocalamus andropogonifolius</i>)	Climbing Bamboo	Yula	2008
7	Guidelines for resource assessment and management of Deynap and Deykap (<i>Daphne</i> spp. and <i>Edgeworthia gardneri</i>)	Daphne	Deynap & Deykap	2010
8	Guidelines for resource assessment and management of Canes (<i>Calamus</i> spp. and <i>Plectocomia himalaya</i>)	Canes	Patsha	2011
9	Guidelines for resource assessment and management of Rubia (<i>Rubia cordifolia</i>)	Indian Madder	Tsoe	2012
10	Guidelines for resource assessment and management of Satuwa (<i>Paris polyphylla</i>)	Love Apple	Dow Setochem (Satuwa in Lhotshamkha)	2012

Note: Harvesting guidelines for additional NWFP species will be developed and added based on the importance and urgency.

8.3 Tree Fodder Harvesting

Tree fodder is an important source of livestock feed in most parts of Bhutan, especially during the winter season. Many households own their own fodder trees and in addition they collect fodder from adjacent forests.

The use of forests for tree fodder production is probably less than that from private lands. The most important fodder species growing in forests are oak (*Quercus species*), willow (*Salix spp.*) Gamari, and various *Ficus spp.* Different forest types contain some quantities of fodder trees. Often the fodder trees in these forests are degraded due to past over-harvesting and lopping. However, fodder trees can be sustainably harvested in forests if harvesting systems follow these procedures:

- Ensure that lopping trees for fodder is included in all forest management plans.
- Do not lop fodder trees every year. Different forest blocks/compartments can be opened for fodder collection in different years. Ideally, trees should be lopped on a 3-4 year cycle. In certain areas and for certain fodder species, annual lopping can be carried out.
- Avoid lopping small trees. This will allow them to grow larger and produce more fodder.
- Do not cut all the branches from the fodder tree. Always leave some unlopped branches at the top of the tree to stimulate regrowth and to avoid killing the tree.
- Lopping should be done with suitable tools to avoid damaging large branches and reducing growth. Sharp axes or knives are best – branches should not be broken off.

8.4 Grass Collection

Grass can be collected from the forests for various purposes including:

- Fodder
- Brooms from Tsakusha (*Thysanolaena maxima*)
- Fibres for rope making and weaving
- Lemon grass (a commercial NWFP).
- Thatch for roofing
- Improving regeneration by removing competing vegetation.
- Reducing fire risk in dry forest types

Areas such as young plantations and open patches in forests will usually develop a good crop of grass if they are protected from grazing. The box gives a few simple procedures for organising and carrying out grass cutting.

Grass collection procedures

- Timing (season) of grass cutting is important. Grass should be cut before the fire season (December onwards) to reduce potential fire damage.
- Caution is needed to ensure that grass cutting does not accidentally damage regeneration.
- An allocation system (who gets what and when) needs to be included in all forest management plans. Open access systems for grass collection is not advisable.
- It may be possible to do some enrichment planting of grasses to improve the grass crop (silvo-pasture development).

8.5 Pine Needle Collection

Pine needles are collected for Chadri/celebrations and religious ceremonies. Currently the needles are collected without any management prescription leading to heavy lopping of branches which may lead to the death of trees.

Following points needs to be considered when collecting pine needles:

- Trees of pole size and below should not be lopped for needle collection,
- Trees bigger than pole size may be considered for lopping. However, the lopping should not be more than one third of the crown length,
- Lopping may be done where the crown density is more than 40%,
- Lopping of solitary tree should be avoided,
- As far as possible avoid collection of needles at the roadside,
- When lopping branches to collect needles, Pruning methodology shall be followed (pruning section).

8.6 Leaf Litter and Organic Matter Collection

Leaf litter collection means the collection of dried leaves and litter from the forest floor for preparation of animal bedding and compost. Organic matter (leaf mould) collection includes leaf mould, humus, top soil, etc. Leaf litter and organic matter collection is done:

- To meet local requirements for leaf litter (for livestock bedding),
- To maintain agricultural soils in a fertile condition,
- To enhance soil fertility during forestry plantations and nurseries,
- For commercial purposes (horticulture, floriculture, etc.).

Collection of leaf litter and organic matter can result in some problems if uncontrolled:

- Insufficient regeneration (due to a combination of fire, overgrazing and sweeping of leaves),
- Damage to regeneration during collection operations,
- Gradual loss of organic matter from the forest floor by sweeping. This deprives seed of a good seedbed and may slowly reduce soil fertility,
- Damage to micro soil organisms' habitat.

Leaf litter and organic matter collection procedures:

- Collection of organic matter should be avoided in areas where slope is more than 100% (45 degrees) gradient,
- For organic matter collection, same spot should not be visited at least for three years in broadleaf forest and five years in conifer forests,
- As far as possible avoid damage to regeneration during collection,
- In fire prone areas, leaf litter and organic matter shall be collected to reduce risk of forest fire and to reduce the intensity in case of forest fire,
- Leaf litter and organic matter collection shall be allowed provided natural regeneration are protected.

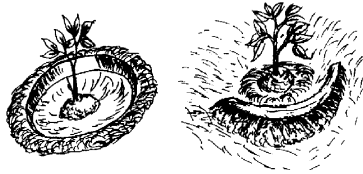


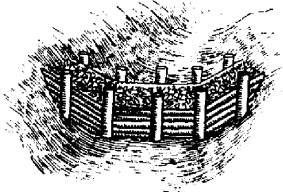
8.7 Soil Conservation



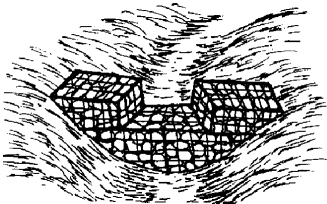
Soil conservation activities are those carried out to reduce or stop soil erosion in the forests. They are mainly carried out for the following reasons:

- To reduce soil loss,
- To improve the forest's ability to protect watersheds and water resources,
- To create better soil conditions for tree growth.

Soil conservation includes a range of activities. Many forests in Bhutan have good quality soil conditions and soil conservation may only be required at certain critical spots (hot spots) that need to be urgently tackled.

Table lists potential soil conservation options for forest areas. This is not a complete list or description of all these options and if soil conservation activities are planned then it will be important to look for technical assistance and specialised advice.

Table 8.2: Soil Conservation Options		
Saucer pits and crescent bunds	<ul style="list-style-type: none"> • Can be combined with tree planting on sloping areas • To increase water infiltration around the planted trees • To reduce runoff and soil loss from new plantations 	
Gully plugs (rubble dams)	<ul style="list-style-type: none"> • In existing or developing erosion gullies • To increase water infiltration and slow down water flow • To trap soil and silt 	
Vegetative barriers	<ul style="list-style-type: none"> • Vegetative versions of gully plugs (using grasses or shrubs) • Usually a series of barriers along a gully • To slow down water flow • To trap soil and silt 	
Brushwood check-dams	<ul style="list-style-type: none"> • Similar to vegetative barriers but using dry branches and other materials • To slow down water flow • To trap soil and silt 	

<p>Contour trenches</p>	<ul style="list-style-type: none"> • Effective for drier sites • Usually combined with planting where trees are established on the trench mounds • Trenches need to be level along the contour • Trenches reduce runoff and soil loss 	
<p>Diversion drains</p>	<ul style="list-style-type: none"> • To reduce runoff and prevent gullyling • To channel water into less critical areas • The slope of the channel is critical i.e. not too steep otherwise it will cause erosion 	
<p>Gabion structures</p>	<ul style="list-style-type: none"> • Stone and wire structures usually in existing and active gullies • Usually a series in a gully • To slow down water flow, increase infiltration and trap soil and silt • Expensive to construct and maintain 	

9. Protecting Forests

All forests need protection regardless of their type and condition. Good forest needs protection to ensure that it doesn't become degraded. Poor quality forests that has already been degraded needs protection from the factors that cause its degradation e.g. repeated fires, overgrazing, illicit and unsystematic cutting of trees, etc.

