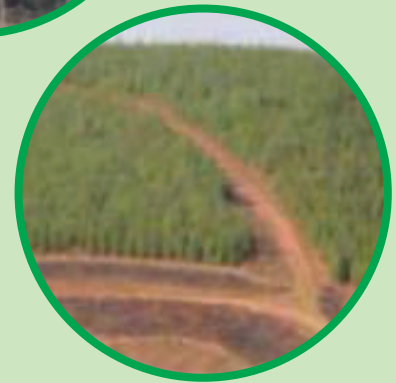
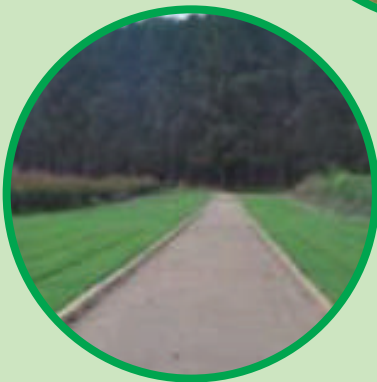
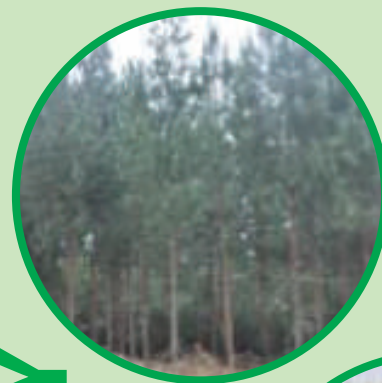




The United Republic of Tanzania
Ministry of Natural Resources and Tourism

TECHNICAL ORDER No 1 OF 2021



QUALITY
PRODUCTIVITY



Forestry and Beekeeping Division
2021

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FOREWORD

Public sector forest plantations and private and communal woodlots in Tanzania have been managed using Technical Order No 1 of 2003, prepared by the Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT). The use of Technical Order ensures application of best practices and thus proper establishment and management of plantations and woodlots resulting in high quality and productivity.

This Technical Order No.1 of 2021 is an improved version, taking into account new research findings, advancement in technology and the need to be inclusive of all activities in the chain of forest operations. This Order is based on proven forest best practices, cumulative traditional and scientific knowledge, experience and observed successful efforts in forestry. The Technical Order offers brief instructional statements. More details and specific elaborations are contained in the Forest Plantation and Woodlot Technical Guidelines (2017) and Integrated Fire Management Guidelines for Commercial Forestry (2019) both published by the FBD.

Justification for these improved technical instructions, among others, include need for better quality of forest stands and the final products, increased efficiency in forest operations, sensitivity to environmental protection, and acknowledging the ongoing implementation of the forest policy. Apart from public forest plantations, this Technical Order was prepared with recognition of increasing investments in woodlots, medium and large-scale commercial forestry in the country. It also considers other related sectors on enhanced fire management in different landscapes. Therefore, these instructions are prepared to provide clear objectives, practical instructions, activities and principles to be applied in order to achieve best quality forest stands and increased productivity during nursery, establishment, management and harvesting operations.

Enforcement of this Technical Order No.1 of 2021 is therefore expected to significantly enhance the quality and productivity of forest plantations and woodlots in Tanzania.

I urge that all public plantations, and other stakeholders including individual/community woodlots owners, use this Order to enhance quality and productivity of forests in order to meet the increasing wood products demand both locally and internationally.




Dr. Aloyce K. Nzuki
PERMANENT SECRETARY

ACKNOWLEDGEMENT

The Technical Order No. 1 of 2021 is a result of a consultative process which extracted valuable technical contributions from selected experts from the Sokoine University of Agriculture (SUA), Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT), Tanzania Forestry Research Institute (TAFORI), Tanzania Forest Services Agency (TFS) and the Forestry Development Trust (FDT).

I am indebted to the experts who spared their valuable time to consult relevant documents and shared their vast experiences to produce this valuable document. Their commitment and professionalism are clearly demonstrated.

The preparation of this Technical Order was funded by the MNRT and the FDT. Further the FDT provided technical guidance and logistical arrangements. The financial and other support is greatly appreciated.



