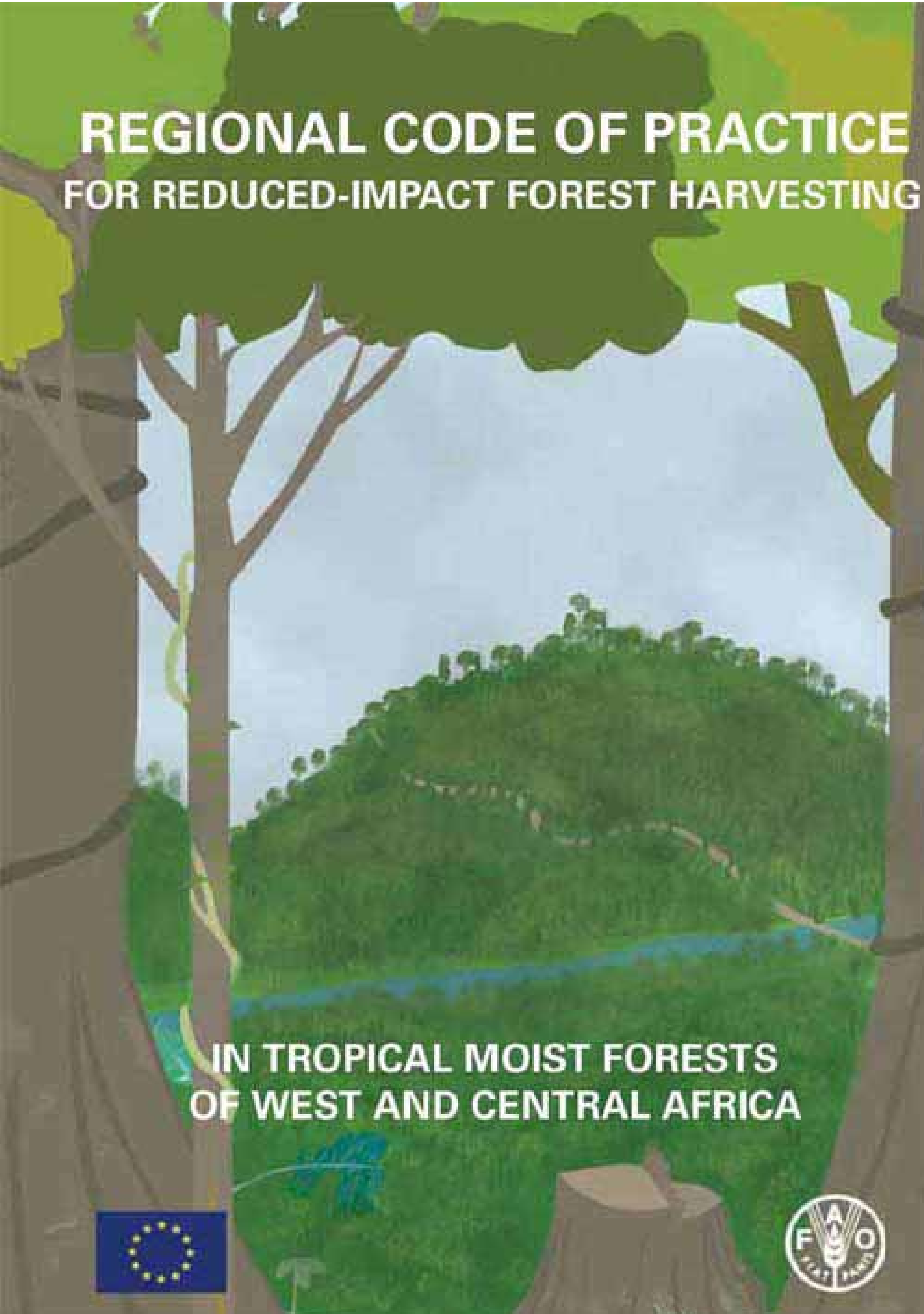
REGIONAL CODE OF PRACTICE

FOR REDUCED-IMPACT FOREST HARVESTING



IN TROPICAL MOIST FORESTS OF WEST AND CENTRAL AFRICA

REGIONAL CODE OF PRACTICE FOR REDUCED-IMPACT FOREST HARVESTING IN TROPICAL MOIST FORESTS OF WEST AND CENTRAL AFRICA

FOREWORD

The United Nations Conference on Environment and Development, held in Rio in June 1992, raised awareness amongst many countries of the importance of forests to their economic, social and environmental development.

Since the last World Summit on Sustainable Development, convened in Johannesburg in 2002, several initiatives have been taken to reinforce forest institutions and modify legislation in order to provide a regulatory framework for forest harvesting.

At the same time, the conservation and rational utilization of West and Central Africa's forest resources have been under increasing international scrutiny.

The promotion of environmentally sound forest harvesting practices has encouraged many companies to embrace the concept of reduced-impact harvesting, although implementation has been limited. One of the reasons for this was the lack of guidelines on reduced impact harvesting adapted to regional and sub-regional conditions.

To fill this gap, a component of the project: «Sustainable Forest Management in African ACP Countries», conducted by the FAO Forestry Department in partnership with the European Community from 2000 to 2003, has focused on timber harvesting in tropical forests.

The result is this publication, *Regional Code of Practice for Reduced-Impact Forest Harvesting in Tropical Moist Forests of West and Central Africa*. The study is directed at forest authorities of member countries, practitioners on the ground and all partners who have joined forces to promote sustainable forest management in the region. This regional code is intended to set guidelines for the implementation of reduced-impact harvesting concepts in the region and to serve as a source of reference for member countries as they shape their own national regulations.

We hope that this code will contribute to implementing improved forest harvesting practices in the Region and will advance the cause of sustainable forest resource management.

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ACKNOWLEDGEMENTS

This publication was prepared under the *Sustainable Forest Management in African ACP Countries project* of the FAO-EC Partnership Programme. It is the fruit of collaboration involving many organizations associated with tropical forestry and forest management in Africa. After noting their convergent interests and activities in forest management in the region, FAO's Forest Products and Economics Division and ADIE agreed in 2001 to combine efforts and prepare a regional code on forest harvesting. Its conception and formulation were directed by a steering committee chaired by FAO and made up of representatives of ADIE, ATIBT, TFF and WWF (members) and of ATO, Cirad-Forêt, FORAFRI, ITTO, IUCN, USDA (advisers). Our sincerest thanks must first go, therefore, to these institutions and to their delegates who were so keen to share their expertise and enthusiasm with us.

The preliminary version of this Code was drafted by Jean Estève who set the general guidelines for the body of technical material relating to forest harvesting in the region. The chapters on wildlife management and relations with local communities were provided by ADIE (FORM). The finalization process benefited from changes decided by the drafting committee chaired by FAO and by comments and suggestions received from many guest reviewers. Henning Fath edited the text and gave the illustrations an ordered structure and a content that reflects current practices, their damaging impact and improved practices. Sinclair Gibbs translated the original French text. Ivan Grifi saw to the uniformity of illustrations and the coherence of graphic design. Joachim Lorbach of FAO's Forest Products and Economics Division coordinated all activities of the Development and Promotion of Improved Harvesting and Economic Practices component of the project.

Pilot studies of current harvesting practices were carried out in four countries of the region, with FAO recruiting national experts in most cases: Messrs Dipapoundji and Boute-Mbamba in the Central African Republic; Boundzanga, Bouta and Matingou in the Republic of Congo; and Oddom in Ghana. Their work accomplished under difficult field conditions was greatly appreciated, all the more given the usefulness of its results.

We are grateful for the support received from the services of the region's national forest authorities who helped us recruiting the experts. We should also like to thank those forest companies that cooperated with FAO and allowed us to conduct our pilot studies on their concessions.

This undertaking involved many people of different cultural and professional backgrounds. It was their shared determination to bring about improved practices and reduce the negative impact of forest harvesting that inspired them to seek consensus whenever differences arose. Our special thanks go to these people whose collaborative effort transcended all cultural and corporate boundaries.

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ATIBT
International Technical Tropical Timber Association

ATO
African Timber Organization

CEFDHAC
Conference of the Central African Tropical Moist Forest Ecosystems

CIFOR
Centre for International Forestry Research

CIRAD-Forêt
Forestry Department of the International Cooperation Centre on Agrarian Research for Development

COMIFAC
Conference of Ministers in Charge of Forests in Central Africa

CTFT
Technical Tropical Forestry Centre (previous name of CIRAD-Forêt)

FAO
Food and Agriculture Organization of the United Nations

FORAFRI
African Forests Project of the French Ministry of Foreign Affairs

GIS
Geographic Information System

GPS
Global Positioning System

ILO
International Labour Office

ITTO
International Tropical Timber Organization

IUCN
World Conservation Union

NGO
Non-governmental organization

RIL
Reduced Impact Logging

TFF
Tropical Forest Foundation

USDA
United States Department of Agriculture

PREFACE

For many countries of tropical and equatorial Africa, the harvesting of forest products in their closed tropical moist forests, especially timber, is an activity that has ecological, sociological and economic significance:

- ecological because penetration of forest areas for harvesting purposes is generally the only or the main form of forest intervention, apart from disruption by natural events;
- sociological because forest enterprises are the main source of private sector employment in the interior of these countries and help retain local populations within the provinces, thus curbing rural outmigration;
- economic because timber often ranks second as contributor to the balance of trade and exports.

Forestry activity is no longer restricted to the production of timber; there is now widespread recognition of the paramount role of forests in maintaining biodiversity, in providing non-wood products, in safeguarding cultural values, in sequestering carbon and in mitigating climate change.

This further complicates harvesting operations which now need to take the many different functions of the forest into account – operations that are already inherently complex as they are dependent on an array of factors: availability of tree stocks, terrain, climate, soil, laws and regulations, productivity and costs, availability and competence of workforce and danger of forest work. The way for forest harvesting to meet the requirements of sustainable management, to address the multi-functionality of forest land and to ensure commercial profitability is to apply methods of reduced-impact logging (RIL).

Contrary to popular belief, this concern for «soft» harvesting and minimized negative impact on the environment is not recent. Back in 1947, Gaston Grandclément was already calling for a change in the way the equatorial forest was being harvested, pointing out that the practice of selectively harvesting precious timber species without order, method or concept of sustained yield could no longer persist. The time when a logging operator worked without a pre-established plan or detailed survey and restricted his efforts to the more accessible parts of a concession had to end. The annual cut needed to be commensurate with sustained yield in the harvesting area, which called for a careful pre-harvest survey of available timber stocks. Such an inventory by the concessionaire would give the forest authorities a precise idea of the economic value of existing forest formations.

Grandclément's ideas were gradually introduced into Africa’s forests over the following 40 years, with many enterprises planning their operations in a rational manner. Then, for reasons unknown, these good practices vanished, to be replaced by «the woodcutters and landclearers».

More recently, we have heard urgent calls to put into practice «all that is known but so seldom applied« (Bruijnzeel and Critchley, 1994). Such is the aim of this Regional Code: to provide the information needed to implement forest harvesting practices that are both environmentally sensitive and economically viable.

CHAPTER 1

«Its overall purpose is to promote harvesting practices that will improve standards of utilization, reduce environmental impacts, help ensure that forests are sustained for future generations and improve the economic and social contributions of forestry as a component of sustainable development.» (FAO Model Code of Forest Harvesting Practice, 1996).

INTRODUCTION

INTRODUCTION

1.1 PURPOSE

This model Regional Code of Practice for Reduced-Impact Forest Harvesting is intended primarily to serve as a reference document for tropical African countries engaged in or aspiring to the sustainable management of their closed moist forests. It seeks to provide a range of standards, guidelines and rules that will help public- and private-sector foresters to adopt appropriate practices. Its aim is thus to function as:

- an interim working paper that can be easily amended or adapted to specific country conditions until respective national codes have been drafted;
- an effective instrument for the implementation of sustainable management of closed moist forests;
- a compendium of guidelines that will facilitate forest activities compatible with international directives and principles, regional criteria and indicators, and procedures of certification;
- a series of guidelines that will help conserve biological diversity, forest regeneration and wildlife protection;
- a tool for promoting enhanced productivity, sustainability and economic viability of forest harvesting;
- a tool for promoting improved living conditions and safety of the workforce;
- a tool for promoting improved relations between logging companies and local communities.