9.1 Fire Management

Fire management covers all activities concerned with prevention, control and use of fire in forests. Fire management in forests is carried out:

- To reduce accumulated hazardous fuels,
- To reduce slash, debris and undecomposed litter and release nutrients stored in accumulated organic materials,
- To improve the condition of the forest,
- To destroy pests and harmful disease organisms, and the habitats that sustains them,
- To kill interfering vegetation or reduce understory plants and colonizing trees to prevent natural reforestation of grassland and shrub ecosystems.

Fire Management Procedures:

- Obtain the necessary permit or authority to conduct prescribed burn,
- Observe weather conditions to determine when to carry out the prescribed burn,
- Always extinguish the fire before leaving,
- Use ground fires to encourage natural regeneration in chir pine forests and controlled fires to reduce the amount of inflammable fuel in forests (dead branches and leaf litter),
- Create fire breaks around forest fringes and in sensitive areas to stop fires spreading. Establish and maintain these in October-November (before the fire season). Fire breaks (Fire line) width may depend on the slope,
- Encourage planting of fire resistant species e.g. *Quercus lanata*, *Schima wallachai*, Chir pine, *salix spp.*, etc.,
- Reduce fuel loads inside high-risk forest stands. This means removing dry woody material that is likely to burn. This can be done by controlled burning or physical removal.

9.2 Grazing Management

Forests in Bhutan are a traditionally part of the livestock management system. They provide 23% of the country's fodder resources most of which comes from free grazing by livestock in the forests. Grazing is therefore an important part of the multiple-use of forests. All forest management plans should include a section on grazing management.

Regulated grazing in forests is essential:

- To protect forest areas (especially regeneration) from livestock damage,

- To meet the fodder resources from forests,
- To reduce weed competition (under certain conditions such as mixed conifer forests with bamboo understorey),
- To enhance natural regeneration through disturbance of soil.

9.3 Protection from Pests and Diseases

Protection of forests from pests and diseases is an important activity for improving forest quality and growth. Table 9.1 lists a few of the major pests and diseases of forest tree species in Bhutan.

Table 9.1 Common pests and diseases			
Pest/Diseases	Pathogen/pest	Symptoms	Measures
Mistletoe	Parasitic plant (dwarf mistletoe).	Reduced vigour of trees and sometimes tree death. Timber damage.	Mistletoe control measures (see below).
The Eastern Himalayan spruce bark beetle	<i>Ips schmutzenhoferi</i> (bark beetle) associated with blue stain fungus <i>Ceratocystis bhutanensis</i> .	Timber damage to Spruce (<i>Picea spinulosa</i>)	Sanitation felling, pheromone, Trap logs, etc.
Root collar weevil	<i>Hylobitelus chenkupdorjii</i> (weevil).	Girdling of young Blue pine (<i>Pinus wallichiana</i>) trees	Sanitation felling.

Mistletoe Control

Mistletoes (*Arceuthobium minutissimum* & *Taxillus kaempferi*) are damaging pathogens in certain forest types. Mistletoe is a parasitic plant that affects mainly blue pine stands in blue pine forest and mixed conifer forest types particularly in drier forests of western Bhutan. Hemlock and spruce trees are also occasionally infected. Its spread has increased in recent years and it can affect trees of all sizes but is most prevalent and damaging on trees in the larger size classes.

Mistletoe reduces the growth and increment of affected trees. It impairs cone production and reduces wood quality. It can also contribute to tree death – especially on drier sites. During timber harvesting operations, affected trees are often avoided because of the effect it has on wood quality. As a result the mistletoe spreads further (it is spread by birds). The most effective options for controlling mistletoe include:

- Removing all affected trees (with growing mistletoe) during other silvicultural operations especially during thinning and harvesting,
- Burn heavily affected trees and branches,
- Favour non-host species during thinning (e.g. not blue pine) if other species are present,
- Restrict the movement of blue pine produce so that mistletoe does not get spread,
- Monitoring forest stands so that sanitation felling can take place as soon as mistletoe appears.

Bark Beetle Control

In Bhutan, the Eastern Himalayan spruce bark beetle, *Ips schmutzenhoferi*, is a serious pest in conifer forests. It attacks mainly living trees or infests freshly felled logs of Spruce (*Picea spinulosa*) and Blue pine (*Pinus wallichiana*) and occasionally Larch (*Larix griffithiana*). Bark beetle is one of the most destructive forest pests in Bhutan and thinning operations can lead to outbreaks if sanitation measures are not properly carried out.

Sanitation measures:

- Remove all harvested logs immediately and debark the stumps and branches up to 10 cm diameter,
- In case logs cannot be removed immediately due to logistic constraints, debark them thoroughly in the forest,
- In case bark beetles are found under the barks, carefully debark logs placed on a tarpaulin sheet to prevent beetles from escaping. Burn all the barks, saw dusts and including beetles,
- In case bark beetle larvae are found under the barks, expose them to strong sunlight so as to kill them too.

Sanitation Felling

Sanitation felling is defined as ‘the removal of trees to improve stand health by stopping or reducing the actual or anticipated spread of pests and diseases’ - see stand improvement. Currently sanitation felling is the best option to tackle the Eastern Himalayan Spruce Bark Beetle.

During sanitation felling, normal silvicultural operations may be overridden i.e. areas harvested may be larger than normal.

Sanitation felling procedures:

- Combine the sanitation felling with planned silvicultural activities if possible,
- Remove affected woody material from the sites as completely as possible and immediately after felling,
- If it is not possible to remove logs, de-bark them in the forest and burn the bark (with the beetles),
- After felling, monitor the stand regularly to ensure whether the pathogen has been effectively controlled or eradicated,
- Combine appropriate measures to ensure successful regeneration of the felled areas e.g. grazing and fire management.

Annex 1: Forest Types of Bhutan

Forest types of Bhutan based on Grierson and Long (1983)

Type	Altitude (m)	Rainfall (mm)	Characteristic tree species	Comments
Subtropical forest	200-1,000	2,500-4,000	<i>Duabanga grandiflora</i> ; <i>Pterospermum acerifolium</i> ; <i>Tetrameles nudiflora</i> ; <i>Acrocarpus fraxinifolius</i> ; <i>Ailanthus grandis</i> ; <i>Dillenia pentagyna</i> ; <i>Gmelina arborea</i> ; <i>Leea asiatica</i> ; <i>Bombax ceiba</i> ; <i>Crateva religiosa</i> ; <i>Shorea robusta</i>	Subtropical and largely deciduous forest with much conversion to agriculture in most accessible areas
Chir pine forest	900-1,800	1,000-1,300	<i>Pinus roxburghii</i> ; <i>Zizyphus incurva</i>	Dry forest on shallow soils and southern aspects. Much degradation due to grazing, felling and burning. Associated with lemon grass (<i>Cymbopogon</i> sp) in the east. Susceptible to fire.
Warm broadleaved forest	1,000-2,000	2,300-3,500	<i>Castanopsis indica</i> ; <i>Bischofia javanica</i> ; <i>Engelhardia spicata</i> ; <i>Eudia fraxinifolia</i> ; <i>Macaranga pustulata</i> ; <i>Schima wallichii</i> ; <i>Alangium chinense</i> ; <i>Alnus nepalensis</i> ; <i>Dendrocalamus hookeri</i> (bamboo); <i>Lithocarpus</i> spp.; <i>Betula alnoides</i> ; <i>Cordia obliqua</i>	Mixture of evergreen and deciduous species. Often cleared for grazing and farming.
Blue pine forest	2,100-3,000	700-1,200	<i>Pinus wallichiana</i> ; <i>Quercus griffithii</i> ; <i>Q. semecarpifolia</i> ; <i>Lyonia ovalifolia</i> ; <i>Rhododendron arboreum</i>	Inner dry valleys. On disturbed or burnt ground. Transition into spruce, hemlock and fir. Susceptible to fire.
Cool broadleaved forest	2,000-2,900	2,500-4,000	<i>Acer campbellii</i> ; <i>Betula alnoides</i> ; <i>Quercus lamellosa</i> ; <i>Symplocus dryophyla</i> ; <i>Exbucklandia populnea</i> ; <i>Persea clarkeana</i> ; <i>Lindera neesiana</i> ; <i>Litsea</i> spp.; <i>Daphniphyllum himalense</i> ; <i>Belschmedia sikkimensis</i> ; <i>Michelia</i> spp.	Evergreen and deciduous forest. On moist slopes with a north aspect especially in the east of Bhutan at the expense of blue pine as a result of moister climate