Dr. Ezekiel E. Mwakalukwa
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1. INTRODUCTION

Large scale tree planting in Tanzania dates back to the 1950s. At present, the total area of public plantations is about 114,533 hectares (ha) while that of private industrial plantations is about 50,827 ha. The total area of private woodlots is estimated at 415,000 ha. The key species are Pines (65%) and Eucalyptus (20%) while the balance is largely made up of Teak and Black Wattle. The main objectives of establishing forest plantations and woodlots are to ensure sustainable supply of forest products as well as provision of environmental services. These objectives can best be achieved if forest plantations and woodlots are responsibly established and managed so that both plantation/woodlot quality and productivity are enhanced.

Technical Orders are a set of technical specifications used to ensure responsible establishment and management of forest plantations and woodlots. They are developed and revised as need arises by the Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT). The existing Government Technical Order was issued by the FBD in 2003. Since then, there have been new research results on various aspects of plantation/woodlot management e.g., rotation age, genetic trials, site-species matching tool (SSMT) as well as guidelines e.g., Forest Plantation and Woodlot Technical Guidelines, and Integrated Fire Management Guidelines for Commercial Forestry. Due to these developments, Technical Order No 1 of 2003 has been revised. This Technical Order 1 of 2020 is an outcome of that revision and should now be used by stakeholders including public sector forest plantations and individual/community woodlots and plantations.

2. SPECIES-SITE MATCHING

Good site selection is one of the most important decisions to be made when considering planting trees for commercial use since tree species prefer certain climates and soils to grow successfully. The objective of technical instructions on species–site matching is to ensure that species are matched to their specific planting sites for maximum survival, growth and productivity and to minimise stress and insect pests and pathogen attacks due to offsite planting.

Forest Managers, Plantation Planners and Stakeholders must assess their sites by conducting Feasibility study(s) and use SSMT to determine species suitability for tree planting before forest plantation/woodlot establishment, especially for new areas. Table 2.1 shows a list of major and alternative tree species matched with respective sites in Tanzania. Details on appropriate provenances and hybrids can be obtained from the Directorate of Tree Seed Production of Tanzania Forest Services Agency (TFS) and Tanzania Forestry Research Institute (TAFORI). Further, details on the use of SSMT can be obtained from TAFORI.