The Code concentrates more on «what needs to be done» than on «how this needs to be done», and will not be directly applicable to all situations and all countries, given their number and variety. The guidelines presented will therefore need to be adapted to individual situations, but the Code does nevertheless lay down important general principles for environmentally sound forest harvesting.

It is not designed as a source of reference on forestry techniques as such, nor as a manual on the use of harvesting tools and equipment.

1.2 APPROACH

This Code draws upon the FAO Model Code of Forest Harvesting Practice of 1996 and is driven by the fundamental principle «that it is possible to conduct forest harvesting operations in ways that are consistent with the needs of sustainability» (FAO, 1996) and that significantly reduce negative impact.

«A necessary condition for the sustainable management of forests is that utilization, and the activities associated with it, must not compromise the potential of forests to regenerate properly and to provide products and services that are essential for the well-being of both current and future generations. This condition can be met by following good harvesting practices, although doing so may not be easy» (FAO, 1996).

Compliance with this fundamental principle requires:

- comprehensive, accurate and detailed planning of harvest-related operations;
- effective conduct, control and monitoring of harvesting operations by experienced personnel;
- post-harvest assessment to identify necessary improvements in methods and techniques;
- a trained, competent and motivated workforce;
- the personal commitment of all company employees.

This document will examine each of these conditions in detail in order to enable readers to find solutions to their specific constraints.

1.3 SCOPE

As its name suggests, the Regional Code of Practice for Reduced-Impact Forest Harvesting in Tropical Moist Forests of West and Central Africa focuses primarily on:

- the African «region» in a broad sense, encompassing the tropical countries of West and Central Africa and their specific characteristics;
- timber harvesting because of its potential damage to the environment. Some guidelines on silviculture and wildlife protection are also included;
- closed natural production moist forests, although some of the guidelines also apply to protection and plantation forests.

1.4 ROLE OF PARTNERS

Each of the main actors of sustainable management and reduced-impact harvesting has specific responsibilities and functions. Their concerted involvement is central to the successful application of the Code.

Government and forest administration

- Formulate forest policy, legislation and regulation; provide education and training; furnish appropriate number of competent supervisory staff, thus providing for the sustainable management and use of forest resources for the benefit of the entire national community;
- help small forest enterprises and local communities implement sustainable forest management and RIL at their respective levels;
- evaluate and approve management and operational plans;
- supervise and monitor in the field the effective implementation of regulations, contract terms and plans, together with training activities;
- Ensure that all operators are treated equally and penalize any failure to observe legal and regulatory obligations.

Logging companies

- Prepare and draw up annual operational harvesting plans in accordance with the guidelines of the management plan and RIL;
- minimize impact on the environment and residual stand by applying RIL practices;
- supervise and assess conformity of harvesting activities with guidelines;
- optimize harvesting and thus reduce pressure on the forest and the annual felling area (by using more commercial species and increasing recovery level at harvesting and processing);
- train or facilitate the ongoing training of the workforce in RIL techniques;
- improve safety at work.

Local communities

- Participate actively in raising the awareness and understanding of local populations of the sustainable management of natural resources, with a special focus on the younger members of the community;
- distribute equitably forest resources and benefits derived from their utilization;
- respect legislation and regulations related to hunting;
- use forest products sustainably, in particular non-wood forest products and wildlife;
- use community forests sustainably in accordance with management plans and RIL guidelines;
- limit slash-and-burn cultivation.

Non-governmental organizations

- Sensitize actors and local communities to sustainable resource management, RIL guidelines and the promotion of this Code, and provide or assist in related training;
- help local communities draw up and implement plans for the use and management of community forests;
- finance and conduct pilot activities or field research on the improvement of harvesting techniques that are compatible with sustainable forest management.

Training and research institutes

- Conduct research and projects aimed at improving RIL techniques and tools;
- conduct research and projects aimed at facilitating implementation of RIL;
- train or help train all actors and sensitize them to sustainable management and RIL;
- participate in the improvement, promotion and dissemination of standards, criteria and indicators related to sustainable management and RIL.

Donors

- Sensitize governments and assist them in adopting a forest policy and code that facilitate sustainable management and RIL;
- help logging companies finance sustainable practices, especially proper management planning and RIL;
- subsidize or encourage the subsidization of activities for the protection of biodiversity and wildlife not under the moral or financial responsibility of the logging companies;
- finance or help finance training and research institutes.

1.5 DESIGN AND STRUCTURE OF THE CODE

The Regional Code is tailored after the FAO Model Code of Forest Harvesting Practice to the specific characteristics and conditions of the closed tropical moist forests of Africa. The latter is therefore a primary source of reflection and reference. It also draws widely upon a variety of publications, including (in random order) the RIL Guidelines and Code of Logging Practice of Vanuatu (Forest Service Vanuatu, 1998), the Code of Practice for Forest Harvesting in Asia-Pacific (FCAP, 1999), and the Practical Management Plan for Natural African Production Forests (ATIBT, 2001).

The Regional Code also takes into account the results of field-driven initiatives, case studies and trials conducted in West and Central Africa.

The Code comprises 13 chapters:

The first chapter – the introduction – states the objectives, approach and scope of the document, outlines the respective roles of the different actors in forest harvesting, explains how the contents are thematically structured, and describes the impact of forest harvesting in a regional context.

The second recalls the overriding principles of sustainable management of production forests, the various functions of the forest, the criteria for its sustainability, the international context surrounding it and the manner in which sustainable management translates into short-, medium- and long-term management planning.

The following two chapters deal with the preparation of harvesting activities (pre-harvest planning, including planning of non-harvest areas), and planning and construction of roads, drainage structures and watercourse crossings.

The fifth chapter deals with the actual harvesting operations: felling, topping, skidding, cross-cutting, loading and transport.

The sixth looks at post-harvest activities aimed at mitigating damage caused to skid trails, roads and watercourses, and at preventing subsequent deterioration.

The following chapter looks at conditions for managing wildlife on and around logging concessions.

Then several chapters provide guidelines on the planning and hygiene of logging camps, the servicing and repair of equipment, workforce qualification and training, and safety measures.

The document also features an important chapter on the principles of control, monitoring and evaluation of harvesting, which serve to examine the extent to which planning and RIL guidelines have been observed during operations.

Finally the Code identifies relations between forest harvesting and local communities, before concluding with a glossary, bibliography and source list.

1.6 IMPACT OF HARVESTING IN A REGIONAL CONTEXT

Like any industrial activity, forest harvesting impacts on the natural and social environment. The creation of infrastructure, felling and the penetration of machinery all damage the forest to varying degrees, depending on intensity and practice. Intercontinental comparison (cf. Table 1) suggests that the low intensity of highly selective harvesting in Africa causes minimal damage. However, inappropriate practices – still fairly widespread because of lack of know-how, regulation and control – can be most detrimental to the well-being of the workforce and local population, to environmental sustainability (forest structure, remaining stand and soil) and to efficiency.

	Africa	America	S-E Asia
No. of stems extracted/ha	1-3	2-5	6-20
Commercial volume extracted (m^3/ha)	5-30	10-50	50-150
Damaged stand (%)	10-15	25-40	50-60

Table 1. Estimated average impact of harvesting on stands

Table 2 presents selected results from a pilot study in Gabon which shows that specific impacts can reach alarming proportions, even with moderate absolute values.

Damage to stand – felling and extraction	Volume of trees (number of trees)
Number of trees felled	2.75 trees/ha
Volume of timber removed	18 m^3/ha
Volume of timber extracted	10 m^3/ha
Damage per hectare	13 m^3 (5.5)
Damage per felled tree	5 m^3 (2.0)
Damage per m^3 wood in boles	0.70 m^3
Damage per m^3 of wood in logs	1.30 m^3

Table 2. Damage to stands caused by felling and extraction

1.6.1 Potentially damaging practices

Hyperselective harvesting («skimming»)

Premium grade roundwood of the most sought-after species is transported over very large distances, generating costs only rendered viable by the high prices paid on the international market. In contrast, species and grades that are not exportable, but nevertheless with commercial value, are usually left in place. The sawing of lower quality logs produces a very high proportion of discarded wood, as production costs can only be offset by exporting premium quality sawnwood. If there is no local processing plant, then only premium species are felled and only one quality trunk recovered from each tree, to be further cut during conversion.

Such hyperselective harvesting of a handful of species (Karsenty, 2002) can jeopardize the sustainability of polycyclic systems. The extraction of a lower volume of timber than planned, means that new harvest areas are constantly sought and higher market demand for new species induces foresters to repeatedly re-enter already harvested blocks without regard to felling cycle. In terms of cubic metre of recovered timber, skimming affects a large surface area and incurs high costs for road construction, extraction infrastructure and production operations. In many countries of the region excessive cutting cycles have already degraded forest structure and impoverished biodiversity.

The pressure that this practice applies to the region's forest resources justifies demanding that operators intensify (within the limits of cutting potential) and diversify their initial harvesting in order to curb frequent re-entry, and apply the reduced-impact harvesting practices that are set out in this Code.

Failure to implement the harvesting plan on the ground

The forest industry is increasingly integrating surveying (harvest layout, tree inventory and marking) into its planning system in order to record trees to be harvested and those to be protected and to establish a spatial structure facilitating extraction. However, specifications are not fully applied in the field, either because not properly conveyed to felling and extraction crews or because the workforce has not been correctly trained in RIL practices. Field crews need to be given explanatory maps and clear instructions to ensure safe, careful and efficient harvesting practices, if disparity between operational planning and actual delivery is to be removed.

Inadequacies in road planning and construction

Forest roads sometimes cross rugged terrain, where earthcut, earthfill and culvert works take up too much space and are not sufficiently stabilized. Steep roads are sometimes without drains or culverts to evacuate rainwater, causing rapid erosion of roadway that can only be remedied by costly repair.

Forest roads on clayey soil are amply cleared for sunlight exposure and, although this considerably reduces the time needed for the road to dry off and become useable, the cleared width could often be narrowed by installing more and better drainage structures.

The construction of low density road networks usually results in skidding over long distances along trails resembling secondary roads not designed or built to meet adequate technical standards with respect to their accessibility. The planning and building these roads in advance should be a prerequisite for reduced-impact harvesting in order to provide an effective spatial configuration that can be maintained throughout operations.

Uncontrolled felling and wasteful topping and butt trimming

Even companies that apply RIL principles when planning their operations have not yet transmitted these principles to their felling crews. This often results in uncontrolled felling with no undercut or backcut, and the inefficient timber recovery during topping and butt trimming. Trees fall in the wrong direction, rendering pre-felling preparations worthless and obstructing extraction as marked trails are partly blocked by felled trees. The resulting damage to the felled tree, remaining stand and soil is considerable and timber recovery relatively low.

Excessive crawler pre-skidding and skidding

Crawler tractor operators often fail to understand that their role is to help the extraction process. Instead they operate in a forest area as though there were no forest, opening trails that wheeled tractors could just as easily open and not only extracting trunks by levelling a whole vicinity but then proceeding to haul them all the way to the landing, causing serious damage to remaining stand and soil.

Sometimes pre-cleared skid trails no longer provide access, as trees have fallen in the wrong direction. Crawler operators then open new trails which, coupled with to the pre-marked network, affect an excessive surface area and undermine the efficiency of extraction.

Wasteful conversion at the landing

Trunks are converted into logs at landings, then numbered and recorded. Depending on company or purchaser requirements, the butt of a trunk with buttresses is often removed, leading to high loss of timber and serious implications for timber recovery.

Landings are often located near watercourses or on steep terrain, causing serious erosion and watercourse sedimentation. These negative consequences are compounded when debris from landings is cleared towards the earthfill slope.

Lack of monitoring, control and impact assessment

Harvest planning systems, which are being applied by an increasing number of companies, provide the wherewithal to track timber flow throughout production, from felling to landing. Overlooked trees or stems are spotted and lost or damaged trunks are noted, which provides comprehensive feedback on harvesting efficiency in terms of timber recovery. However, few companies regularly evaluate the efficiency of their extraction process or the damage caused by felling and extraction in terms of cleared surface area and harm to remaining stand and soil.