Type	Altitude (m)	Rainfall (mm)	Characteristic tree species	Comments
Evergreen oak	2,000-2,600	2,000-3,000	<i>Acer campbellii</i> ; <i>Castanopsis hystrix</i> ; <i>C. tribuloides</i> ; <i>Quercus lamellosa</i> ; <i>Q. lanata</i> ; <i>Q. glauca</i> ; <i>Q. semecarpifolia</i> ; <i>Juglans regia</i> ; <i>Skimmia arborescens</i> ; <i>Symplocos lucida</i> ;	Drier than cool broadleaf forest. Felling for grazing, fodder and fuelwood
Spruce forest	2,500-3,100	700-1,200	<i>Picea spinulosa</i> ; <i>Pinus wallichiana</i> ; <i>Larix griffithiana</i> ; <i>Acer spp.</i> ; <i>Lindera heterophylla</i> ; <i>Taxus baccata</i>	Drier than hemlock forest.
Hemlock forest	2,800-3,100	1,300-2,000	<i>Tsuga dumosa</i> ; <i>Picea spinulosa</i> ; <i>Taxus baccata</i> ; <i>Larix griffithiana</i> ; <i>Acer spp.</i> ; <i>Betula utilis</i> ; <i>Arundinaria griffithiana</i> (small bamboo); <i>Magnolia globosa</i> ; <i>Rhododendron spp.</i> ; <i>Sorbus thibetica</i>	On wetter sites than spruce forest. Mixes with <i>Pinus wallichiana</i> and <i>Quercus sp.</i> at lower elevations. Disturbed areas colonised by small bamboo (<i>Arundinaria sp.</i>)
Fir forest	3,000-3,800	> 1,300	<i>Abies densa</i> ; <i>Rhododendron spp.</i> ; <i>Juniperus sp.</i> ; <i>Betula utilis</i> ; <i>Tsuga dumosa</i>	Highest forested ridges. Sometimes cleared for grazing and colonised with small bamboo (<i>Arundinaria sp.</i>)
Juniper/Rhododendron scrub	3,700-4,200	NA	<i>Juniperus spp.</i> ; <i>Rhododendron spp.</i>	Excessive grazing may convert to grassland
Dry alpine scrub	> 4,000	NA	No large tree species, but woody shrubs of <i>Rhododendron sp</i> ; <i>Ephedra spp.</i> ; <i>Salix spp.</i>	Above the tree-line

Annex 2: Glossary of Forestry and Silvicultural Terms

Term	Description
Artificial regeneration	The establishment of young trees by direct seeding or by planting seedlings or cuttings
Basal area	The cross section area of the stem or stems of a tree or of all trees in a stand, generally expressed as square units per unit area. The cross section area of a tree stem is usually measured at breast height and is inclusive of bark.
Biodiversity	The variety of life forms in a given area. Diversity can be categorized in terms of the number of species, the variety in the area's plant and animal communities, the genetic variability of the animals, or a combination of these elements
Block	An area of land or timber that has been defined for forest management purposes. One block may be composed of stands of different species or ages
Bole	Trunk of a tree
Broadleaf	A tree with leaves that are broad, flat and thin
Canopy	The cover provided by tree crowns forming the overstorey. It can vary in density.
Clump	A group of stems or culms issuing from the same root, rhizome system, stump, or stool.
Compartment	Similar to a block – but usually a permanent forest management unit and often with clearly marked boundaries
Conifer	Tree that is a usually evergreen, with cones and needle-shaped or scale-like leaves, producing wood known commercially as softwood
Controlled burning/ Prescribed burning	Use of fire to destroy logging debris, reduce build ups of dead and fallen timber that pose wildfire hazards, control tree diseases, and clear land. Other functions of a controlled burn include clearing a buffer strip in the path of a wildfire.
Conversion	The transformation of timber into a product either: primary conversion (initial sawing of the log into timber) or secondary conversion (any subsequent working or finishing of the timber into products)
Coppice	(a) Production of new stems from the stump or roots of a plant. (b) To cut the main stem (particularly of broadleaved species) at the base to stimulate the production of new shoots for regeneration
Crown	The upper part of a tree, including the branches and foliage.
Culm	A stem of a grass or bamboo
DBH	Diameter at breast height (usually measured over bark)
Even-aged	Stand of trees in which there are only small differences in age among the individual trees
Firebreak/Fire line	Any non-flammable barrier used to slow or stop fires. Several types of firebreaks are mineral soil barriers; barriers of green, slow-burning vegetation and mechanically cleared areas.

Term	Description
Forest Management	The practical application of biological, physical, quantitative, managerial, economic, social, and policy principles to the regeneration, management, utilization, and conservation of forests to meet specified goals and objectives while maintaining the productivity of the forest
Forest management plan	Written guidelines for current and future management practices recommended to meet the forest owner's objectives
Forest type	Groups of tree species commonly growing in the same stand because their environmental requirements are similar
Group selection system	The removal of small groups of trees to regenerate shade-intolerant trees in the opening
Light demanding	Trees that cannot thrive in the shade
Mensuration	The measurement and calculation of volume, growth, and development of individual trees or stands and their timber products
Natural regeneration	The establishment of a plant or a plant age class from natural seeding, sprouting, suckering, or layering
NWFPs	All forest products except timber, including resins, oils, leaves, bark, plants other than trees, fungi, and animals or animal products
Over storey	The vegetation forming the highest level of a forest. It may be continuous or scattered
Patch felling system	A system of felling trees in small groups and re-establishment of young trees in the felled area (patch)
Pole	Young tree below saw log size, ready for use after removal of the bark without further conversion
Pruning	The removal, close to the branch collar or flush with the stem, of side branches (live or dead) from a standing tree
Regeneration	The re-establishment and development of vegetation
Rhizome	A modified stem that grows below ground, commonly stores food materials, and produces roots, scale leaves, and suckers irregularly along its length
Rotation	The number of years required to establish and grow trees to a specified size, product, or condition of maturity.
Sanitation felling	The removal of trees to improve stand health by stopping or reducing the actual or anticipated spread of insects and disease
Selection system	A planned sequence of treatments designed to maintain and regenerate a stand with three or more age classes. It can be either single tree or group selection
Shade bearing	Trees that require shade for regeneration

Term	Description
Shelterwood system	The cutting of most trees, leaving those needed to produce sufficient shade (the shelterwood) to produce a new age class in a moderated microenvironment. The sequence of treatments can include three types of cuttings: (a) an optional preparatory cut to enhance conditions for seed production, (b) an establishment cut to prepare the seed bed and to create a new age class, and (c) a removal cut to release established regeneration from competition with the over-wood; cutting may be done uniformly throughout the stand (uniform shelterwood), in groups or patches (group shelterwood), or in strips (strip shelterwood).
Silviculture	The art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis
Single tree selection system	Uneven-aged silvicultural system in which single trees are periodically selected to be removed from a large area so that age and size classes of the reproduction are mixed
Singling	Similar to pruning but involving the removal of one or more growing shoots from multiple-stemmed plants leaving a single shoot or stem
Soil conservation	Actions taken to control and prevent soil losses through erosion
Sokshing	A traditional category of forest use in Bhutan allowing those with sokshing rights to remove dry leaves and leaf litter from the forest as well as some other defined products
Stand	An easily defined area of the forest that is relatively uniform in species composition or age and can be managed as a single unit
Stocking	A description of the number of trees, basal area, or volume per hectare in a forest stand compared with a desired level for balanced health and growth. Most often used in comparative expressions, such as well-stocked, poorly stocked, or overstocked
Thinning	A cultural treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality
Understorey	All forest vegetation growing under an over storey
Uneven-aged stand	A forest stand composed of trees of different ages and sizes.