Table 2.1: Tree species-site matching according to forestry zones in Tanzania

Zone, [Regions] & Major Species	Alternative Exotic	Indigenous Species	Altitude/Climate Remarks
Lake Victoria [Kagera, Geita, Mwanza, Shinyanga, Simiyu, Mara] <i>P. tecunumanii</i>	<i>Pinus caribaea, P. kesiya, P. merkusii, Corymbia citriodora, Eucalyptus saligna, Cedrela odorata, Acrocarpus fraxinifolius, Grevillea robusta</i>	<i>Antiaris toxicaria, Maesopsis eminii, Markhamia platycalyx Syn. M. lutea, Milicia excelsa, Halleerubro stipulata, Trichilia emetica, Podocarpus usambarensis, Khaya anthotheca</i>	Altitude: >1000 masl; Rainfall: 800 to >1000 mm Temperature: 16-27°C Suitable for areas receiving more than 1600 mm mean annual rainfall
	<i>Albizia lebbeck, P. kesiya, Azadirachta indica, E. alba, E. crebra, E. cloeziana, E. melonophlora, E. microtheca, E. camaldulensis, Mellia azedarach</i>	<i>Faidherbia albida, Acacia nilotica, A. polyacantha, Afzelia quanzensis, Dalbergia melanoxylon, Julbernadia globiflora, Pterocarpus angolensis, Vitex keniensis</i>	Suitable for areas receiving less than 700 mm mean annual rainfall
Inland Plateau [Manyara, Kigoma, Ruvuma, Singida, Dodoma, Tabora, Rukwa, Katavi] (None)	<i>A. crassicarpa, Albizia lebbeck, P. kesiya, Azadirachta indica, E. alba, E. crebra, E. cloeziana, E. melonophlora, E. microtheca, E. camaldulensis, Eucalyptus hybrids, Mellia azedarach, Casuarina equisetifolia, Tectona grandis (dry area provenance), Terminalia sambesiaca, Oxytenanthera braunii, Bambusa vulgaris var striata</i>	<i>Afzelia quanzensis, Dalbergia melanoxylon, Julbernadia globiflora, Pterocarpus angolensis, Vitex keniensis</i>	Altitude: 500 – 1500 masl; Rainfall: > 700 mm; semi-arid parts < 700 mm; Temperature: 13-31°C Miombo covers 40% of the country, hence potential for future forestry development
Highland Areas [Mbeya, Iringa, Njombe, Morogoro, Tanga, Kilimanjaro, Arusha] <i>P. patula</i> <i>Cupressus lusitanica</i> <i>E. grandis</i> <i>E. regnans</i> <i>E. saligna</i>	<i>Casuarina junghuhniana, C. cunninghamiana, Cupressus lindleyi, C. benthamii, P. elliotii, P. kesiya, P. oocarpa, P. taeda, Cedrella odorata, Cryptomeria japonica, Cinamomum camphora, Grevillea robusta, P. radiata (resistant strains), E. botryoides Combrya citriodora, E. globulus, E. maculata, E. maidenii, E. microcorys, Eucalyptus hybrids, Arundinaria alpine, Oreobambos buchwaldii, Oxytenanthera braunii, Oxytenanthera abyssinica</i> Only for Southern Highlands <i>E. benthamii, E. urophylla, E. badjensis, E. nitens, E. dunnii, E. cloeziana, Eucalyptus hybrids</i>	<i>Beilschmedia kweo, Cordia Africana, Cephalosphaera usambarensis, Fagaropsis angolensis, Newtonia buchananii, Olea capensis, P. usambarensis, Vitex keniensis, Ocotea usambarensis, Olea capensis, Juniperus procera, Acacia sieberiana var. sieberiana, A. seyal</i>	Altitude: >1000 masl; Rainfall: Often > 1000 mm; Temperature: < 20°C; Humidity is low
Eastern Arc Mtountains foothills [Kilimanjaro, Morogoro, Iringa, Tanga] <i>T. grandis</i>	<i>C. odorata, Gmelina arborea, G. robusta, Terminalia superba, T. ivorensis, C. japonica, Oreobambos buchwaldii, Bambusa bambos</i>	<i>Brachylaena huillensis, Entandrophragma stolzii, K. anthotheca, Milicia excelsa, Trichilia emetica, P. angolensis, Sterculia appendiculata, Dalbergia melanoxylon</i>	Altitude: 150- 700 masl; Rainfall: > 1000 mm; Temperature: 15-32°C
Coast [Mtwara, Lindi, Coast, Tanga] <i>P. caribaea, P. elliotii, P. tecunumanii</i>	<i>A. crassicarpa, A. auriculiformis, Dalbergia sissoo, E. camaldulensis, E. tereticornis, Eucalyptus hybrids, C. equisetifolia, C. junghuhniana, Acacia mangium, Oxytenanthera braunii, Bambusa vulgaris var striata</i>	<i>D. melanoxylon, Rhizophora spp. P. angolensis, Sterculia appendiculata</i>	Altitude <500 masl; Rainfall > 700 mm; Temperature: > 20°C; Humidity > 60%

3. TREE SPECIES DIVERSIFICATION

Tree species diversification involves use of several compatible species on the landscape to increase stability against environmental and economic perturbations. The objective of technical instructions on tree species diversification is to serve as an insurance against insect pests, pathogens and climatic fluctuations. Additionally, this may result in increased market security through species and product diversification. Table 2.1 shows a list of tree species for diversification. With market considerations in mind, stakeholders should use a minimum of four tree species in large scale plantations, and as much as possible in equal proportions area wise.

4. TREE SEEDS AND VEGETATIVE PROPAGULES

Planting materials can be seeds or vegetative propagules (cuttings, single cell/organ used in tissue culture). The objective of technical instructions on tree seeds and vegetative propagules is to ensure genetically improved seeds and vegetative propagules are used for the establishment of productive and quality plantations and woodlots.

Planting materials must be sourced from seed orchards. For the indigenous tree species which have no seed orchards, the seeds must be obtained from seed stands.

5. TREE NURSERIES

A nursery is a place where plants are propagated and grown to a desired age/size. The objective of technical instructions on tree nurseries is to produce quality seedlings with high survival and initial growth in the field.

In order for a nursery to produce high quality planting materials, the following should be adhered to:

1. Nursery site selection should be based on the most favourable combination of climatic and environmental conditions;
2. Apply the recommended methods of raising seedlings (e.g., container pots (7-10 cm lay flat diameter and 9-15 cm long), multi-cavity trays or seedbed) suitable for the site and species;
3. Use proper nursery cultural techniques which involves watering, shade, root pruning, fertilization, weed control, pest control and inoculation;
4. Maintain an up-to-date nursery records on schedules of irrigation, all nursery cultural techniques, climatic data, finances and labour;
5. Ensure clear and correct labels in seed beds;
6. Ensure seedlings for planting have a height of 20-35 cm and root collar diameter of 3-4 mm; and
7. Observe care during lifting, packing, transporting and storage of seedlings to avoid damage.