1.6.2 Environmental and social impacts

The following structural/environmental and social indicators are used to measure and assess impacts:

Impact criteria (and subjects)		
Sustainability (structure, remaining stand, soil)	**Well-being (workforce)**	**Well-being (communities)**
Area cleared for roads, trails and landings	Remuneration	Unsustainable secondary uses
Number of trees and extracted volume Canopy opening	Training and instruction	Synergy/conflict with subsistence or remunerative activities
Timber recovery	Safety Lodging	
Damage to remaining stand and soil	Nutrition and transport	

Table 3. Matrix of impact indicators

Structural and environmental impacts

Whatever methods and machinery are used, harvesting operations will inevitably affect the forest structure and disrupt its vegetation and soil: total deforestation to clear for roads, landings and logging camps, and disruption during felling and extraction according to number of trees felled and practices employed.

The following informative figures regarding surface area affected by harvesting, are derived from five pilot studies in the region:

	Rep. of Congo 1997	**Rep. of Congo 2003**	**Cameroon**	**Gabon**	**Central African Republic**
Volume extracted (m^3/ha)	**6**	**7**	**5**	**10**	**50**
Road network	1.7	4.0*	1.5	1.6	2.0
Landings	0.2	0.1	0.3	-	1.5
Skid trails	2.7	-	3.1	6.8	7.4
Canopy opening	3.8	0.6	2.0	9.5	13.0
TOTAL	**8.4 %**	**4.7 %**	**6.9 %**	**17.9 %**	**23.9 %**

* Including skid trails.

Table 4. Surface area affected by infrastructure and harvesting as percentage of worksite or cutting unit area

By way of comparison, the area affected in Guyana and Brazil for extraction of 10 stems/ha was 32 and 35 percent respectively (Karsenty et

Maître, 1994). This incremental damage to the stand has led many foresters to call for a limitation of harvest intensity as a prerequisite for sustainable management.

Stand damage concerns in particular small trees with a DBH of 10 to 20 cm, which have the highest mortality. Damage during felling is from crown breakage for larger trees and general debranching for smaller trees. The damage is proportionate to the number of trees felled, the size of their crowns and the felling methods used.

Extraction causes injury to trunks and roots of large stems but does not generally uproot small trees. On the other hand, it can seriously affect the structure of the forest cover, depending on the method of extraction used.

Major soil damage caused by repeated passage of machinery takes the form of compaction, rutting and scalping with the removal of topsoil. The direct consequences are erosion and leaching from rainwater, and more or less complete and rapid sterilization which slows or prevents forest regeneration.

Impact on the retention and absorption of water

Much rainfall hits the canopy before reaching the soil and filtering through the forest litter. Forest harvesting however creates openings which allow more water to reach the soil since less will be intercepted by the canopy. This results in higher soil moisture levels in forest clearings despite higher ground temperature and evaporation (Bruinjzeel and Critchley, 1994). This is not a major problem if soil absorption capacity is retained, but where the forest litter has been removed or the soil compacted by the construction and use of skid trails and landings, the absorption capacity becomes insufficient, triggering runoff, erosion and leaching. Flat sandy terrain is clearly less vulnerable than steep clayey terrain.

Impact on erosion and sedimentation

Surface erosion in an untouched forest, protected by litter and root cover, has one of the lowest levels for tropical soils, but erosion and sedimentation increase after forest harvesting (Bruinjzeel and Critchley, 1994). As rain splashes onto exposed soil, particles become detached and displaced, especially on steep, compact ground, and can cause significant build-up of sediment that obstructs natural or man-made waterflow.

At the same time, erosion rills form along roadways and side drains when erosion and speed of runoff reach a certain level. These can then widen and deepen into full-fledged gullies, especially on sandy soils, along skid trails, on poorly drained spur roads or on approaches to bridges where the erodible subsurface has been exposed by earthworks. Too high a sediment load can also change the composition of a river's fish population, impacting on the food supply of local populations (Bruinjzeel and Critchley, 1994).

Impact on wildlife

Forest harvesting can also impact on wildlife:

- increased pressure on local wildlife, either directly because of the increase in population associated with the logging camp or forest industry, or indirectly because easier access to forest land and transportation encourage commercial hunting and/or poaching;
- disruption and sometimes fragmentation of wildlife populations with roads acting as barriers to the movement of small game;
- loss or deterioration of habitat because of changes in habitat and food supply.

Improvements from RIL

Few large-scale studies seem to have been conducted to provide an accurate assessment of the positive impact of RIL and existing documented data are generally incomplete. However, an example from Sarawak (thus under different conditions to those of Africa) relating to the harvesting of 25 to 50 m^3/ha provides a more comprehensive picture of improvements that can be attributed to RIL.

Impact indicators	**Impact reduction from RIL**
Density of skid trail	- 57 %
Length of trail per m^3 harvested	- 20 %
Average gradient of trail	- 16 %
Soil area exposed	- 49 %
Area affected	- 38 %
Trees damaged	- 29 %

Table 5. Improvements from RIL

Social impact

The forests of West and Central Africa shelter populations of different cultures who depend directly on them for their food resources, construction materials and medicinal products. They also play an important spiritual function and role in cultural identity. Their harvesting is of direct concern to company workers and the inhabitants of villages in and near the harvesting area.

Most causes of forest destruction are social in origin, the prime culprit probably being poverty. If the objective of sustainable forest management is to be achieved, forest use needs to benefit not only the harvesting company and the State as owner, but also the company workers and local communities.

Personnel

Efficient and sustainable production requires well planned and well organized interaction between company personnel at all levels. The workforce represents the frontline for the implementation of reduced-impact practices and thus needs to be properly instructed, trained and paid to achieve the objectives of sustainable harvesting. However, this is not always the case. Workers are often poorly qualified to carry out their assigned duties, insufficiently paid, trained or motivated to work effectively, with obvious repercussions on the quality and safety of their work. In many cases they are also not provided with adequate housing. As a result, the work is not done carefully, safely and efficiently. Managers, supervisors and workers need to share the same objectives if production is to benefit all partners equitably. The concessionaire holds primary responsibility for providing the working conditions needed for applying reduced-impact harvesting practices.

Local communities

At present, local communities have no or few rights of ownership over the forest on which they depend. Harvesting activities very often fail to take their interests into account, for example the use of forest products around their villages or in areas where the forest has traditionally been used for nutritional, cultural or religious purposes. The local population is very often sidelined from forest management. An innovative approach is therefore needed to ensure that the fruits and efforts of forest management are shared by all stakeholders, with particular importance attached to dialogue between forester and local community.


Tunisia
Morocco
Algeria
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Eritrea
Djibouti
The Gambia
Senegal
Guinea Bissau
Guinea
Burkina Faso
Nigeria
Ethiopia
Somalia
Côte d'Ivoire
Central African Republic
Cameroon
Sierra Leone
Liberia
Uganda
Kenya
Benin
Togo
Gabon
Congo (DRC)
Rwanda
Burundi
Ghana
Equatorial Guinea
Tanzania
Malawi
Seychelles
Congo
Angola
Zambia
Madagascar
Zimbabwe
Namibia
Mozambique
Mauritius
Bostwana
Swaziland
South Africa
Lesotho

CHAPTER 2

«Far too many harvesting operations are carried out without the benefit of any kind of formal, written plan. Such operations are difficult to coordinate, impossible to control adequately and in their effects often more closely resemble mining operations than harvesting operations designed for the sustainable utilization of forest products.» (FAO Model Code of Forest Harvesting Practice, 1996).

SUSTAINABLE MANAGEMENT OF PRODUCTION FORESTS

SUSTAINABLE MANAGEMENT OF PRODUCTION FORESTS

2.1 FORESTS AND THEIR MULTIPLE FUNCTIONS

Forests perform a number of functions that are important to our planet and to the survival of human communities and of many other organisms whose continued existence is in our interest. These functions are essentially ecological, socio-economic and socio-cultural.

Ecological functions

The forest environment has multiple attributes by virtue of its biodiversity:

- living environment for humans and the complex of animal and plant species;
- reservoir of genetic information;
- producer of biomass, fuel and minerals;
- regulator and stabilizer of the biosphere.

The need to conserve biodiversity and its attributes means that forest harvesting should not significantly change the different ecosystems encountered. Measures need to be taken to conserve and protect threatened species. Hunting and the extraction of forest products need to comply with legislation and international agreements.

Socio-economic functions

The continuity of a forest's socio-economic functions can be assured if it maintains its wood and non-wood product potential and if the scale of utilization is thus strictly adapted to sustainable yield and regeneration capacity. Damage to the remaining stand and future crop trees must be kept to a minimum.

Another important key to success is involving local communities in the sustainable management process and in decision-making. They need to have a share in the revenue, to retain their land tenure rights and to see an improvement in their living conditions.

Socio-cultural functions

The socio-cultural functions of the forest need to be maintained, particularly those associated with the cultural identity of local populations (e.g. sacred or initiation trees, forests or sites). The negative consequences of forest harvesting need to be limited and mitigated by applying reduced-impact harvesting practices.

2.2 INTERNATIONAL CONTEXT

Reduced-impact harvesting is integral to sustainable forest management. It is in fact a vital element as forest harvesting can have many negative consequences that partly affect forest regeneration and thus the potential volume of subsequent cutting cycles.

Furthermore, harvesting operations are activities which can be controlled most directly and easily by logging companies striving for sustainable management. We should perhaps briefly recall the context of international reflection that led to the concept of sustainable forest management which can be defined as «the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment» (ITTO, 1992).

Back in 1990, the ITTO published its guidelines for the sustainable management of natural tropical forests, some relating directly to felling operations, access roads, extraction and the post-harvest management of forest stands.

However, the concept of sustainable forest management was formally enshrined at the Conference of Rio, in June 1992, where this form of management emerged as an attractive way of reconciling forest development to meet socio-economic needs and conservation to protect forest resources as well as the rights of future generations.

The main forest-related outcomes of the Earth Summit of Rio were cast into the non-legally binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests (the «Forest Principles») with clear references to the concepts of sustainable management and RIL.

Among the 40 chapters of Agenda 21, the operational platform dealing with the various spheres of environment and development, Chapter XI «Combating deforestation» lists four programme areas:

- sustaining the multiple roles and functions of all types of forest, forest land and woodland;
- enhancing the protection, sustainable management and conservation of all forests, and the greening of degraded areas, through rehabilitation, afforestation, reforestation and other rehabilitative means;
- promoting efficient utilization and assessment to recover the full value of goods and services provided by forests, forest lands and woodlands;
- establishing and/or strengthening capacities for the planning, assessment and systematic observation of forests and related programmes, projects and activities, including commercial trade and processes.

The Agenda's key proposals include the political will to associate local populations more closely in forest management, the importance given to management tools (databanks, inventories), the important multiple roles and functions of forests, the promotion of cross-sectoral approaches and capacity building.

The United Nations Framework Convention on Climate Change aimed at stabilizing greenhouse gases at a level that will not disrupt the global climate.

Forests are explicitly referred to on two occasions:

- with regard to the conservation of sinks and reservoirs of greenhouse gases; and
- with regard to specific aid to developing countries with forested areas and areas liable to forest depletion.

The United Nations Framework Convention on Biological Diversity.

This Convention is aimed at drawing up strategies and plans of action for the conservation and utilization of biological diversity and the integration of these objectives into sectoral policy. Forests are never actually cited as such.

The United Nations Convention to Combat Desertification in countries seriously affected by drought and/or desertification.

All the African countries targeted by this Regional Code have signed and ratified these three Conventions and have turned to the Rio Summit when updating or reworking their recent or ongoing national forest policy and legislation.

At the regional level, countries with forest sectors have worked towards the sustainable management of production forests and the certification of timber by defining a package of management principles, criteria, indicators and benchmarks, within the framework of the African Timber Organization (ATO).