Annex 3: Silvicultural Characteristics of the Main Timber Trees

Chir pine (*Pinus roxburghii*)

- Regenerates easily from seed.
- Highly light demanding, although regeneration may require some shade on the hottest, dry sites
- Drought resistant
- Fire resistant. 5-year old regeneration can normally tolerate ground fires without permanent damage.
- More resistant to grazing than blue pine
- Fast growing especially during early stages
- Grows on poor and dry sites

Blue pine (*Pinus wallichiana*)

- Regenerates easily from seed
- Seed is produced after about 15 years of age. Seed years are frequent.
- Grows over a range of sites and altitudes
- Highly light demanding (from an early stage)
- Sensitive to grazing
- Sensitive to fire – especially younger trees
- Fast growing, although slower to establish than Chir pine
- Grows on poor and dry sites
- Trees liable to snow damage (especially unthinned pole-stage stands)
- Prone to mistletoe attack
- Prone to bark beetle damage

Hemlock (*Tsuga dumosa*)

- Regenerates easily on moist sites with some shade and northern aspects
- Shade tolerant but regeneration hindered very dense shade under bamboo or rhododendron
- Seed years are frequent and much seed is produced
- Seedlings are sensitive to drying out
- Regenerates on the moss bed created by fallen logs
- Pole-stage trees are liable to break under wet snow or strong winds
- Sensitive to grazing and fire
- Slow growing, but trees can reach a very old age (400 years plus) and become very large

Spruce (*Picea spinulosa*)

- Regenerates easily from seed under the right conditions
- Tolerates some shade but less light demanding for germination than blue pine
- Grows on slightly drier micro-sites than hemlock but otherwise in similar situations
- Older trees require less shade than recently germinated seedlings
- Less sensitive to grazing than other conifer species

- Very susceptible to spruce bark beetle attack
- Grows to a very large size

Fir (*Abies densa*)

- Regenerates well from seed provided site and light conditions are suitable
- Dense rhododendron growth can restrict regeneration
- Requires moist sites with good soils and high rainfall (but well-drained)
- Requires shade to regenerate and grow. Shade requirements reduce with age
- Growth of regeneration and subsequent tree growth is slow
- Sensitive to fire and grazing.

Chestnut (*Castanopsis spp.*)

- Different chestnut species grow in different forest types. In order of ascending altitude, *C. indica* - *C. tribuloides* – *C. hystrix*
- Regeneration from seed can be difficult. Seed is eaten by animals and insects and good humus with moist soils are needed for it to germinate
- Fresh seed can be grown easily in nurseries although planted seedlings tend to grow slowly
- Coppice regeneration is good although medium-sized trees coppice better than very large ones.
- Seedlings are shade tolerant, although require light later to develop into larger trees
- Sensitive to grazing

Sisi (*Quercus griffithii*)

- Moderately light demanding and regenerates well in open spaces and gaps.
- Grows on drier sites than other oak species
- Deciduous species

Jishing (*Quercus semecarpifolia*)

- Germination from seed is difficult because acorns are predated by animals and insects. Under suitable conditions it can be very good.
- Lopping of branches for fodder also reduces seed production
- One year in three is a good seed year
- Seedlings require sufficient light to establish
- Early seedling growth is slow even with adequate light. Although growth increases after roots have developed. Seedlings cannot develop under shade.
- Seedlings are sensitive to grazing
- Coppices well

Thom (*Quercus lamellosa*)

- Germination from seed is difficult because acorns are predated by animals and insects. Under suitable conditions it can be very good
- Seed germinates on a carpet of leaves and organic matter.

- Seedlings develop under shade
- Early growth is faster than *Q. semecarpifolia*
- Full light is needed to grow at a later stage
- Fire and grazing sensitive
- Coppices well

Alder (*Alnus nepalensis*)

- It is a pioneer species
- Regenerates easily from seed which is light and carried by wind
- Regeneration is best on bare, moist mineral soils and under full light conditions
- Growth is rapid on suitable sites and under unshaded conditions
- Often grows as a pure stand in moist ravines and along roadsides.
- Casts a dense shade

Acer (*Acer campbellii*)

- Regenerates on newly exposed soils near water and on landslips
- Requires sufficient light for regeneration

Patangshing (*Duabanga grandiflora*)

- Regenerates profusely from seed
- Regenerates on exposed soils and landslips
- Prefers moist sites in river valleys and steep slopes
- Easily grown from seed in nurseries
- Fast growing
- Light demander

Paka saaj (*Terminalia tomentosa*)

- Can regenerate easily from seed either naturally or in nurseries
- Can be grown from stump cuts
- Coppices well
- Light demander
- Grows on better soils in subtropical forests (valley bottoms)

Chashing (*Acrocarpus fraxinifolius*)

- Grown from seed in nurseries
- Light demander
- Sensitive to frost and grazing

Puyam (*Schima wallichii*)

- Regenerates easily by natural regeneration
- Prefers good soils
- Coppices well

Sal (*Shorea robusta*)

- Regenerates easily from seed
- Seed has a very short viability
- Difficult to grow from seed in nurseries
- Prefers free draining soils
- Tolerates fire and drought
- Management of natural regeneration can be difficult
- Regeneration requires some shade
- Saplings need light for rapid growth
- Coppices extremely well

Walnut (*Juglans regia*)

- Can be grown from seed in nurseries
- Prefers good well-drained soils with some moisture
- Fast growing on good sites

Champ (*Michelia champaca*)

- Straight bole
- Seeds often predated by rodents
- Short seed viability
- Seeding year/cycle is more than three years?
- Moderate light demander
- For good growth, it needs moist, well drained and deep fertile soil

Annex 4: Bibliography of Silviculture and Forest Management for Bhutan

There is an increasingly large literature on silviculture of Bhutanese forests. This bibliography lists those sources that were utilised and read during the preparation of this manual – but it cannot claim to be comprehensive. Most recent material is readily available on-line but older material can be difficult to find in electronic format. Much of this older material has been reviewed and summarised by Rosset (1999) – listed below.

In addition to the materials listed below, a range of unpublished material was also used during the preparation of this manual. Much of this was in the form of training materials, posters, power-point presentations etc.

- Buffum, W., 2007. Sustainability Issues Related to Community Management of National Forests in Bhutan. PhD Thesis. University of natural Resources and Applied Life Sciences, Vienna, Institute Of Forest Ecology
- Buffum, B., Gratzner, G., Tenzin, Y., 2008. Forest Grazing and natural Regeneration in a late Successional Broadleaved Community Forest in Bhutan. Mountain research and Development Vol.29 No.1 pp. 30-35
- Buffum, B., Gratzner, G., Tenzin, Y., 2008. The sustainability of selection cutting in a late successional broadleaved community forest in Bhutan. Forest Ecology and Management 256 pp. 2084-2091
- Bürgi, A., Rinchen, Dorji, T., 1992. Structure, Productivity, Regeneration and possible utilisation of the Fir (*Abies densa* Griff) forests in Chumi Valley, Central Bhutan. Lame Gompa Forestry Research Station, Bumthang
- Bürgi, A., 2002. Fir (*Abies densa*) forests in Central Bhutan: a model-based approach to assess sustainable utilisation. Forestry, Vol 75, No. 4 pp 457-464
- Chhetri, D.B., undated. Forest Fire Season in Bhutan. Unpubl. Document
- Chhetri, P.B., 2004. Structure and composition of mixed conifer forests in Western Bhutan. Thesis submitted in partial fulfilment for the degree of Master of Sciences in Mountain Forestry, UNI BOKU Vienna
- Darabant, A., Chhetri, P.B., Rai, P.B., Dorji, K., Gratzner, G., 2001. Light requirements of the main tree species in Bhutan's conifer belt. RNR-RC Jakar, Special Publication No. 4
- Darabant, A., Rai, P.B., Eckmullner, O., Gratzner, G., Gyeltshen, D., 2011 Guidelines for nation-wide thinning of blue pine. RNR-RDC Jakar, Department Of Livestock Ministry of Agriculture and Forests
- Darbellay, T., undated. Stand stability trial. Unpubl. Research document
- Davidson, J., 1998. Silviculturalist/Plant Ecologist Consultancy. First consultancy term report. Third Forestry Development Project, Forest Services Division, Ministry of Agriculture