Details of these instructions are elucidated in the Forest Plantations and Woodlot Technical Guidelines document.

6. PLANTATIONS AND WOODLOTS ESTABLISHMENT

Plantation/woodlot establishment includes site preparation, pitting, spacing and planting. The objective of technical instructions on plantations and woodlots establishment is to ensure maximum survival and high initial growth of seedlings in the field.

Site Preparation

Site preparation or land preparation can be done manually, mechanically or by use of chemicals. Land preparation should either be strip cultivation (and slashing) or complete cultivation of the planting site. The following should be adhered to:

1. Avoid mechanical site preparation during the rainy season;
2. Avoid site preparation on areas with slope beyond 60%;
3. Do not use slash and burn land preparation technique;
4. Retain valuable indigenous tree species;
5. Identify, map and protect high biodiversity sites, wetland areas, water sources, burial, archaeological, cultural and spiritual sites; and
6. Avoid site preparation within 60 m from water bodies.

Spacing

The spacing regimes shown in Table 6.1 should be used for the respective tree species.

Table 6.1: Initial planting spacing, end product and rotation age of tree species

Tree Species	End product	Rotation age (years)	Initial planting spacing (m)
<i>Pinus species</i>	Saw logs	18	3.0 x 3.0
	Pulpwood	11	2.0 x 2.0
<i>Cupressus lusitanica</i>	Saw logs	18	3.0 x 3.0
<i>Gmelina arborea, Grevillea robusta, Cedrella odorata and Maesopsis eminii</i>	Saw logs	20	3.0 x 3.0
<i>Terminalia superba</i>	Saw logs	20	3.0 x 3.0
<i>Tectona grandis</i>	Saw logs	20	2.5 x 2.5 3.0 x 3.0
<i>Eucalyptus provenances/ hybrids</i>	Saw logs	18	3.0 x 3.0
	Pulpwood	7	2.0 x 2.0
	Poles	7	2.0 x 2.0
<i>Acacia melanoxylon and Acacia mangium</i>	Saw logs	18	3.0 x 3.0
<i>Dalbergia melanoxylon</i>	Saw logs	40	4.0 x 4.0
<i>Milicia excelsa</i>	Saw logs	32	4.0 x 4.0
<i>Khaya anthotheca</i>	Saw logs	30	3.0 x 3.0
<i>Olea capensis</i>	Saw logs	30	6.0 x 6.0
<i>Juniperus procera</i>	Saw logs	40	3.0 x 3.0
<i>Pterocarpus angolensis, Ocotea usambrensis</i>	Saw logs	30	5.0 x 5.0
<i>Casuarina equisetifolia</i>	Saw logs	18	3.0 x 3.0
	Poles	7	2.0 x 2.0
<i>Araucaria cunninghamii</i>	Saw logs	30	3.0 x 3.0
<i>Azelaia quanzensis</i>	Saw logs	30	5.0 x 5.0

Spacing depends on several factors: species, purpose for which it is grown, availability of moisture at critical periods of the year, tolerance of the species to weed, competition and economics.

Pitting

Pitting should be done as follows:

1. Pits be 20 - 30 cm deep x 20 - 30 cm diameter;
2. For drier areas, pits be 40 cm deep x 40 cm diameter; and
3. Dig pits after first rain to easy pitting and ensure, rapid and favourable soil moisture build up.

Planting

Planting is a critical stage of plantation establishment. Poor planting techniques can result into poor survival and growth. Planting must adhere to the following:

1. Seedlings/transplants for planting out be 25 – 30 cm height and of $\geq 3 - 4$ mm root collar diameter;
2. Planting be done when soil moisture has built up to a depth of 15 to 30 cm;
3. Press soil gently and firmly around the seedling to eliminate air pockets and bring the earth into intimate contact with the roots; and
4. Beating up be done timely when mortality is $\geq 20\%$ or 10% for lower stocking.

7. PLANTATION MAINTENANCE

Post planting care is necessary for healthy and well stocked stands. Therefore, maintenance of plantations/woodlots must be timely and properly done to offset competitions for growth resources. Maintenance includes all activities connected to weeding, pruning and thinning. The objective of technical instructions on plantation and woodlot maintenance is to reduce competition for moisture, nutrients, space and light in order to enhance forest/woodlot productivity and quality.