This package is the culmination of a series of tests conducted from 1995 to 1998 with CIFOR in West Africa (Côte d'Ivoire) and Central Africa (Cameroon, Central African Republic and Gabon). Comprising 4 principles, 15 criteria and 51 indicators (PCIs), this package was endorsed in October 2000 at an ordinary ministerial conference of the 14 ATO member countries in Brazzaville. Four principles and 10 criteria relate more specifically to RIL.

The ATO has also urged its member countries to set up national working parties to explore management and certification at national level and to come up with proposals for a more specific and appropriate set of principles, criteria and indicators. These efforts have so far culminated in a set of PCIs issued jointly by ATO and ITTO for the sustainable forest management of African natural tropical forests, both at the national and the forest-management-unit level, a harmonized document which refines the ATO's PCIs and makes them consistent with the ITTO's criteria and indicators (ATO & ITTO, 2003).

Actions by the Conference of Central African Moist Forest Ecosystems (CEFDHAC) or Brazzaville Process and by the Conference of Ministers in Charge of Forests in Central Africa (COMIFAC) have reflected the overall objective of getting Central African countries to manage their forest ecosystems sustainably, by sharing the same vision to achieve coherence of forest policy and legislation as well as management principles, instruments and practices.

2.3 PLANNING SUSTAINABLE MANAGEMENT AND FOREST HARVESTING

The Annual Programme or Plan of Operations, also referred to as the Annual Coupe, is the last and most immediate level (1-2 years) of operational planning in the sustainable management of a forest area or concession.

This is the phase that involves the planning, design and implementation of all RIL harvesting activities. However, this plan and its operations can only be successful if the sustainable management of the forest area has been rationally pre-determined by the concession holder or logging company, eschewing a predatory approach and opting for entrepreneurial behaviour that is more respectful of the ecosystem and of the social and economic environment of the forest.

After all, the key objective of managing production forests is to secure a balanced, regular and sustainable harvest of forest products by deploying reduced-impact practices that are well-planned and prepared within a permanent forest area, while at the same time ensuring maximum conservation of forest resources and safeguarding their social and ecological functions.

Furthermore forest management should:

- provide social, technical and financial benefits to all actors and should therefore be agreed to by all stakeholders: forest owner, logging company and local communities;
- help decision-making by shaping practical, realistic and feasible programmes of action;
- take into account the multi-functionality of forests.

Forest utilization should also respond to:

- national legal and regulatory obligations;
- the ecological constraints of sustainable ecosystem management, notably the optimal protection and conservation of diversity of flora and fauna;
- the socio-economic requirements of the areas concerned;
- the constraints of commercial profitability in the context of international trade.

At company level, forest utilization should ensure the continuity of forest resources and sustained supply of raw material, and should enable a company's internal and external strategy and management to shift gradually from a short-term to a long-term perspective.

However, given existing political, social and economic conditions in forest-rich countries of Africa and our limited understanding of the dynamics of tropical ecosystems, the design and application of forest utilization can only be guided initially by simple, but realistic, principles and rules.

Finally, while planning is normally the prerogative of forest owners, many countries have opted to delegate some or this entire task to the concession holders, thereby granting them virtually full responsibility for the proper or improper management of production forests.

Detailed management planning produces three documents of differing duration and strategic importance, whose general characteristics are given in Table 6:

- the strategic management plan: the long-term document covering 20-40 years and reviewable every 5-10 years, where decisions adopted by the public authorities and the logging company will shape the forest policy of these two principal actors.
- the tactical management plan: the medium-term document covering successive 5-7 year periods, with indications for the utilization of concessions subdivided into management units;
- the annual plan of operation or coupe through which the management plan is programmed, implemented and monitored annually. This is the tool for the everyday management of harvesting, with all interventions recorded in the forest register

2.3.1 Strategic (long-term) management plan

The plan begins by describing the forest area and gives an outline of the logging company and its human and technical resources. It then covers the following main stages:

Examination of the forest and its socio-economic environment

The first section deals with the natural setting, topography, hydrography, climate, forest and other formations which are examined using existing maps and documents.

Analysis of the socio-economic environment is

STRATEGIC MANAGEMENT PLAN Long term > 15 years
• formulation of the strategy of sustainable management of forest area • global and thematic mapping at 1:200 000, 1:50 000 and/or 1:20 000 • analysis of the forest and its socio -economic environment • quantitative and qualitative assessment of forest resources and wildlife • management decisions: - determining the harvesting cycle - minimum diameters for harvesting and management - sustainable yield and annual allowable cut
TACTICAL MANAGEMENT PLAN Medium term: 5 to 7 years
• mapping at 1:50 000, 1:20 000 and /or 1:10 000 • delimitation and demarcation of boundaries • establishing harvesting areas: sectioning into management units and annual cutting blocks • pre-determination of harvest activities in space and time • establishing modalities for survey methods and harvesting (equipment and workforce) • harvesting programme: characteristics of units and blocks, strata sizes • planning of primary road network
OPERATIONAL PLAN Short term: 1 year
• planning of harvesting operations at the level of the annual allowable cut • harvesting map at 1:10 000 or 1:5 000 • complete harvest inventory • identification and marking of trees • layout of secondary forest roads, skid trails and landings • training of staff, worker safety • monitoring, control and evaluation of harvesting

Table 6. Planning documents.

central to the management plan, as it will identify opportunities and constraints for company integration into the existing socio-economic context. Appraisal of expectations for education, health, and better living conditions will provide an analytical socio-economic profile that will be useful for directing actions to involve local communities into a collaborative management strategy and to facilitate social consultation and negotiation over land tenure and planned social structures.

The analysis should also look at employment opportunities for villagers and young qualified workers and enhance their skills through further training. The final part looks at the present state of the forest and examines previous interventions that might have modified the forest environment or in some way affected its evolution.

Identifying the resource

Two key chapters deal with mapping, photo-interpretation and forest stratification.

Mapping is generally conducted on three levels:

- an overall view of the forest stand and its general characteristics, where a scale of 1:200 000 is usually required. This work draws on existing documents, base maps at this scale, satellite imagery and radar images;
- a forest and topographical stratification of the area using aerial photographs, base maps and thematic maps, with a working scale of 1:50 000 or even 1:20 000 for aerial photographs;
- contour maps of 1:50 000 as the basic work tool for concession managers. These can be enlarged to 1:5 000 or 1:10 000 for a closer look at the terrain and can be supplemented with further details (rock outcrops, impenetrable wetlands, cliffs) coming to light during the harvest survey.

Mapping prior to ground work is based on remote sensing in the form of aerial photographs and satellite and radar images, which make it possible to:

- map or update the mapping of the land cover;
- accurately delimit the forest area to be surveyed;
- stratify the forest area by major type of stand and natural formation. The description of strata is based on straightforward criteria used to identify and delimit main types of terrain (firm soil, floodland, marshland or steep slopes) and forest cover (type and density of plant cover).

The stratification process will also detect and map topographical conditions relevant to the planning of infrastructure, especially roads:

- unharvestable areas – limits have to be set regarding slope, frequency of rock, type of soil, above which an area becomes unharvestable;
- wetlands and flood-prone areas;
- obligatory or impossible points of passage (e.g. cliffs, deep valley lines).

Mapping and stratification will have to be based on all available documents. Existing conventional aerial coverage at 1:50 000, or better 1:20 000, is strongly recommended as stereoscopic interpretation is still the only way of gaining a precise picture of the terrain.

Aerial coverage can often be supplemented or replaced by SPOT or LANDSAT satellite images. Maps at 1:50 000 should be used for drawing up the survey sampling plan but such coverage is by no means comprehensive, so 1:200 000 maps will sometimes have to be enlarged.

Management inventory

The general inventory of the forest area – the management inventory – is the central management tool as it provides basic data to determine the general framework for the management of a concession, indicating immediately harvestable timber potential and medium-term crop tree potential. The purposes of this inventory can be summarized as follows:

- to refine the stratification obtained from remote sensing;
- to locate and quantify stand types in order design appropriate patterns of silvicultural treatment, to schedule the advance of cutting cycles over space and time and to calculate work volumes;
- to provide an accurate quantitative and qualitative estimate of first-rotation harvests per species and to make projections for second and third cutting cycles.

The management inventory, focusing on harvestable areas only (i.e. within production zones), will be a statistical survey based on systematic sampling at one degree. Sample plots are laid out contiguously along parallel sampling alignments with maximum intervals of 2 to 2.5 km for a generally accepted average sampling ratio of 1 percent. This may in fact vary between 0.5 and 1.5 percent, depending on the level of accuracy required and uniformity of forest area.

For estimating the number and volume of harvestable and potential crop trees of the species currently identified as merchantable with sufficient statistical reliability, this sampling method requires a relative error of not more than 15 percent. Counting is done in 10cm diameter classes of all trees of identifiable species with a diameter of more than 20 cm.

Although requiring additional expenditure, it is most advisable to seize the opportunity of plot sampling and forest inventory on the ground to compile ecological and/or wildlife inventories and if possible, to conduct the field surveys at the same time.

The inventory report should provide:

- a set of maps and tables collating all available information on the entire forest area to facilitate the demarcation of series and management units during the conception of the management plan;
- a set of more concise tables on available commercial volume, its spatial distribution and its accessibility, which will later form the basis for harvest planning and scheduling of the cutting cycle.

Long-term management decisions and proposals

The inventory concludes the field work needed to formulate decisions on resource utilization and proposed management strategy. Examination of all factors influencing the regenerative capacity of forest and tree species after harvesting:

- average annual growth in tree diameter;
- natural mortality rate of tree species, and
- potential damage from felling and skidding, will help calculate the interval required between two cutting cycles, i.e. the rotation.

The pattern of diameter distribution and the growth and mortality of the main commercial species will indicate their minimum management diameter (MMD). Subsequently, the rotation period and MMDs will serve to calculate the overall sustainable yield from the forest and the annual allowable cut.

2.3.2 Tactical (medium-term) management plan

The tactical management plan expresses the strategic management plan at the medium-term level. It restates the main objectives of forest utilization, describes its stratification and summarizes the inventory results.

The main chapter reports the management prescriptions:

- rotation period, annual allowable cut and diameter limits;
- location, area and map of management series: production, protection, agriculture, etc.;
- establishment of concession plan, i.e. dividing the production cycle into management units, then into annual harvest blocks or coupes.

This division can be done:

- either by dividing the total harvestable area by the rotation, which produces annual coupes of equal size (rotation by area) but sometimes very unequal volume;
- or by dividing the total commercial volume by the rotation, giving similar harvest volumes (rotation by volume) but coupes of variable size.

A combination of the two is often applied. The harvestable area is first divided into management units with equal volumes corresponding to 5-7 years of harvesting and are therefore of unequal size. Each of these units is then divided into annual coupes of equal size.

Other ways of dividing and organizing the concession can be imposed by the authorities.

The harvesting cycle is the sequence of harvesting in space and time for both management units and annual coupes. The harvesting of a new block – generally for a period of two years – cannot be initiated before closure of the previous coupe, and any return for harvesting (re-entry) is forbidden until the following rotation.

Management rules mainly concern concession boundaries, harvesting and harvest survey modalities:

- delimitation of concession perimeter: the ground-marking of concession boundaries with clear demarcation points and the clearing of boundary lines or their marking with paint;
- definition of harvesting rules: prescribed practices and equipment, constraints (slope, rainfall, etc.), safety regulations;
- planning and training of workforce.

Harvest survey modalities

Although the two main methods of conducting harvest surveys are explained in Chapter 3, the general characteristics and purpose of such survey are described below.

The survey will indicate the number, quality and location of harvestable and potential crop trees of all commercial species, starting from a minimum diameter, in addition to type of soil and availability of road-improving materials. It will also provide a detailed topographic survey of the terrain. This is the only way of:

- truly gauging harvestable volumes by species and quality, and pinpointing their location with sufficient accuracy to harvest them without loss – thus significantly increasing the extracted volume per hectare and reducing the land area to be harvested;
- organizing, planning, rationalizing and optimizing the coordination of harvest activities;
- optimizing the layout of secondary roads, skid trails and landings;
- reducing harvesting damage to the environment;
- significantly raising productivity and thus reducing production costs.