- Davidson J., Moktan, M.R., Gyeltshen, J., 2000. Indicative results of harvesting and regeneration of the mixed broadleaved forests of eastern Bhutan. Journal of Renewable Natural Resources Bhutan Volume I No. 2, Ministry of Agriculture, Thimphu
- Desmond, D., Chhetri, D.B., 1998. The appropriate use of fire for agricultural purposes. RNR-RC Yusipang (draft)
- Desmond, D., Norbu, L., 1999. Sixth year results of a blue pine thinning trial in western Bhutan. RNR-RC, Working Document WD99/1, Ministry of Agriculture
- Dhital, D.B., 1997. Impacts of resin tapping in chir pine forests of eastern Bhutan. Forest Resources Development Section, FSD, MoA, Thimphu
- Dick, J.H., Yonten, D.P., 1996. Biodiversity conservation guidelines for the managed forest: With special reference to Eastern Bhutan. TFDP, Working Document No. 31, Forest Services Division, MoA, Thimphu
- Dorji, S., 2004. Natural regeneration at cable crane logged sites in the mixed conifer belt of Gidakom FMU, Thimphu, Bhutan. Thesis submitted in partial fulfilment for the degree of Master of Sciences in Mountain Forestry, UNI BOKU Vienna
- Dorji, S., Donaubauer, E., Wingfield, M.J., Chhetri, D.B., Kirisits, T., 2012. Himalayan dwarf mistletoe (*Arcuethobium minutissimum*) and the leafy mistletoe (*Taxillus kaempferi*) on blue pine (*Pinus wallichiana*) in Bhutan. Journal of Agricultural Extension and Rural Development Vol. 4(9) pp. 217-220
- Evans, P., 1996. Agroforestry handbook. TFDP, Working Document No. 30. RGoB
- FAO, 1996. Non-Wood Forest Products of Bhutan. RAP Publication 1996/6, FAO, Bangkok
- Forest Fire Management Programme, 2012. Guidelines for agriculture debris burning. Department of Forest and Park Services, Ministry of Agriculture
- Forest Research Institute, 1967. Growth and yield statistics of common Indian timber species (Himalayan Region). Volume I. Forest Research Institute, Dehradun
- Forest Resources Development Section, 1998. *Taxus baccata* (Himalayan yew). Its importance and distribution in Bhutan. FRDS, Forest Services Division, Ministry of Agriculture, Thimphu, Bhutan
- Forest Services Division, 2000. Information on some of the important afforestation species in Bhutan. Unpublished document
- FRDD, 2008a. Guidelines for resource assessment and management of *Borinda grossa*. Ministry of Agriculture, Thimphu
- FRDD, 2008b. Guidelines for resource assessment and management of Chirata, *Swertia chirayita*. Ministry of Agriculture, Thimphu
- FRDD, 2008c. Guidelines for resource assessment and management of *Illicium griffithii*. Ministry of Agriculture, Thimphu

- FRDD, 2008d. Guidelines for resource assessment and management of Lemon Grass. Ministry of Agriculture, Thimphu
- FRDD, 2008e. Guidelines for resource assessment and management of Pipla, *Piper pedicellatum*. Ministry of Agriculture, Thimphu
- FRDD, 2008f. Guidelines for resource assessment and management of Yula, *Neomicrocalamus andropogonifolius*. Ministry of Agriculture, Thimphu
- FRDD, 2011a. Guidelines for resource assessment and management of Deynap & Deykap, *Daphne* spp. & *Edgeworthia gardneri*, Ministry of Agriculture and Forests, Thimphu
- FRDD, 2011b. Guidelines for resource assessment and management of canes. Ministry of Agriculture and Forests, Thimphu
- FRDD, 2003. Twenty important non-wood forest products of Bhutan. Forest Resources Development Division, Department of Forestry Services, Ministry of Agriculture, Thimphu.
- FRDD, 2005. Management of Forest Areas outside FMU System (Planning Guidelines). Department of Forests, Ministry of Agriculture, Thimphu
- FRDD, 2011. Silvicultural Systems. Forest Management Code of Bhutan Part 3, Section 3.07 (revised August 2011). Department of Forests, Ministry of Agriculture, Thimphu
- FRDD, 2011. Silviculture Implementation Guidelines. Forest Management Code of Bhutan Part 5, Section 5.03 (revised August 2011). Department of Forests, Ministry of Agriculture, Thimphu
- Geisch, C., 2000. Evolution of the forest uses and their impact on the forest structure with regard to sustainability in central Bhutan. Unpubl. Dissertation, Swiss Federal Institute of Technology, Zurich
- Ghildyal, B.N., 1991 Oak. Production, Management and Use in the Himalayas. FAO, Regional Wood Energy Programme, Bangkok
- Gratzer, G., Rai, P.B., Glatzel, G., 1997. Ecology of the *Abies densa* forests in IFMP Ura, Bhutan. IFMP research report
- Gratzer G., Darabant, A., Chhetri, P.B., Rai, P.B., Eckmullner, O., 2004. Interspecific variation in the response of growth, crown morphology and survivorship to light of six tree species in the conifer belt of the Bhutan Himalayas. Can J. For. Res. 34: pp. 1093-1107
- Gratzer, G. Rai P.B., 2004. Density-dependent mortality versus spatial segregation in early life stages of *Abies densa* and *Rhododendron hodgsonii* in Central Bhutan. Forest Ecology and Management 192 pp. 143-159
- Gratzer, G., Rai, P.B., Glatzel, G., 2004. The influence of the bamboo *Yushania microphylla* on regeneration of *Abies densa* in Central Bhutan. Can J. For. Res. 29, pp. 1518-1527
- Grierson, A.J.C., Long, D.G., 1983. Flora of Bhutan. Volume 1 Part 1, Royal Botanic Garden, Edinburgh

- Guglhör, W., 1997. Management of fir forest. In 'Proceedings of the Integrated Forest Management Workshop, June 1997 Volume 1
- Herbst, P., 1992. A proposal for management activities in fir. In 'Proceedings of the workshop on Forest Inventory and Management' Lamé Gompa, Bumthang. Forest Management and Conservation Project, Department of Forests, MoA
- <https://www.for.gov.bc.ca/hfp/training/00014/index.htm> accessed August, 2016
- Joshi, S.C., 1986. Forestry Handbook of Bhutan. International Book Distributors, Dehradun
- Kinley, T., Gratzner, G., Darabant, A., Rai, P.B., 2010. Regeneration and gap dynamics in spruce-dominated mixed conifer forests of the Bhutan Himalaya. Abstract in 21st century Forestry: Integrating ecologically-based uneven-aged silviculture with increased demands for forests', 7th IUFRO conference on uneven-aged silviculture, Ljubljana, Slovenia 23-30 September 2010. IUFRO
- Kleine, M., 1996. Silvicultural management of broadleaved and chir pine forests in the Punakha and Wangdue Phodrang Districts of Bhutan. Working Paper No. 8, Bhutan-German Integrated Forest Management Project, GTZ, Thimphu, Bhutan
- McKinnell, F., 2000. Forest fire management in Bhutan. Consultant report, Third Forestry Development Project, Forest Services Division, MoA, Thimphu
- Ministry of Agriculture, 1997. Bamboo and cane study of Zhemgang Dzongkhag. RGoB, Thimphu
- Moktan, M., 2000. Recovery of young chir pine plantations burned by wildfire. Journal of Renewable Natural Resources, Bhutan. Volume I, Issue 2, November 2000, Ministry of Agriculture
- Moktan, M.R., Gyaltzen J., 2002. A survey report on sustainable management of Sokshing in Eastern Bhutan. RNR Yusipang Report YREP 2002/1, Department of Research and Development Services, Ministry of Agriculture, Thimphu
- Moktan, M.R. 2008. Comparison of regeneration, species composition and structure in single-tree and group selection logged and unlogged stands in mixed conifer forests of the Western Bhutan Himalayas. Dissertation for obtaining a doctorate degree at the Institute of Forest Ecology, Department of Forest and Soil Sciences, University of Natural Resources and Applied Life Sciences, Vienna
- Moktan, M.R., Gratzner, G., Richards, W.H., Rai, T.B., Dukpa. D., Tenzin, K., 2009. Regeneration and structure of mixed conifer forests under single-tree harvest management in the western Bhutan Himalayas. Forest Ecology and Management 257 pp. -2121-2132
- Moktan, M.R., Gratzner, G., Richards, W.H., Rai, T.B., Dukpa. D., Tenzin, K., 2009. Regeneration of mixed conifer forests under group tree selection harvest management in western Bhutan Himalayas. Forest Ecology and Management 258