Weeding Techniques

Weeding can be manual, mechanical or use of chemicals. Weeding must be either strip with slashing or complete. The following aspects must be observed:

1. Weeding must be done on time, and as a minimum twice a year, during the first three years;
2. Taungya should be allowed for only one cropping season and be closely supervised;
3. Strip weeding (0.5 m) should be applied on each side of the tree line; and
4. Climbers cutting should be done during scheduled weeding.

Pruning

Pruning provides access into plantations/woodlots, reduces fire risks, facilitate felling and extraction of thinnings and production of knot free timber and add net value of stand. Therefore, at all times:

1. Use sharp curved pruning saw to ensure a clean cut and prevent tearing of tree's bark;
2. Avoid pruning during wet season as the bark is loose and easily slips from the wood causing serious wounds, as well as easy entry of pests and pathogens;
3. Remove only between 40-50% of the living crown;

4. Splinter of woods or broken stubs should not be left as they interfere will callus formation; and
5. Pruning must follow specified schedules shown in Tables 7.1 and 7.2.

Table 7.1: Pruning schedules for common tree species in Tanzania

Pruning type	Site Class I			Site Class II			Site Class III			
	Age, years	Ht, m mean	Ht, m pruning	Age, years	Ht, m mean	Ht, m pruning	Age, years	Ht, m mean	Ht, m pruning	
Pines all species (Non-naturally regenerating)										
1 st	3.0	5.5	2.7	3.5	4.9	2.4	-	-	-	W.C
2 nd	5.0	9.8	5.8	5.5	7.3	4.6	7.0	6.1	3.7	S
3 rd	7.0	13.7	8.2	7.5	10.4	6.1	9.0	7.9	4.9	S
Naturally regenerating <i>P. patula</i> age 1-3 years										
1 st	3		2.7							
2 nd	5		5.8							
3 rd	7		8.2							
Naturally regenerating <i>P. patula</i> age above 3 years										
1 st	4		2.7							
2 nd	6		5.8							
3 rd	8		8.2							
<i>C. lusitanica</i>										
1 st	1.0	2.4	1.2	2.0	2.4	1.2	-	-	-	W.C
2 nd	3.0	6.7	3.4	4.0	5.5	2.7	5.0	4.0	2.0	S
3 rd	5.0	10.1	6.7	6.0	7.3	4.9	7.0	5.2	3.4	S
4 th	7.0	12.8	8.5	8.0	9.1	6.1	9.0	6.4	4.3	S

Notes: WC=Whole crop pruned; S=selective pruning; Ht=Height

Table 7.2: Pruning schedule for *T. grandis* in Tanzania

Age (years)	Prune to (m)
4	2.5
6	5.0
8	7.5

Thinning

Thinning involves the removal of a proportion of individual living trees from a forest/woodlot stand to maximize the production of large saw logs. Therefore:

1. Every tree must be assessed individually and marked by competent personnel;
2. Thinning must be done at the right time, way and intensity; and
3. Thinning must follow the specified schedule (Table 7.3).

Table 7.3: Thinning schedules for common tree species in Tanzania

Species	Age (years)	Stems per ha
<i>Pinus species</i>	0	1,111
	8	650
	13	400
	18	0
<i>C. lusitanica</i>	0	1,111
	8	650
	13	400
	18	0
<i>T. grandis at 2.5 m x 2.5 m</i>	0	1,600
	5	800
	15	400
	20	0
<i>T. grandis at 3.0 m x 3.0 m</i>	0	1,111
	8	650
	13	400
	20	0
<i>G. robusta</i>	0	1,111
	6	785
	15	370
	20	0

Maintenance of Naturally Regenerating *P. patula*

Maintenance of naturally regenerating *P. patula* should involve the following:

1. For woodlots 1-3 years of age, clean and respaced individuals to approximately 3 m x 3 m;
2. For woodlots aged above 3 years, clean and respaced individuals to approximately 3 m x 3 m, at ages 4-6 years; and
3. All other specifications for weeding, pruning and thinning should be maintained as specified (Tables 7.1 and 7.3).

8. FOREST HEALTH

Abiotic and biotic disturbances have major impacts on the health and vitality of plantations and woodlots. It is therefore important that these disturbances are well managed to avoid adverse effects on tree growth and survival, yield and quality of wood and non-wood products. The objective of technical instructions on forest health management is to protect forest plantations and woodlots against fire, pests, invasive species and diseases in order to enhance productivity and quality.