The last part of the management plan looks at the harvesting programme and describes the management units and harvesting blocks: limits, area and strata characteristics, harvestable species and volumes by quality and diameter class, harvesting period and mapping.

2.3.3 Annual plan of operation or coupe

The planning of operations on the area authorized for harvesting in one year (annual harvesting block) focuses mainly on:

- conducting the harvest survey and evaluating results relevant for operational planning;
- spotting and marking (by tape or paint) harvestable trees, future crop trees, seed trees and trees of special importance (heritage trees);
- pinpointing, from 1:5 000 or 1:10 000 scale maps, harvestable trees, identifying micro-topographical features and constraints of terrain, and laying out secondary roads, skid trails and landings;
- designing training programmes, arranging the purchase and maintenance of equipment and machinery, and prescribing safety regulations;
- conducting internal monitoring, control and assessment of harvesting operations.

Applying the full array of planning tools for sustainable management will clearly be limited to large and medium-size companies holding long-term concessions. However, this should not exclude or hamper the dissemination and total or partial deployment of RIL techniques among smaller logging companies and among short-term licence or permit holders.

CHAPTER 3

«Many logging operators believe that environmental protection can only be achieved through costly measures that will drive them to the brink of bankruptcy. This is simply not true. The experience of operators who develop thorough harvest plans and then carry out the operations as specified in these plans has demonstrated clearly that these procedures not only improve operational control and reduce environmental impacts, but can also reduce costs and substantially increase profits.» (FAO Model Code of Harvesting Practice, 1996)

PRE-HARVEST PLANNING

PRE-HARVEST PLANNING

Objectives:

- to reduce harvesting damage for enhanced protection of the environment;
- to permit efficient and competitive forest harvesting;
- to plan harvesting operations on an annual level;
- to compile and analyse all biological, topographical, hydrographical and socio-economic data required for the preparation of harvesting operations.

Pre-harvest planning is an essential component of RIL. It involves annual harvest estimates based on stand potential in designated harvest areas. It follows the harvest cycle and can cover one or more harvesting blocks. The planning is normally 1 to 2 years before harvesting (Table 7) and generally produces a document on scheduled operations, actions to be taken, means to be employed and a detailed map (1:5 000 or 1:10 000) of the areas to be harvested.

2 years in advance:

- Demarcation of area to be harvested
- Annual allocation for allowable harvesting volume
- Harvest survey: volume, quality, location, detailed topography
- Delimitation and demarcation of non -harvest areas
- Harvesting map at 1:5 000 or 1:10 000
- Planning of secondary forest roads

1 year in advance:

- Survey and zoning of harvesting area; counting, recording and preliminary marking of harvestable trees

4-6 months:

- Construction of secondary roads

1-3 months:

- Tree spotting and marking
- Locating and ma rking of skid trails and landings
- Marking of trees next to skid trails and around harvestable trees

Harvesting:

- Clearing of skid trails and landings
- Felling, topping and butt trimming
- Winching and skidding
- Cross-cutting, scaling, marking and treatment of logs at roadside landings
- landings
- Transport
- Control, monitoring and post -harvest assessment

Table 7. Diagram for the planning and implementation of harvesting operations

3.1 MAPPING TOOLS

The management plan provides the operations manager with all the mapping and survey data needed to draw up detailed harvesting maps. The mapping documents vary from one country to another, but generally include:

General documents

- 1:200 000 quad maps with or without contour lines (40 m intervals);
- 1:200 000 thematic maps: hydrography, geology, pedology, morphology, vegetation;
- 1:50 000 quad maps with contour lines (20 m intervals);
- 1:50 000 LANDSAT or SPOT satellite imagery;
- 1:200 000 radar imagery;
- old and recent aerial photo coverage at a scale of 1:20 000 to 1:50 000.

Documents produced by the management plan

a) Base map: essentially a 1:50 000 topographical map with contour lines at 20 m intervals. It displays location and layout of the following elements:

- contour lines and peaks;
- river system and permanent waterbodies;
- main and secondary roads, railways, airstrips;
- towns, villages and large logging camps;
- administrative boundaries of provinces, departments and districts;
- boundaries of forest concession.

b) Map of forest strata: this 1:50 000 map should indicate the different types of plant formation, using conventional colours and codification and distinguishing in particular:

- primary forests;
- secondary forests;
- forests on steep slopes;
- riparian formations and gallery forests;
- marshland forest types;
- savannahs;
- crops and fallows.

The map is based on the interpretation of the previously mentioned documents (aerial photographs, SPOT images, radar images) and is completed with the examination of existing thematic maps.

c) Consolidated forest map: this map at 1:100 000 or 1:50 000 is obtained by generalizing the contours of the forest strata map (after any necessary aggregation) and overlaying important topographical information. A table summarizing aggregated strata areas accompanies this map. Like all cartographic databases, it can be digitally converted and fed into a Geographic Information System (GIS).

3.2 GEOGRAPHIC INFORMATION SYSTEM – A MANAGEMENT TOOL

A Geographic Information System is a computer-based system which, drawing from a variety of sources to compile, collate, process, analyse, combine, elaborate and display geographically related information, can effectively contribute to the management of landscapes and natural resources.

A GIS permits four types of activity: digital capture of geographical coordinates, navigation, thematic handling of data, spatial analysis, and establishment of maps.

Maps produced from remote-sensing, all other geo-referenced data and data from the management inventories and harvest surveys are digitized and logged into the GIS. These data can be:

- thematic maps (land cover, geological, pedological, etc.) or existing topographical maps;
- the inventory sample plot system;
- forest mensuration, flora, fauna and environment data gathered from sample plots and surveyed harvesting blocks;
- ground observations.

All information fed into and processed by the GIS enhances the utility of an inventory as it permits the integration of a variety of attributes and constraints of terrain (topography, non-accessible areas, etc.). It can also help identify representative areas for the conduct of a pre-inventory.

The field data are then also fed into the GIS and can be plotted as distribution maps for the different inventoried variables:

- distribution of species,
- volume by species, diameter class, hectare.

These distribution maps are immensely useful for determining management prescriptions. The GIS also ensures that documents are up-to-date (e.g. by integrating harvest survey results) and reflect the dynamic evolution of the forest under management. The progress of harvesting operations can be monitored and schedules forecast through the regular examination of ongoing activities.

The sophistication and complexity of GIS software and performance will depend on company requirements. It can be combined with management and logistics software in order to provide computerized operational data that will enable a company to monitor all activities relating to:

- the harvest areas and annual coupes, the road and trail network, marketing and the processing structures;
- the management of machinery, equipment and consumables;
- the workforce.

This tool gives the company an interface between financial accounting and cost accounting, enabling it to ensure that its field operations and its management are sound. Linkage between these databases and the GIS means that timber can be tracked from standing tree to point of sale or processing site, rendering forest products traceable throughout the production chain.

N.B.

With regard to the use of computer equipment (computers, GIS, database software, etc.) and advanced hardware (GPS, etc.) requiring considerable investment, it is important to note that all planning techniques required for RIL practices (compilation and analysis of inventories/surveys, planning and layout of extraction network, mapping, etc.) can also be carried out using simple conventional means (manual compilation, pocket calculator, compass, clinometer).

3.3 HARVEST SURVEY

The harvest survey, or inventory, is an intrinsic prerequisite of RIL. It has been made mandatory for concession holders by all recent forest legislation.

Objectives:
- to quantify and qualify available volumes by species, to identify trees in the annual harvesting unit and the felling block without error or loss;
- to organize and optimize the coordination of harvesting activities and the utilization of industrial production and marketing capacity and to improve control over operations;
- to optimize the layout of the secondary road network, skid trails and landings;
- to facilitate reduced-impact harvesting and thus limit damage to the environment;
- to facilitate the production of a detailed map indicating the precise location of trees to be harvested and trees to be protected, species and volumes, topographic and hydrographic details and non-harvest areas.

Because of their intrinsic diversity, tropical forests have to be comprehensively searched to identify each harvestable tree, requiring a full or 100 percent inventory coupled with geographical and topographical surveys.

The two survey methods currently employed in Africa are:
- the pocket inventory, where the harvest unit is divided into blocks and pockets of varying size demarcated by natural boundaries, normally the area between two watercourses. These natural boundaries are then connected by transects to close the pocket. This method reduces the need to clear survey lines but requires topographical maps of at least 1:50 000 and highly trained, experienced crews to avoid errors in coverage of terrain and counting of trees;
- the systematic parcelling inventory, which uses East-West and North-South transects to demarcate survey units of equal size (usually 20 to 100 ha, depending on the spacing between survey lines). More survey lines need to be cleared with this method, but unit layout is clear and without risk of error.

Before describing these two methods, we need to look briefly at criteria for identifying and recording the species to be inventoried.

3.3.1 Survey criteria

These include:

a) A list of species to be inventoried: in principle the commercial species to be harvested which are often determined by the authorities, plus other merchantable or potentially merchantable species determined by the logging companies and designated by their commercial name.

b) The status of trees and species:
- harvestable trees of targeted species with a diameter above the MMD;
- potential crop trees of the same species but with a diameter below MMD. Such trees are generally recorded as having a diameter of MMD minus 20 cm or a general diameter applicable to all species (e.g. 50 cm). Their registration is not obligatory in all countries;
- protected trees or species: rare species, outstanding trees (very big diameters exceeding 2 m) or heritage trees (nutritional, cultural, religious or other value);
- seed trees in apparent good health, with remarkable phenotype and existing in sufficient numbers to foster natural regeneration.

c) Inventory quality grades:
- Quality 1: very well shaped export trees with at least one long log;
- Quality 2: trees for export or sawnwood with limited defects and at least one log shorter than 6 m;
- Quality 3: trees destined for processing for local consumption and sale;
- Quality 4: rejected trees.

3.3.2 Description of the pocket inventory

Using a 1:50 000 scale map with contour lines, the coupe or the annual harvesting unit is structured into blocks equating to 3-4 month logging targets. This division is based on natural topographical boundaries. The blocks are then - manually or using a GIS - subdivided into pockets of 10-60 ha, depending on existing natural boundaries.

Figure 1 *Division into blocks and pockets*

Figure 2 *Survey map from pocket inventory*

A main survey line following the ridge crest(s) is identified on the map by letter and number. Its horizontal length and compass bearing are recorded on a data sheet consigned to the leader of the inventory crew. Using a GIS, the pocket boundaries and survey line are then plotted on a 1:5 000 map with contour lines. The main survey line starts from the roadside and is tentatively plotted on the basis of maximum skidding distance, harvestable timber stock, terrain characteristics and occurrence of non-harvest areas.

The main survey line, with minor ground modifications, and any necessary secondary survey lines, will constitute the skid trail layout.

Each pocket is flagged at the roadside entry of the main survey line by indicating the pocket and main survey line number on a tree. The pocket inventory is generally carried out by a crew of 9-10 people, including a crew leader, a compass surveyor, 2 slashers and 5-6 tree counters. The alignment with a maximum width of one metre is cleared by machete. The operation begins with a preliminary reconnaissance of the pocket, localizing the ridge crest and the main survey line and if necessary modifying its alignment. The compass surveyor indicates the line of direction and the slashers proceed to clear the required width. The survey line is staked every 100 metres with a picket recording its number (with paint or tape) and distance from starting point.

Tree counting is conducted in successive cruises determined by terrain and pocket layout and decided by the team leader, who makes sure the entire pocket is covered. Secondary lines divide the pocket into subpockets to facilitate counting. The tree counting crew has 5 counters and a crew leader. Each enumerator has a diameter gauge, a marker and a marking device (e.g. tape, tag or plaque).

At the start of a cruise, the team leader places himself on the main survey line from where he can control survey progress with the help of the 100-metre pickets. The counters advance in parallel at 30-metre intervals from each other, counting the trees to their right. Each counter is assigned a set of numbers in units of 100 (1 to 100, 101 to 200, etc.) at the start of each block.

For each counted tree, the enumerator calls out his name, the number he is about to give the tree and its characteristics (species, diameter, grade and status). The crew leader registers the tree and number on the survey map and enters details on the enumeration sheet. The tree number and other details are also noted on plastic tape attached to the tree trunk or to a wooden picket planted next to the tree.