- Moktan, M.R., 2010. Impacts of recent policy changes on rural communities and species diversity in Government-managed forests of Western Bhutan. *Mountain Res. and Development* Vol 30 No. 4 pp. 365-372
- Mukhia, P. K., Wangchuk, T., 2000. Preliminary survey report on cane of Chukha Dzongkhag. Forest Resources Development Division, Department of Forestry Services, Ministry of Agriculture, Thimphu
- Negi, S.S., Naithani, H.B., 1995. Oaks of India, Nepal and Bhutan. International Book Distributors, Dehradun
- Norbu, L., undated. Grazing management in broadleaf forests. PhD abstract submitted to the Swiss Federal Institute of Technology, Zurich
- Norbu, L., Desmond, D., 2000. Effect of soil moisture and forest floor preparation on seedling regeneration in a group-selection-felled mixed conifer forest. *Journal of Renewable Natural Resources of Bhutan*, Vol. 1, Issue 2, November 2000, Thimphu
- Norbu, N., 2000. Sustainability of chir pine forests under resin tapping and its socio-economic impacts in Bhutan. Forest Resources Development Division, DoFS, MoA, Thimphu
- Nyland, R.D., 2002. *Silviculture Concepts and Applications*. Second Edition. Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020
- Oberholzer, E., 2005. Community forest management. Posters with explanations, silviculture training of Geog forestry extension agents and community forest management group. PFMP report 19, PFMP, Social Forestry Division, DoFPS, Ministry of Agriculture, Thimphu
- Oberholzer, E., Schwitter, R., 2010. Training of Trainers in Silviculture and Establishment of a Silvicultural Expert Group. Consultancy report for PFMP No. 41, PFMP, Social Forestry Division, DoFPS, Ministry of Agriculture, Thimphu
- Oberholzer, E., Schwitter, R., 2012. Refresher Training for the Members of the Silvicultural Expert Group. Consultancy report for PFMP No. 47, PFMP, Social Forestry Division, DoFPS, Ministry of Agriculture, Thimphu
- Ohsawa, M., 1987. Vegetation zones on the Bhutan Himalaya. In Ohsawa (ed) *Life Zone Ecology of the Bhutan Himalaya*, 1987, Chiba University
- Pradhan P., Moktan, M., Legha, P.K., Dukpa, D., 2000. Perspective on the sustainable use of Chirata in eastern Bhutan. *Journal of Renewable Natural Resources in Bhutan*. Volume 1, Issue 2, November 2000, Ministry of Agriculture, Thimphu
- Pradhan, R., 2001. Assessment of the Socio-Economic Situation of Forest Grazing in the proposed Rimchu FMU. Bhutan-German Sustainable RNR-Development Project (BG-SRDP), Project Document No. 53

- Rai, P.B., Darabant, A., Dukpa, D., Dorji, T., Eckmullner, O., Sangay, Gratzner, G., Tenzin, K., Burgi, A., Rai, T.B., Chhetri, Y.R., 2010. Effects of thinning on productivity and stability of Blue pine forests. *Journal of Renewal Natural Resources Bhutan*. Vol.6. Number 1 June 2010
- Rai, P.B., Darabant, A. Dorji, T., Sangay., Dukpa, D., Staudhammer, C.L., Gratzner, G., 2014. Effects of Silviculture Openings, Livestock Grazing, Understory competition and microsites on mixed conifer regeneration in Western Bhutan. *Journal of Renewable Natural Resources Bhutan*. Number 10, 146-160
- Rai, P.B., Darabant, A., Gratzner, G., Dorji, T., Sangay., 2012. *Silviculture in Temperate Conifer Forests of Bhutan*. RNR RDC, Jakar, Department of Livestock, Ministry of Agriculture and Forests.
- Rinchen., Godi, F., Darbellay, T., 1995. Natural regeneration in mixed conifer stand. IFDP Research Section Report, Lame Gompa
- Rinchen., Godi, F., 1995. Forest research trials at the regional forestry research station Bumthang: Some first results. *Tsenden* Vol. 5, No. 1 pp. 25-35
- RNRC-Jakar, 2001. Management and improvement of grassland. Extension publication LO6
- Roder, W., Wangdi, K., Gyamtsho, P., Dorji, K., 2001. Feeding the herds. Improving fodder resources in Bhutan. ICIMOD, Kathmandu
- Roder, W., Gratzner, G., Wangdi, K., 2002. Cattle grazing in the conifer forests of Bhutan. *Mountain Research and Development*. Vol22 No. 4, 1-7
- Rosset, J., Rinchen, 1997. Effect of thinning on productivity, stability and economical aspects for young blue pine stands. RNR-RC research report.
- Rosset, J., 1998. Study of natural regeneration in small openings created by group selection system in mixed conifer stands rich in hemlock, Central Bhutan. RNR-RC Jakar Research Report
- Rosset, J., 1998. Seedfall Patterns in temperate conifer forests of Central Bhutan 1989-1997. RNR-RC Jakar, Ministry of Agriculture
- Rosset, J., 1999. Temperate conifer forests of Bhutan. A review of forestry research activities until June 1998. RNR-RC Jakar Special Publication No. 3
- Rosset, J., Rinchen, 1999. Effect of thinning on productivity, stability and economics of young blue pine stands. *Journal of Renewable Natural Resources of Bhutan* Vol. 1, Issue 1, Thimphu
- Royal Government of Bhutan, 1991 Master Plan for Forestry Development. Annex Report No. 3, Development of Forest Management in Bhutan. Department of Forestry, Ministry of Agriculture, Thimphu
- Royal Government of Bhutan, 2011. National Forest Policy of Bhutan
- Sargent, C., Sargent, O., Parsell, R., 1985. The forests of Bhutan: a vital resource for the Himalaya? *Journal of Tropical Ecology*, 1:265-286
- Seydack, A.H.W., 2001. Research for broadleaved forest management in the Kingdom of Bhutan

- SFED, 2016. Norms and Standards for Nursery and Plantation (revised Version, 2016)
- Statz, J., Wyrsh, D., 1993. Silviculture manual. IFDP reference manual, IFDP, Bumthang, Bhutan
- Storey, P.J., undated. Bamboo. A valuable multi-purpose and soil conserving crop. A practical guide to the growing of bamboo
- Tenzin, K., Rinzin. Undated. Impact of livestock grazing on the regeneration of some major species of plants in conifer forest. RNR-RC Jakar
- Tenzin, K., undated. The management of blue pine (*Pinus wallichiana*) in secondary forest in Bhutan. MSc thesis, University of Edinburgh Institute of Ecology and Resource Management
- Tewari, D.N., 1994. A monograph on chir pine (*Pinus roxburghii* Sarg.). International Book Distributors, Dehradun
- Thinley., U. 2002 Reduced impact logging in Bhutan. Paper presented at Asia-Pacific Forestry Commission Conference 2001 'Applying reduced impact logging to advance sustainable forest management' Eds. Durst et al, FAO, Bangkok
- Third Forestry Development Project, 2000a. Site selection manual for afforestation/reforestation. A matrix of criteria and tools. Field Document No. FD 0012, TFDP, Tashigang
- Third Forestry Development Project, 2000b. Social Forestry in Eastern Bhutan. A study of the Third Forestry Development project 1994-2000. TFDP, Ministry of Agriculture, Tashigang, Bhutan
- Third Forestry Development Project, 2000c. Nursery and plantation operations for the social forestry programme in Eastern Bhutan. A manual for training nursery operators. Third Forestry Development Project, Field Document 01, Project Facilitation Office, Tashigang, Bhutan
- Troup, R.S., 1921. The Silviculture of Indian Trees Volumes I-III. Clarendon Press, Oxford
- Ura, K., 1993. Gambling for sustainability – local institutions for pasture management in Bhutan. Forest Trees and People Newsletter No. 22
- Various, 2004. Silvicultural Operations for Community Forestry. Community Forestry Manual for Bhutan Part III. Wang Watershed Management Project/Bhutan-German Sustainable Renewable Natural Resources Project and PFMP
- Wangchuk, K., 2007. Natural regeneration ecology of mixed conifer forests in Western Bhutan. Thesis submitted in partial fulfilment for the degree of Master of Sciences in Mountain Forestry, UNI BOKU Vienna
- Wangchuk, U., 2010. Natural Regeneration Issues in Logged Conifer Forests, Bhutan. Article submitted in partial fulfilment of the degree for Master of Forestry, ANU, Australia
- Wangchuk, K., Chettri, P.B., Thinley, P., Dorji, K., Roder, W., Wangdi, K., undated. The intermediate results of silvopastoral experiment at Dhur in Bumthang. Unpubl. Report