Fire Management

Fire is a serious threat to forest plantations and woodlots therefore necessary precautions must be taken to avoid negative consequences. Therefore, integrated fire management actions must be implemented as follows:

1. Every plantation must prepare and enforce fire management plan;
2. Construct fire look-out towers for fire detection on high elevated areas;
3. Establish and annually maintain Internal (5 m) and external (≥ 10 m) fire breaks;
4. There must be a well-trained fire standby crew during fire season;
5. Map reliable sources of water;
6. Maintain a suite of working basic fire management equipment and tools;
7. Establish quick and effective communication system;
8. Seek and maintain good relationship with staff and community members;
9. Remove burnt materials and re-plant with the same or other tree species;
10. Establish compartment size of 30 ha to minimize large impacts from fire;
11. Maintain a buffer zone of 100 m from the village boundary for the existing plantations and 200 m for newly established plantations;
12. Prepare and enforce bylaws to safeguard against forest fires in villages with plantations/woodlots;
13. Institute effective committees dealing with forest fires in villages with plantations/woodlots;
14. Incentivise informers of people who set fires intentionally on forests;
15. Establish fire funds in villages with plantations/woodlots to facilitate fire control activities;
16. Report fire incidences and extent of damage immediately to the authorities; and
17. Include all issues of forest fires in annual reports.

Pests and Diseases Protection

Protection of pests and diseases is important to ensure fast growing stocks and reduce serious future outbreak. Several pests and diseases have been reported in Forest Plantation and Woodlot Technical Guidelines prepared by FBD.

It is therefore important that all sources of pests and diseases are controlled through:

1. Good silvicultural practices: careful planning combined with good silviculture can greatly reduce stress and thereby promote healthy trees. These include:
 - a. Use of disease free broad genetic base planting stock
 - b. Plant healthy seedlings and do beating up timely
 - c. Proper post planting weeding should be done
 - d. Match species to site and diversify tree species
2. Reduce unnecessary mechanical damages and stresses to trees;

3. Report all suspected pests or diseases to TAFORI;
4. Shorten rotation of susceptible host tree species;
5. Use of certified planting materials must be adhered to;
6. Train staff on recognising basic symptoms of the major pests and diseases;
7. Conduct monitoring quarterly by trained staff to detect basic pests and diseases symptoms;
8. Control wild and domestic animals which cause damages to forest trees; and
9. Remove and burn all infected tree individuals to prevent further spread.

Invasive Plant Species Control

Invasive species (IS) are species introduced outside their natural habitats which invade and outcompete natives. These species have increasingly become a threat to forest health and productivity. A list of invasive species common in forests is found in National Invasive Species strategy and Action Plan 2019-2029.

To control IS, the following actions must be done:

1. Identify areas invaded and type of invasive species to control the spread;
2. Monitor (quarterly) alien tree species to detect potential biological threats including invasions;
3. Create awareness to ensure that major invasive species are immediately detected;
4. Report all known and potential invasive species to TAFORI; and
5. Remove all invasive species from the forests and woodlots.

9. FOREST ROAD CONSTRUCTION AND MAINTENANCE

There are two main types of forest roads, Access road and Branch road. Forest access road connects the forest with the nearest public road. This road should be laid out and constructed during site preparation. Depending on traffic volume, there may be main and secondary access roads. Forest branch road connects the harvesting area to the access road and should be laid out and constructed during harvesting operations.

The objective of technical instructions on forest road construction and maintenance is to provide a standard road network that guarantees operational access, timely and economic delivery of forest establishment materials, protection and extraction of forest products.

Construction Specification of Forest Roads

Engineering principles should be applied for laying out and constructing forest roads to achieve the following minimum specifications (Table 9.1).

Table 9.1: Design limiting specifications for forest roads

Design element	Unit	Type of road		
		Main Access	Secondary Access	Branch
Right of way width	m	30	20	15
Roadway width	m	9.0	6.5	4.5
Roadbed width	m	6.0	4.5	3.5
Minimum curve radius	m	45	25	15
Maximum favourable gradient	%	10	12	14
Maximum ditch depth	%	6	8	10
Minimum ditch depth	m	0.75	0.5	0.3
Minimum ditch width	m	1.5	1.5	0.1
*Surface layer thickness	m	0.25	0.20	0.15
Base layer		Yes	No	No
Camber slope	%	3	4	5
Design speed	kph	60	40	25
Turnout interval	m	-	300	200

1. Surface layer thickness should be determined by the native subgrade bearing capacity, the normal force (load/tyre) and print area of a design tyre; and
2. Avoid excessive cut and fill during road construction.