The status of the tree is also marked on its trunk by paint or machete, for example:

- harvestable tree: a blaze (axed gouge) or cross
- seed tree: S
- heritage tree (food tree, tree with cultural, religious or other significance): H

The tree counters also note terrain features: small waterbodies and their flow, passes, elephant tracks, steep slopes, swamps, rocks, inaccessible areas, occurrence of laterite and gravel.

Each crew is equipped with a GPS which can pinpoint a location to within 10 m. This inexpensive instrument will become increasingly essential for determining location in a forest, for verifying the layout of a survey pocket and for establishing the exact position of a tree.

Observations:

Tree counting without systematic cruise patterns determined by the shape of the pocket and the judgement of the crew leader always leaves doubt as to whether the whole pocket has in fact been covered and every tree counted. There could also be discrepancies between the position of pockets on a map and on the ground.

It is up to survey crews to determine which techniques they will use to identify and count trees. The means suggested above are by way of example only.

Striped tape and wooden pickets are useful but can often be removed by monkeys, causing confusion during final tree spotting and marking prior to felling.

3.3.3 Description of the inventory by systematic survey lot

Starting from a baseline (e.g. a road, an existing skid trail or a former survey line) serving as topographical axis of reference and access, the harvesting unit is covered with a grid of survey lines:

- Primary survey lines along magnetic East-West and North-South at intervals of 500-1000 m, sometimes more, producing quadrilateral lots measuring 50, 100 ha, etc. The length is measured, with or without slope correction, by cord and calibrated cable, and regularly checked. Hardwood pickets are planted at 50-100 m intervals or a tree is tagged or painted. The survey lines are cleared by machete, axe or chainsaw to a width of 1-2 m. They have to remain visible for 1-2 years as points of reference for final tree spotting prior to felling and for the control and monitoring of harvesting activities.
- Secondary survey lines generally running North-South and spaced at 200, 250 or even 500 m intervals. These have a width of about 1 m. They are roughly cleared by machete, are not signalled by picket or tag, and can deviate significantly in direction, although always remaining within the block.
- These primary and secondary survey lines therefore demarcate 20, 25 or 50 ha lots that constitute the survey units. They may not always be rectangular as the secondary survey lines can deviate, but this is unimportant in practice so long as the points of departure and arrival on the baseline are properly recorded. However, the survey map should accurately reflect the layout of survey lines as found on the ground and not as expected in theory

A survey-line clearing crew may comprise a crew leader, a compass surveyor, a rod man and 5 or 6 labourers, making a total of 8 to 9 people.

Typically a clearing crew can open up 2 km of survey line each day, depending on its competence, the terrain and the density of undergrowth. Primary alignments can be designated by letter and secondary alignments by number to facilitate the use of survey documents. The crew leader makes a note of work done and topographical features encountered and sketches the forest along the

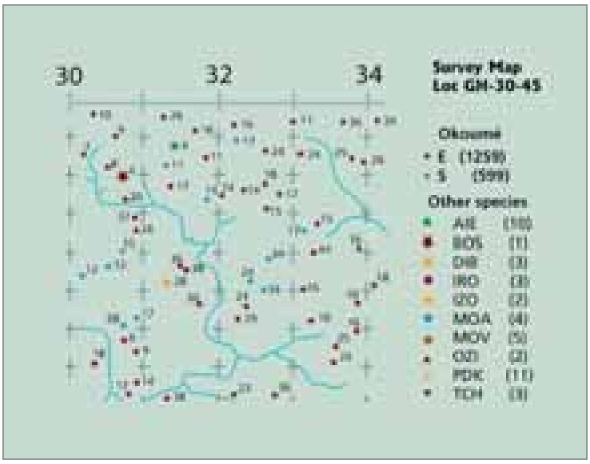

Figure 3 *Inventory by systematic survey lot*

survey line, indicating the position of pickets. This sketch will be used to draw the map.

The trees are then counted. Each cruise covers a width of 200-250 metres, so one return cruise will normally be enough for each lot.

The crew of one tallyman and six tree counters advances in line. The counter at one extremity remains on the survey line while the counter at the other extremity marks the line of passage for the return cruise. The crew periodically stops to get back in line. The trees are counted in the same way as for the pocket inventory.

A team of 7 people can cover about 50 ha each day depending on their expertise and training and

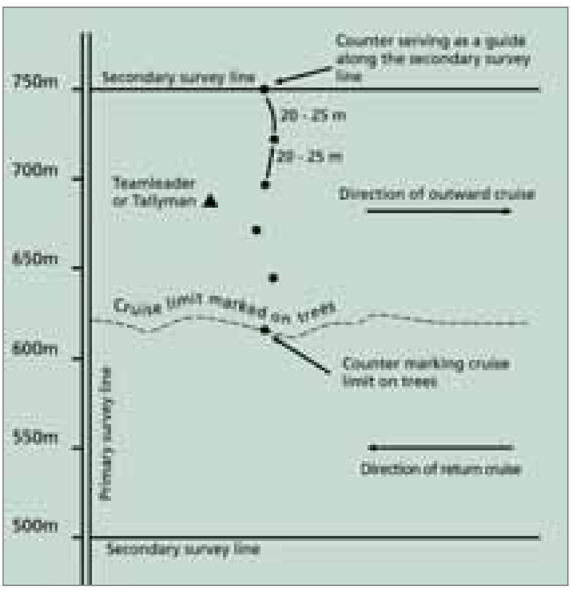

Figure 4 *Organizing the survey*

on the number of trees to be counted. The tallyman notes the location of each stem on a tally sheet together with relevant information on the terrain, especially ridge crests that would be suitable as baselines for log extraction.

Under both inventory methods, the survey and enumeration sheets and the duly completed maps are delivered each day to the management unit for computer entry and processing.

These documents are digitized by scanner and transferred to the GIS. A database is then created containing datasets for each counted tree (number, location, species, diameter, quality, status).

Harvesting blocks representing a company's monthly production target are then defined, either by grouping inventory pockets, or by referring to natural boundaries and roads, depending on the inventory method used. A large scale (1:5 000 or 1: 10 000) survey map is then produced to facilitate the proper planning of the road and skid trail configuration. The survey map indicates:

Topography

- Terrain with contour lines;
- natural and artificial boundaries of the harvesting block;
- watercourses;
- swamps;
- pre-existing roads and trails, villages;
- steep slopes and rugged terrain;
- crests;
- impenetrable areas.

Forest resources

- Harvestable trees with their survey number and species symbol or code: OK: Okoumé; MA: Mahogany; PDK: Padouk, etc.;
- seed trees with their species code;
- potential crop trees with their number (if numbered) and species code;
- protected trees with their code.

The harvest survey should ideally be started two years before harvesting so that the mapping can be completed one year in advance.

3.3.4 Impact of survey activities on the forest

The inventory impacts marginally on the forest. The visible results are the 1-2 metre wide survey lines that are generally cleared by machete only, the wooden pickets and the marking of trees with paint or tape. These signs of intrusion rapidly disappear. On the other hand, the survey lines:

- allow survey workers to locate and poach game more easily;
- facilitate access to external poachers and possibly to illegal loggers.

3.4 NON-HARVEST AREAS

Objectives:

- to identify and protect areas to be excluded from harvesting;
- to reduce negative impact on local populations, resources and the ecosystem.

3.4.1 Delimitation

Full reconnaissance of the annual harvesting unit during inventory makes it possible to locate and demarcate areas to be excluded. These need to be clearly marked on the survey map and should, of course, be distinguished from areas that are already eliminated on regulatory grounds (e.g. roadside areas restricted to community use) or because of stratification in the management plan (protection series).

Non-harvest areas are:

- unharvestable areas: swamps, very steep slopes (normally above 45 percent for tractor skidding), rock outcrops;
- sites of cultural or religious value: sacred trees and forests (these need to be identified with the local population);
- areas of ecological, scientific or touristic importance: areas with extensive diversity of wildlife, habitat of endemic species, unique and fragile habitats, etc.;
- environmentally sensitive areas, i.e. adjacent to permanent watercourses and backwaters or around swamps. The designation 'environmentally sensitive area' protects banks from erosion and excessive sedimentation. Such areas can also function as small biodiversity reserves and points of refuge for animals during harvesting.

Recommended widths for environmentally sensitive areas vary according to practitioner but the following average figures would seem to be acceptable:

Watercourses:	**Width of sensitive area**
Width < 10 m	10 m on each bank
Width < 20 m	20 m on each bank
Width < 40 m	30 m on each bank
Gully	10 m on each side
Creek or backwater	5 m on each side
Swamp	10 m from edge

Table 8. Width of sensitive areas

If necessary, exclusion areas and their stewardship may be negotiated among partners.

3.4.2 Special precautions

Non-harvest zones and their environmentally sensitive areas need to be protected as follows:

- no tree to be felled within these areas, and trees located in the immediate vicinity should, if possible, be felled away from the area and from watercourses;
- if a tree is inadvertently felled into a watercourse, all its debris should be removed causing as little disturbance as possible to the river bed and banks;
- machinery is banned from these areas, except under special circumstances in which case the crossing distance should be as short as possible to minimize disruption;
- temporary log crossings may be authorized if machinery needs to cross a watercourse, for example to build drainage structures;
- when absolutely necessary, watercourses may be crossed on rock or gravel beds;
- no earth movement or grading work is allowed in these areas;
- no harvesting debris should be introduced into protected or environmentally sensitive areas.

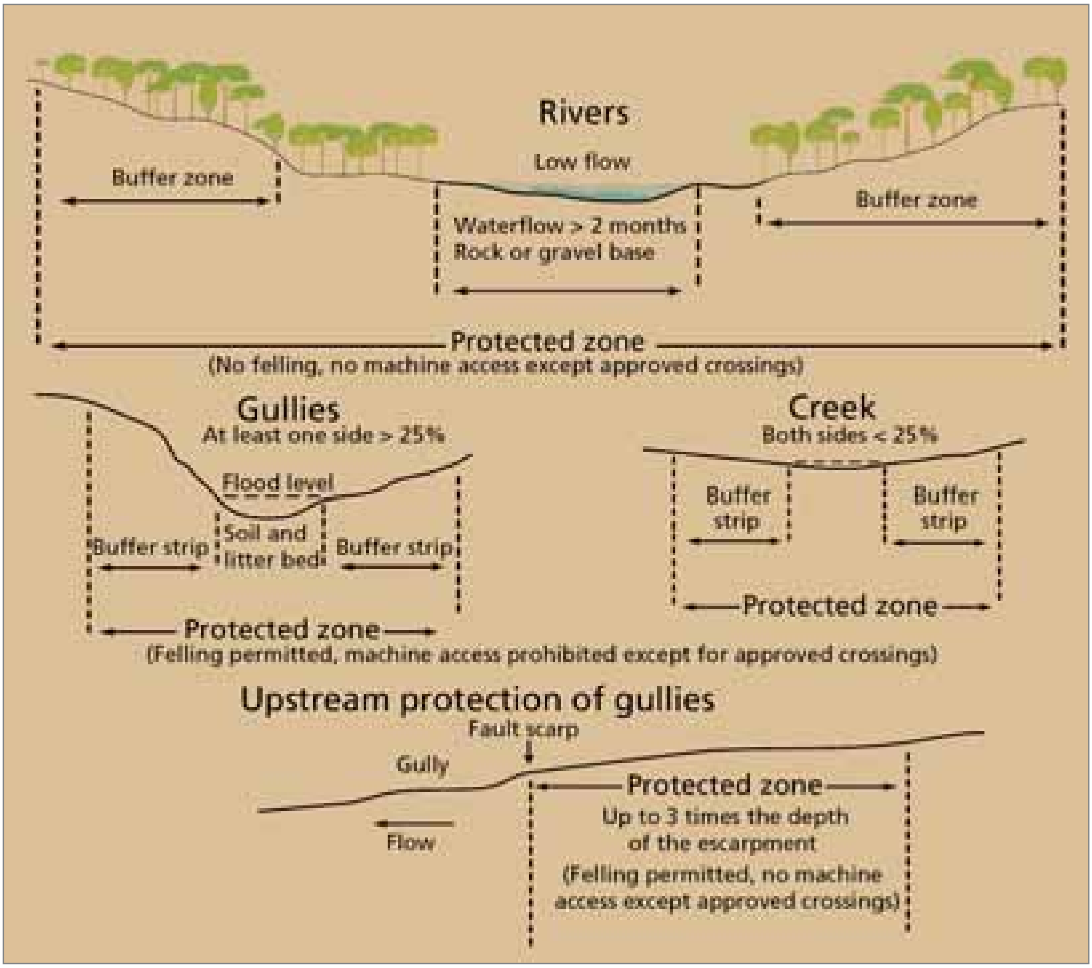

Figure 5 *Watercourses and sensitive areas*

3.5 TREE SPOTTING AND MARKING – PLANNING AND OPTIMIZING THE EXTRACTION LAYOUT

Objectives:

- to limit impact on remaining stand, soil and watercourses;
- to limit areas deforested and disturbed by roads, skid trails and landings;
- to enhance stand and harvesting productivity by ensuring no harvestable tree is omitted;
- to enhance productivity of harvesting operations and thus reduce costs.