- Wangchuk K., Roder, W., Darabant, A., Rai, P.B., 2008. Silvo Pasture: An Alternative Land Use Option for the Temperate. Journal of Renewable Natural Resources of Bhutan. Vol. 4. Number 1 August 2010
- Wangchuk, S., 1991. Annex 1 In 'Master Plan for Forestry Development. Annex Report No. 3, Development of Forest Management in Bhutan' Department of Forestry, Ministry of Agriculture, Thimphu
- Whitfield, P., 2001. Report of the Forest Harvesting and Inventory Specialist. Wang Watershed Management Project, Paro, Bhutan
- Wolf, R., 2001. Practicing sustainable silviculture. Project document No. 52. Workshop on forest assessment and sustainable harvesting organised by FDC, FRDD and WWMP, Thimphu

Annex 5: Scientific and Common Names for Selected Plant Species

Scientific	Plant type	Dzongkha	Lhotshampkha
<i>Abies densa</i>	Coniferous tree	Dungshing	Gobre salla
<i>Acer campbellii</i>	Broadleaved tree	Chalam	Kapasi
<i>Acrocarpus fraxinifolius</i>	Broadleaved tree	Chashing	Mandaney
<i>Ailanthus grandis</i>	Broadleaved tree	Pekashing	Gokul
<i>Alangium chinense</i>	Broadleaved tree		Baman patti
<i>Alnus nepalensis</i>	Broadleaved tree	Gamashing	Utis
<i>Arceuthobium minutissimum</i>	Parasitic shrub		
<i>Arundinaria griffithiana</i>	Small bamboo		
<i>Arundinaria racemosa</i>	Small bamboo		
<i>Bambusa alamii</i>	Bamboo	Jatshoe (khenkha)	Mugi bans
<i>Bambusa clavata</i>	Bamboo	Gug (khenkha)	
<i>Bambusa nutans sub sp. cupulata</i>	Bamboo	Zhushing	Mal bans
<i>Bambusa tulda</i>	Bamboo		Karey bans
<i>Belschmedia sikkimensis</i>	Broadleaved tree		
<i>Betula alnoides</i>	Broadleaved tree	Taapshing	Saur
<i>Betula utilis</i>	Broadleaved tree	Latap	Bhojpatra
<i>Bischofia javanica</i>	Broadleaved tree	Goileshing	Kainjal
<i>Bombax ceiba</i>	Broadleaved tree	Pemageysershing	Simal
<i>Borinda grossa</i>	Bamboo	Baa	
<i>Calamus acanthospathus</i>	Cane	Tsem	
<i>Calamus erectus</i>	Cane		
<i>Calamus flagellum</i>	Cane	Bagpa (Khenkha)	
<i>Calamus latifolius</i>	Cane	Grey/Khran (Khenkha)	
<i>Calamus leptospadix</i>	Cane		
<i>Castanopsis hystrix</i>	Broadleaved tree	Sokeyshing	Patle katus
<i>Castanopsis indica</i>	Broadleaved tree	Labsokay	Dhalne katus
<i>Castanopsis tribuloides</i>	Broadleaved tree	Thomsokey	Masure katus
<i>Cephalostachyum capitatum</i>	Bamboo		
<i>Cephalostachyum latifolium</i>	Bamboo		Ghopi bans
<i>Chimonobambusa callosa</i>	Bamboo		
<i>Cordia obliqua</i>	Broadleaved tree	Boeshing	Bohori
<i>Crateva religiosa</i>	Broadleaved tree		Sipligan
<i>Cupressus corneyana</i>	Coniferous tree	Tsenden	
<i>Cymbopogon citratus</i>	Grass		
<i>Cymbopogon flexuosus</i>	Grass	Humchu Tsa	Pirhe ghans
<i>Daphne bhola</i>	Woody shrub	Deshing-deynap	Kagate; Lokta
<i>Daphniphyllum himalense</i>	Broadleaved tree		Rakchan

Scientific	Plant type	Dzongkha	Lhotshampkha
<i>Dendrocalamus hamiltonii</i>	Bamboo	Su	Choya bans
<i>Dendrocalamus hookeri</i>	Bamboo		Bhalu bans
<i>Dendrocalamus sikkimensis</i>	Bamboo	Zang	
<i>Dillenia pentagyna</i>	Broadleaved tree		Tatari
<i>Drepanostachyum annulatum</i>	Bamboo		
<i>Drepanostachyum intermedium</i>	Bamboo		Tite nigalo
<i>Drepanostachyum khasianum</i>	Bamboo		Ban nigalo
<i>Duabanga grandiflora</i>	Tree	Patangshing	Lampate
<i>Edgeworthia gardneri</i>	Woody shrub	Deshing-Deykap	Kagate; Argeli
<i>Engelhardtia spicata</i>	Broadleaved tree		Mauwa
<i>Eudia fraxinifolia</i>	Broadleaved tree		Kanukpa
<i>Exbucklandia populnea</i>	Broadleaved tree	Chenjushing	Pipla
<i>Gaultheria procumbens</i>	Woody shrub		Patpate
<i>Gmelina arborea</i>	Broadleaved tree	Gamarishing	Gamar
<i>Illicium griffithi</i>	Broadleaved tree	Doomleeshing	
<i>Juglans regia</i>	Broadleaved tree	Tashing	Okhar
<i>Juniperus recurva</i>	Coniferous tree	Shupshing	Dhupi
<i>Lagerstroemia hirsuta</i>	Broadleaved tree		Jarul
<i>Larix griffithiana</i>	Coniferous tree	Zashi	Barge salla
<i>Leea asiatica</i>	Broadleaved tree		
<i>Lindera heterophylla</i>	Broadleaved tree		
<i>Lindera neesiana</i>	Broadleaved tree		Siltimur
<i>Lithocarpus pachyphylla</i>	Broadleaved tree	Dungtsoshing	Falant
<i>Litsea monopetala</i>	Broadleaved tree	Bagabup	Kutmero
<i>Lyonia ovalifolia</i>	Broadleaved tree	Zentrushing	Angeri
<i>Macaranga pustulata</i>	Broadleaved tree		Malata
<i>Magnolia globosa</i>	Broadleaved tree		Goge champ
<i>Michelia champaca</i>	Broadleaved tree	Khashing	Champ
<i>Michelia doltsopa</i>	Broadleaved tree	Khashing	Rani champ
<i>Morus alba</i>	Broadleaved tree	Tsendhey	Kimbu
<i>Neomicrocalamus andropogonifolius</i>	Climbing bamboo	Yula (Khenkha)	
<i>Nyssa javanica</i>	Broadleaved tree		Lekh chilaune
<i>Persea fructifera</i>	Broadleaved tree	Guli	Lapche phal
<i>Picea spinulosa</i>	Coniferous tree	Seyshing	Kalo salla
<i>Pinus roxburghii</i>	Coniferous tree	Thetongphu	Khote salla
<i>Pinus wallichiana</i>	Coniferous tree	Tongphushing	Gobre salla
<i>Piper pediculatum</i>	Shrub		Pipla
<i>Plectocomia himalayana</i>	Cane	Patsha	
<i>Pterospermum acerifolium</i>	Broadleaved tree		Hattipainla