Drainage Structures

Water is the main contributor to the wear and damage of forest roads. Well-designed road includes in-road drainage structures: road camber, side ditches, mitre drains, catch water drains and water bars. In presence of much water, culverts (cross-drains), drifts and bridges should be constructed.

The size of rain water culverts should be determined by engineering principles which account for the rain intensity, catchment area and ground cover. Ditch relief culverts should serve to protect the road from static water, erosion and road flooding. Table 9.2 shows the indicative spacing of ditch relief culverts.

Table 9.2: Indicative spacing between ditch relief structures

Road grade (%)	Spacing between structures (m)
2	120
4	100
6	80
8	60
10	50
20	40

Road Maintenance

A well-maintained road guarantees minimum impact on natural resources, availability of the road for the intended use while protecting the investment made in its development and improvement. Prescriptions for a well-maintained road:

1. Keep existing roads to the intended design standards;
2. Uphold a fully functional drainage system;
3. Minimize soil disturbance during forest operations;
4. Provide a protocol for identifying and responding to immediate maintenance needs; and
5. Put in place a comprehensive road maintenance strategy to address underlying planning issues such as inventory, inspection, timing, coordination, options, monitoring and prioritization.

10. FOREST HARVESTING

Forest harvesting is the conversion of trees into consumable products (e.g. saw logs, poles, pulp wood, veneer, chips, resin, wattle barks) and subsequent delivery to the utility centres. The objective of technical instructions on forest harvesting is to practice forest harvesting operations for quality, productive, safe, and reduced impact to the environment and subsequent crop.

Optimum Harvesting Age and Size

Quality and productivity of trees/products harvested in plantation/woodlots normally depends on various factors including optimal age and size (diameter). Trees in plantation/woodlots can be harvested at different optimal ages and sizes for the following targeted end products: veneers, utility poles (power transmission and distribution poles, telegraphic poles, construction poles (*mirunda*), mining timber (*matimba*), fence poles), sawn timber, pulp wood, firewood, wattle barks and resin. Optimum age (year) and diameter (cm) for forest harvesting shall be as indicated in Table 10.1.

Table 10.1: Optimum age (years) and diameter (cm) for forest harvesting

Tree species	End product	Harvesting criteria*	
		Age (years)	Diameter over bark (cm)
<i>Pinus</i> species	Saw logs	18	
	Pulp wood	11	
	Veneer		Top 11 ≤ 40
	Resin		DBH ≥ 20
	Poles		Butt 6 to 10
	Firewood		DBH < 5

Tree species	End product	Harvesting criteria*	
		Age (years)	Diameter over bark (cm)
<i>Eucalyptus provenances/hybrids</i>	Saw logs	18	
	Pulp wood	7	
	Veneer		Butt 11 ≤ 40
	Power transmission poles	7	Top 18 ≥ 25.5 DBH 20.8 ≥ 32.8
	Telegraphic poles	7	Top ≥ 16 DBH ≥ 19
	Fencing poles (length of 1.5 – 4 m)	5	DBH 10 ≥ 15
	Construction poles (length of 4 – 6 m)	5	DBH 7.5 ≥ 11
	Firewood		DBH < 10
<i>Tectona grandis</i>	Saw logs	20	
<i>Gmelina aborea</i>	Saw logs	20	
<i>Grevillea robusta</i>	Saw logs	18	
<i>Cupressus lusitanica</i>	Saw logs	18	
<i>Acacia melanoxylon</i>	Saw logs	18	
<i>Acacia mearnsii</i>	Wattle barks	7	
<i>Acacia mangium</i>	Saw logs	18	
<i>Casuarina equisetifolia</i>	Saw logs	18	
	Poles	7	
<i>Cedrela odorata</i>	Saw logs	18	
	Poles	7	

* Felling stump height for all species and all end products shall be ≤ 15 cm

Harvesting System

A harvesting system is the combination of conversion of trees to logs, extraction method and long distance transport. Choice of the best harvesting system depends on type of equipment available; size of trees; extraction distance; terrain condition; type of harvesting operation (thinning or clear-felling); size of felling units and landings; appropriate felling direction, roads condition; log quality (demand requirements) and labour characteristics.