The harvest inventory provides all the information required for:

- optimizing the layout of the secondary road network;
- identifying and marking trees considered harvestable because of species and quality;
- planning the skid trail and landing network and optimizing realization on the ground;
- establishing corporate commercial policy: species to be harvested, volumes, quality grades and harvesting schedule.

These operations are carried out by specialized teams, other than the inventory team.

3.5.1 Layout of the secondary road network

The layout and realization of access and main road networks are carried out on the basis of information provided by the mid-term management plan. However, planning the secondary road network within a harvesting unit needs to be based on the findings of the harvest inventory and is carried out one year before harvesting.

The secondary road network has to ensure that the harvesting unit is properly accessible, while maintaining a balance between skidding distance and network intensity. Layout will be determined by:

- relative abundance (distribution, volume and quality of species);
- topography and hydrography;
- terrain characteristics.

These three features will determine the harvesting period (i.e. dry or rainy season) and thus the characteristics of the roads to be built.

The road network will avoid areas with few harvestable trees and areas with serious topographical and terrain constraints (steep slopes, swamps). It will also seek to safeguard potential crop trees and heritage trees.

Tracing the road network will be entrusted to a specialist or the technical chief of operations. The provisional layout will be based on the survey map and additional ground inspections.

3.5.2 Preparing the harvesting block – planning and layout of skid trails and landings

The harvesting blocks have to be prepared a few weeks or (at most) months before harvesting. Preparation involves:

- identifying, from the map, the blocks demarcated by natural boundaries, which generally correspond to the area between two watercourses crossed by a ridgeline leading to a spur or secondary road;
- clearing a track by machete along the ridgeline which will essentially serve as the main skid trail.

(N.B. In the case of a pocket inventory, these two operations were already done at the time of the inventory.)

Spotting and final marking of trees to be harvested or protected

– The spotting crew examines each tree identified as harvestable for the inventory and accepts or rejects its harvestability according to market criteria (species, diameter and quality). A rejected tree has its tag removed or number erased. An accepted tree is formally identified with a new number (harvesting number), an additional marking (cross, blaze) or a set of plaques. Many loggers use the plaque method to ensure that all harvestable timber has been extracted. Three metal plaques bearing the number of the tree, the number of the harvesting block, the species and quality are nailed to the trunk. The first will be removed by the feller, the second by the choker-setter and the third by the harvest enumerator, and all will be sent to the operations chief’s office for verification. A tree disregarded or rejected by the inventory team but subsequently judged acceptable is given a harvesting number and identified on the survey map. Potential crop trees or trees to be protected, whether identified or numbered during the inventory or not, and trees to be safeguarded during felling and skidding (e.g. adjacent to a tree to be felled or beside a skid trail) are signalled by striped tape. All this information is noted on a tally sheet linking survey operations, especially numbering, with actual harvesting.

Layout of skid trails and landings

As the harvestable trees are given their final marking, the spotting crew optimizes the skid trail layout by tracing, with machete or tape, the trajectory of each log from stump to the main skid trail. The gradient of a trail without earthwork should be no more than 30 percent; above which cut-and-fill profiles are required. Gradients of more than 45 percent, the operating threshold of ground-based skidding equipment, should never be used in order to avoid accidents and prevent erosion.

The layout of these trails should avoid damaging potential crop trees and, as far as possible, penetrating environmentally sensitive zones or crossing watercourses. Where a secondary trail joins a main trail, the number of trees to be felled is notched onto a picket, sometimes with details of species.

Where the main skid trail joins the roadside landing or the road directly, the final picket will indicate the total number of trees to be felled within the harvesting block.

Logs extracted along a main skid trail are generally taken to a roadside landing but, if few in number, may be left directly at the roadside, without a landing site being cleared. Two main skid trails can lead to the same landing. The location of a landing is decided when laying out the main skid trail. Its size has to be proportionate to the volume of timber to be handled but should always be kept to a minimum.

The best layout for skid trails and landings can be tentatively determined in the office and noted on the survey map using the GIS. The tentative layout can then be verified on the ground and amended as necessary.

3.6 PRODUCING THE OPERATIONAL HARVESTING MAP

The harvesting map is nothing more than the survey map at a scale of 1:5 000 or 1:10 000 supplemented with information from the tree marking and the harvesting block preparation. It shows the boundaries and numbering for each harvesting block, and the roads, skid trails and landings. Non-harvest trees are normally removed from the map for purposes of clarity. It therefore only shows the trees to be harvested, their harvesting number and their species code and includes a boxed summary of the number of trees per species to be harvested within the block. The harvesting crews are then given the map and briefed on all its indications, for reference during felling and extraction.

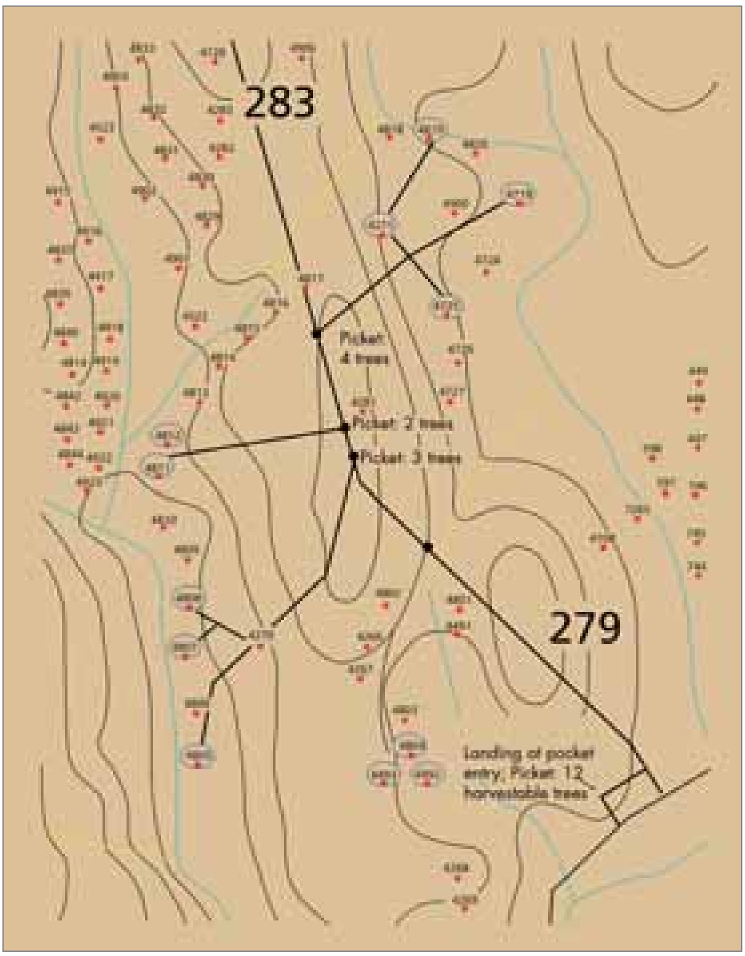

Figure 6 *Specimen harvesting map*

CHAPTER 4

«Road engineering involves the specification of design standards and the actual engineering design, field layout, construction and maintenance of forest roads and subsidiary structures such as bridges and culverts.» (FAO Model Code of Forest Harvesting Practice, 1996)

PLANNING AND CONSTRUCTION OF ROAD NETWORK, DRAINAGE STRUCTURES AND WATER CROSSINGS

PLANNING AND CONSTRUCTION OF ROAD NETWORK, DRAINAGE STRUCTURES AND WATER CROSSINGS

Objectives:

- to ensure efficient access to the forest under best possible conditions;
- to limit the area cleared for the road network to minimize the impact on soil erosion, forest and harvesting costs;
- to convey harvested products to point of sale or processing;
- to provide efficient and safe transportation of personnel;
- to reduce maintenance costs of haulage equipment;
- to meet obligations laid down in the logging contract.

4.1 ROAD CLASSIFICATION

Forest roads can be classified into four categories:

- Access roads that connect the boundaries of a concession with a public road, waterway or railroad network. These roads have to carry the full load of timber harvested during the entire duration of a permit and must therefore be permanently traversable. They carry tens to several hundreds of thousands of tonnes each year.
- Main roads within the harvesting permit that give access to part or all of the concession area and often branch from a trunk axis running virtually the length of the permit area. This transit road and all roads connecting a management unit, a village or a public facility must be permanent. The others need to be traversable for at least one year, sometimes several years. They must be kept in good condition and serviceable throughout the year.
- Secondary roads or feeder roads that lead to each harvesting block. Their life span is limited to a few weeks or months at most, so they often require little maintenance. The landings are usually located along these roads.
- Spur roads that are short roughly graded tracks used on gentle terrain in the dry season to connect remote landings with secondary roads.

4.2 CHARACTERISTICS OF THE ROAD NETWORK

The harvesting road network usually has features that distinguish it from the public road network:

- the roads are generally private; their characteristics are often determined solely by the demands of the concessionaire who is free to choose the size of haulage equipment to be used and to adapt the road infrastructure accordingly;
- the purpose of these roads is to collect goods rather than connect locations. Vehicles do not therefore need to travel fast and roads can be wind around terrain contours, requiring less earthwork;
- the volume of traffic is limited to the extraction of forest products and related activities. A main road will carry an average of 30 to 40 vehicles a day;
- roads serving as main axes of a permit area will have to be kept open all year for the regular supply of timber to log yards and mills and for logistics to camp facilities and harvesting units;
- the direction of transport is mainly forest to log yard or mill, with vehicles returning unladen able to handle steeper slopes than outgoing vehicles travelling laden;
- most of the roads are built for a limited life span, especially secondary roads which will serve to remove timber and then be closed until the next rotation some 25 to 40 years later. Construction standards and resilience can therefore be lower than for public roads;
- some areas with difficult access are only harvested during dry weather, so secondary roads servicing these areas will be of lower standard than all-weather roads.

In some countries, forestry main roads tend to become rapidly absorbed into the public road network and therefore have to meet the official standards set by the road authorities.

4.3 ROAD CHARACTERISTICS

Each road is defined by three elements:

- its profile or cross section;
- its horizontal or bird's-eye layout;
- its longitudinal section (projection along the vertical axis).

4.3.1 Cross section

The most common widths are:

right-of-way	30 to 45 m maximum
forest clearing	15 to 30 m
levelling subgrade	7 to 12 m
grading of roadbed (ditch bed to ditch bed)	6 to 9 m
sunlight exposure on gentle terrain	10 to 17 m
sunlight exposure on hilly terrain	5 to 30 m

On hilly terrain, width clearing is always broader on upslope side and an East-West road requires less width clearing than a North-South road as it has longer sunlight exposure.