Scientific	Plant type	Dzongkha	Lhotshampkha
<i>Quercus semecarpifolia</i>	Broadleaved tree	Bijishing	Khasru
<i>Quercus glauca</i>	Broadleaved tree	Thomshing	Sano falant
<i>Quercus griffithii</i>	Broadleaved tree	Sisishing	Khasru
<i>Quercus lamellosa</i>	Broadleaved tree		Bajranth
<i>Quercus lanata</i>	Broadleaved tree	Gumshing	Bajranth
<i>Rhododendron arboreum</i>	Broadleaved tree	Aetoshing	Lali gurans
<i>Rhododendron hodgsonii</i>	Woody shrub	Aetoshing	
<i>Salix babylonica</i>	Woody shrub	Chongmashing	Bainsh
<i>Schima wallichii</i>	Broadleaved tree	Puyamshing	Chilaune
<i>Shorea robusta</i>	Broadleaved tree	Gotenshing	Sal
<i>Skimmia arborescens</i>	Broadleaved tree		
<i>Sorbus thibetica</i>	Broadleaved tree		
<i>Swertia chirayta</i>	Herb		Chirata
<i>Symplocus dryophyla</i>	Broadleaved tree	Pangtseshing	Kharane
<i>Symplocus lucida</i>	Broadleaved tree	Pangtseshing	
<i>Taxillus kaempferi</i>	Parasitic shrub		
<i>Taxus baccata</i>	Coniferous tree	Keranshing (shachop)	Dhengre salla
<i>Tectona grandis</i>	Broadleaved tree		Sagwan
<i>Terminalia myrocarpa</i>	Broadleaved tree		Panisaj
<i>Terminalia tomentosa</i>	Broadleaved tree		Paka saj
<i>Tetrameles nudiflora</i>	Broadleaved tree	Kadonshing	Maina
<i>Thamnocalamus spathiflorus</i>	Bamboo		Rato nigalo
<i>Thysanolanea maxima</i>	Tall grass	Tsakusha	Amliso
<i>Toona ciliata</i>	Broadleaved tree		Tooni
<i>Tsuga dumosa</i>	Coniferous tree	Bashing	Thingre salla
<i>Yushania microphylla</i>	Bamboo		Malingo
<i>Yushania pantlingii</i>	Bamboo		
<i>Zizyphus incurva</i>	Broadleaved tree	Tsoshing	Bayer

Annex 6: Format to Assess and Record Stand Condition in CFs

Location (Forest/Block/Compartment/Sub-Compartment)			Date:
STEP 1: Identify the forest type		STEP 3: Select forest management objectives (write a short description of the long term vision for the stand {after about 30 years})	
STEP 2: Assess the forest stand condition (write a short description of history and current use of the stand)		Write down how the stand will be managed for:	
Criteria	Current status	Desired status after 10 years	Utilization:
Species with indication of use e.g. P = Preferred species T = Timber F = Fuelwood Po = Poles Fo = Fodder N = NWFP	1.		Improvement:
	2.		Protection:
	3.		
	4.		Additional Field Notes (Comments):
	5.		
	6.		
	7.		
	8.		
Number of storeys			
Canopy density %			
Basal area m ² /ha			
Estimated growing stock m ³ /ha			
Dbh-class distribution (no./ha)	Drashing (>40cm dbh)		
	Cham (30-39 cm dbh)		
	Tsim (20-29 cm dbh)		
	Dangchung (10-19cm dbh)		
Stability			
Established regeneration (all species)			
No. of seed trees/ha			
Ground vegetation			

Description of criteria used in the stand assessment format

Criteria	Definition/calculation	Input into format
Number of storeys	Upper story (= canopy), middle story, under-storey	1, 2 or 3
Canopy density %	> 40% = dense; < 40% = open	Estimated %
Basal area (m ² /ha)	> 18 m ² /ha = good; 12-18 m ² /ha = moderate; 6-12 m ² /ha = degraded; < 6 m ² /ha = open	Average of 4 to 5 measurements /ha
Estimated growing stock (m ³ /ha)	Thumb rule: GS = basal area x ½ mean tree height	Estimated GS in m ³ /ha
Dbh-class distribution number/ha	Count trees per dbh-class in 10 x 10 m plots No. in 2 plots x 50 = no./ha No. in 4 plots x 25 = no./ha	No./ha
Stability (only required for conifer forests)	Stability factor: Tree height (m) / dbh (m) Example: 10 m height / 0.1 m dbh = factor 100 Chir pine factor < 100 = stable tree Blue pine factor < 80 = stable tree	Stable/unstable (majority of trees)
Established regeneration of desired species (only required if regeneration is needed)	Definition for established regeneration is 30 cm height and/or 9.9 cm diameter. Abundant = > 1,600 established plants/ha > 30 cm Scattered = < 1,600 established plants/ha > 30 cm None = no established regeneration	Indication in words e.g. abundant, scattered, none for the desired species
Number of seed trees/ha		Name of the species and number/ha. Indicate whether this is sufficient or not
Ground vegetation e.g. prone to forest fire, competition for regeneration, grazing pressure	Leaf litter, competitive weeds, invasive species	Describe if there are any problems
Area calculation	1 hectare = 100 x 100 m = 10,000 m ² ; Sample plot of 10 x 10 m = 100 m ²	

Annex 7: Format to Assess and Record Stand Condition in FMUs

FOREST MANAGEMENT INVENTORY: TALLY SHEET															1/2		
1)	Inventory Unit						2)	Plot Number						3)	Special?	Y	N
4)	Sheet Number				5)	Crew Leader						6)	Date				
7)	Altimeter						8)	Land use type									
9)	Canopy height	<5	<10	<20	<30	30+		10)	Canopy closure	<10	<40	40+	11)	Accessibility	Y	N	
								If not, remarks:									
If plot not accessible, or LUT no natural forest/tall bamboo: stop recording here																	
Trees 10+ cm dbh (dbh 30+ cm on major plot, r <12.62 m; dbh 10-29 cm on major plot, r < 5.64 m)																	
	Species	Code	Dbh	Special	Total height	% log grades						Conifer					
						P	A	B	C	I	X	Rad inc	Bark thk				
1																	
2																	
3																	
4																	
5																	
6																	
7																	
Regeneration < 10 cm dbh (1.3 m height – 9 cm dbh of commercial species on regeneration plot, r < 3.57 m)																	
	Species				Code				Number								
1																	
2																	
3																	
4																	
5																	

FOREST MANAGEMENT INVENTORY: TALLY SHEET														2/2			
Site (observation on major plot)																	
Aspect																	
12	Azimuth, downhill				13)	Slope% down				14)	Slope% up						
Stand Condition																	
15	Common Mistletoe			(Y)	(N)	16)	Bark Beetle			(Y)	(N)	17)	Dwarf Mistletoe			(Y)	(N)
18	Fir Dieback					(Y)	(N)										
Non-tree vegetation																	
19	Understorey cover%			None				<2	<10	<40	40+						
	Understorey main type		Moss		Grass		Herbs		Bamboo <5m		Shrubs <2m		Shrubs 2<5m				
20	Bamboo cover%		None	<2	2+												
	Bamboo cover type			Spreading		Clump	Dbh (cm)	<2	2<4	4+							
21	Cane cover%		None	<2	2+	Dbh (cm)	<2	2+									
22	Daphne cover		None	<2	2+												
Signs of:																	
23	Commercial wood extraction			(Y)	(N)	24)	Domestic wood extraction			(Y)	(N)	25)	Grazing			(Y)	(N)
26	Fire			(Y)	(N)	27)	Abandoned sifting cultivation			(Y)	(N)	28)	Cardamom cultivation			(Y)	(N)
Soil																	
29	Stoniness	<70x70cm	<4x4m	<9x9m	>=9x9m	30)	Depth litter + humus (cm)			<2	2<5	5+					
31	Topsoil moisture	Dry	Moist	Permanent wet		32)	Topsoil colour		Dark	Reddish	Yellowish						
33	Topsoil texture		Sand		L. Sand	S. Loam	Loam	Clay									

Wildlife (observation on major plot)										
	Species	Code				Evidence	Code			
1										
2										
3										
4										
5										
6										
34	General Remarks									

Annex 8: Format to Assess and Record Stand Condition Outside FMUs and CFs

Geog	
Comp. No. + Name	
Sub-Comp. Name	
Sub-Comp. No.	

Officer	
Date	
Year	

No. of sample plots	
Operable	
In-operable	

Prism factor	
Non Forest A.	ha
Protection	ha
Production	ha

For trees > 90 cm calculate average dbh per species. Enter in column Av. Dbh, and in number of trees.

	Species	Reg.	< 1.3m	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90 +	Av. Dbh	No
R															
T															
F															
R															
T															
F															
R															
T															
F															
R															
T															
F															

Note: R = Regeneration, T = Timber, F = Fodder, Reg. = Regeneration.