Forest harvesting involves soil disturbances which may result in erosion and compaction. Excessive soil erosion and compaction have negative impacts to sustainability of the subsequent crop. In order to minimise the adverse impacts, the following must be adhered:

1. Schedule machine harvesting and heavy trucks for dry season;
2. Concentrate machine traffic onto as few extraction tracks as possible;
3. Prohibit use of crawler tractors in harvesting operations inside compartments; and
4. Strive to have minimum proportion of the harvested area occupied by log landings and extraction tracks.

Harvesting Plan

Any harvesting operation should be guided by a harvesting plan in order to minimize harvesting and transport costs subject to constraints imposed by environmental, ecological, and social considerations. Figure 10.1 illustrates key components of a generic harvesting plan. A generic chronology of activities in harvesting operation is represented in Table 10.2. Depending on number and sophistication of crews and equipment, some of the activities may run concurrently or skipped.

Table 10.2: Generic chronology of activities in harvesting operation

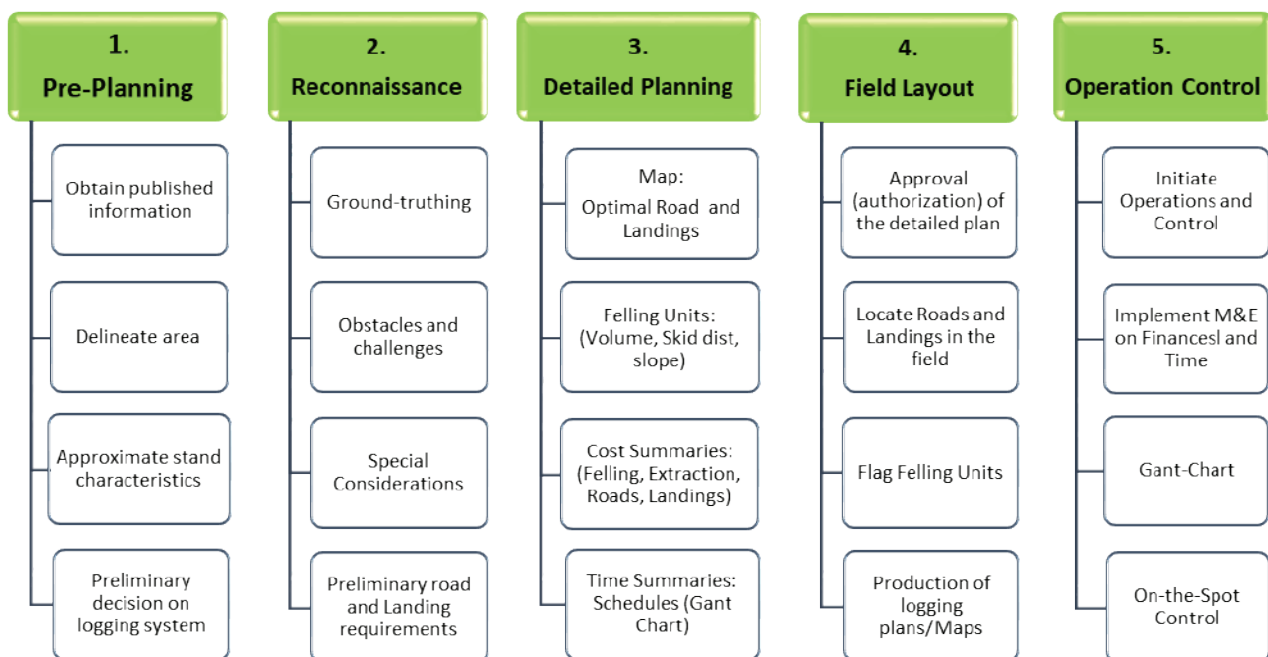
S/N	Activity
1	Begin branch road layout work*
2	Complete road layout
3	Begin flagging boundaries of felling units
4	Begin road construction
5	Complete flagging of felling units
6	Complete road and landing construction
7	Begin felling in felling unit 1
8	Begin skidding in felling unit 1**
9	Begin hauling from felling unit 1***
10	Complete felling in felling unit 1
11	Move to and begin felling in subsequent unit

*Roads for harvesting transmission poles should have specification on access roads (Table 9.1)

**Skidding in Unit 1 shall be completed when felling in subsequent unit is underway

***Hauling in Unit 1 shall be completed when skidding in subsequent unit is underway

Figure 10.1: Key components of a harvesting plan



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