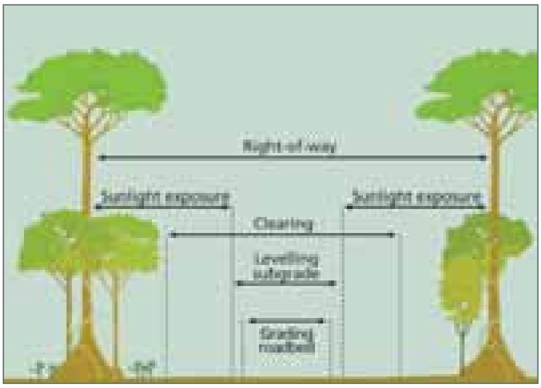

Figure 7 *Cross section of road on flat terrain*

Width of the roadbed (between inner ditch edges)

Measurements most commonly encountered are:

Access roads	10 -12 m
Main roads	8 -10 m
Secondary roads	5 - 7 m

Profile of road surface and shoulders

The road surface or roadway should always be cambered to facilitate lateral rainwater runoff. The most effective slope that also avoids washout is 3 to 5 percent.

Side drains

The ditches channel runoff water to outlets. They are triangular when dug by grader. Their upper width is 1-1.5 m and their slope generally 2/1 internally and ½ externally.

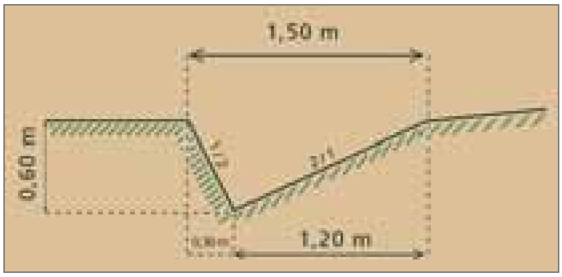

Figure 9 *Standard side drain profile*

4.3.2 Horizontal alignment

Each alignment is unique but follows certain principles:

- on gentle terrain, roads are built along or adjacent to ridgelines, thus limiting earthwork, facilitating drainage and avoiding flooding during the rainy season;
- in areas without continuous ridges, roads lead from one elevation to the next, along slopes between two obligatory points of passage;

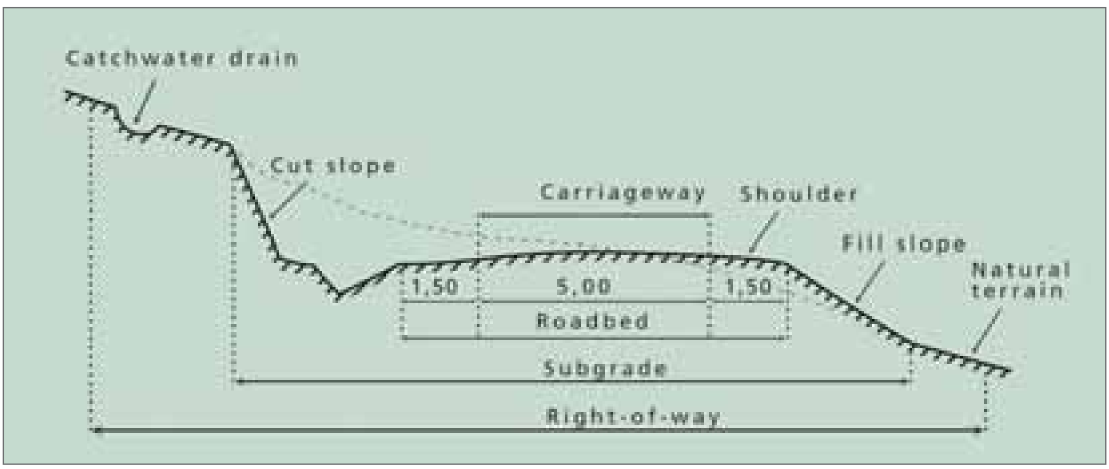

Figure 8 *Cross section of a standard cut-and-fill hillside road*

- on steep terrain, roads run along valleys and cross small waterbodies as far from the mouth as possible.

Curves
Minimum curve radius is determined by external turning lock of vehicle. Timber trucks require 15-20 m but far greater radii are generally adopted.

	Minimum radius	Recommended radius
Gentle terrain	40 m	100 m
Steep terrain	20 m	40 m

Table 9. Curve radius

Curve widening
Articulated vehicles deflect around tight curves with the rear trailer wheels following a different trajectory to the tractor wheels. Added width is therefore needed which then tapers back to a straight line at curve entry and exit.

Radius of curve	Widening	Adjustment length
20 m	2.5 m	20 m
50 m	1.0 m	30 m
100 m	0.5 m	30 m

Table 10. Widening and adjustment of curve

Two successive curves in opposed directions have to be separated, as far as possible, by a straight line of 40 to 50 metres on gentle terrain and at least 10 metres on steep terrain. For reasons of safety a curve should never be placed immediately before a bridge; straight approach and exit lines of at least 50 m are required.

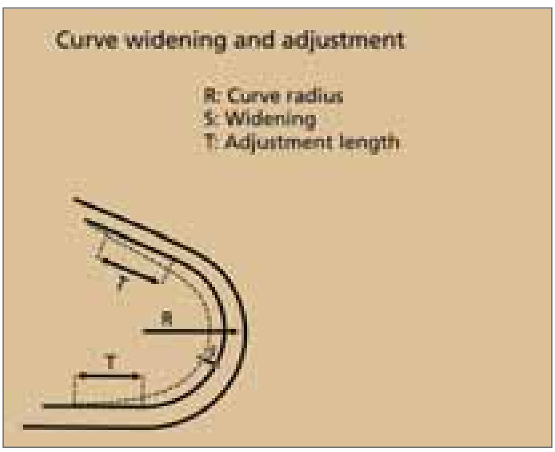

Figure 10 *Widening and adjustment of curve*

Visibility in curves
Visibility in curves is also an essential safety requirement. The minimum visible distance should be twice the braking distance for a given speed.

Speed (km/h)	Braking distance (m)	Visibility distance (m)
30	20 m	40 m
50	45 m	90 m
60	60 m	120m

Table 11. Visibility distance

To enhance visibility on hilly terrain, a ledge can be cut into the hillside at the height of the driver's line of vision, about 1-1.25 m above the surface of the roadway.

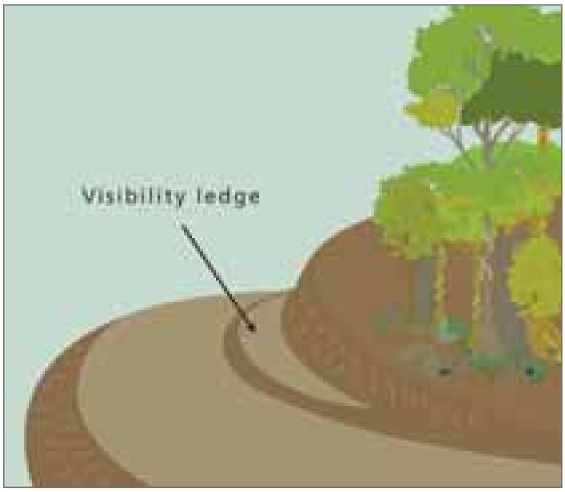

Figure 11 *Visibility ledge*

4.3.3 Longitudinal profile

The longitudinal profile of the road should:

- permit water runoff without surface washout. A minimum slope of 1 percent, for example, is always preferable to a flat section, but damage from washout can soar when a slope exceeds 5 percent, entailing costly repair;
- avoid steep updrive and downdrive gradients. The following maximum road grades should be observed:

	Travelling laden	Travelling unladen
Gentle terrain	4 %	8 %
Steep terrain	8 %	12 %

A steeper grade is acceptable, if unavoidable, but only for a very short section. It is important to note that:
- the gradient on curves should be less than on straight stretches;
- gradients should be zero on hairpin bends;
- level or gently sloped intersections should be built into long ramps;
- slopes in the direction of generally unladen travel should not be too steep to prevent the occasional traffic of laden trucks towards the forest and logging camps (e.g. trucks carrying equipment, tank trucks).

4.4 ROAD CONSTRUCTION

4.4.1 General rules

Because of their nature, forest roads require special construction rules:
- roadlines need to follow terrain contours for reasons of economy, thus forest roads are winding. Earth is usually moved sideward during blading, with lengthwise movement restricted to short sections and special purposes, such as creating embankments or bridge ramps;
- gradients should be as gentle as possible because of the predominance of timber truck traffic. Maximum road grades towards the forest (unladen travel) can be higher than from the forest (laden travel);
- roadways are made of compacted natural soil with the addition, where possible, of a thin layer of aggregate, usually laterite. Bearing capacity standards are not the same as for public highways, so meteorological constraints (wet-weather barrier regime) need to be observed, with haulage prohibited during and immediately after rainfall.

4.4.2 Layout

Road layout is the result of a series of complementary studies, starting with provisional desk alignment using the GIS or existing maps and proceeding to reconnaissance on the ground.

The provisional layout is determined by landscape and natural elements, identifying valley lines and main ridgelines and sketching basic macro-relief features. The requisite road alignment is then explored step-by-step, determining points of obligatory passage and tentative connecting lines, avoiding points considered impassable. Generally, roads should be located:
- along ridgelines on gentle terrain for minimal earthwork, easier drainage and preferable uphill skidding;
- along slope flanks to connect one elevation to the next, where ridgelines are not continuous;
- along valley bottoms on steep terrain where these are sufficiently broad.

Finally, roads should preferably be laid in flat, timber-rich areas and in savannahs or old plantation areas that are easy to cross. Provisional roadlines have to be compared with the reality of terrain by means of on-foot surveys, best done in the rainy season to get a true picture of soil characteristics, swamp limits and maximum width and depth of watercourses.

Certain rules apply when plotting final road layout:
- on rugged terrain, only main roads run from one valley to the next; secondary roads only access secondary valleys and do not cross ridgelines;
- roads along hillsides should be laid on ground with moderate slopes;
- roads along hillsides that have steep flanks require blading to cut a profile for stronger roadbed and easier drainage. Cutting into a hillside also permits rainy season work as the road subgrade remains untouched.

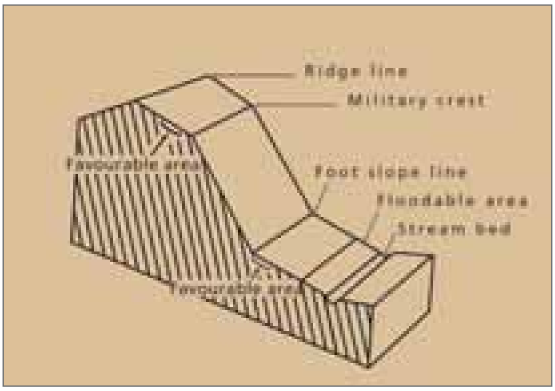

Figure 12 *Hillside profile*

Watercourses in broad flat valleys are generally not crossed next to points of confluence in order to reduce the number of bridges.

The final layout is a 1-metre wide line staked at regular intervals to indicate the exact horizontal alignment. The roadline must avoid protected areas and where possible, environmentally sensitive areas as well as future crop and heritage trees.

4.4.3 Clearing

Vegetation and top soil are cleared from the subgrade, which is always done by crawler tractor. For reasons of safety, large trees are felled by chainsaw and their stumps are then removed by tractor.

4.4.4 Blading (earthwork)

The road subgrade is bladed immediately after clearing, generally using the same crawler tractor to move material, build earthfills and install side drains and outlets. The volume of material moved should be limited to the extent a crawler tractor can economically sustain. Longitudinal movement is kept to a minimum (earthfill for valley lines, embankments and approaches to bridges).

Although not very common in Africa, tracked excavators offer several advantages when constructing hillside cut-and-fill roads over steep terrain:

- tree stumps, crowns and earthcut debris can be easily extracted and placed at the foot of the earthfill to form a filtration litter, preventing sediment from reaching a watercourse. This also keeps plant debris separate from earthfill and thus avoids the risk of subsidence from plant decay;
- earthcut can be reduced by 20 to 30 percent as compared to bulldozer blading;
- earthfill can be in successive 30-50 cm layers that are easier to form and better compacted. Where terrain permits, earthfill can be laid on a foundation of stones, rocks or resistant trunks put in place by hydraulic excavator shovel;
- the cutslope profile can better match the natural slope, thus lessening the risk of erosion and landslide;
- the fillslope profile can be shaped, corrected and covered with branches, thus reducing unprotected surfaces and facilitating plant regeneration on the slope.

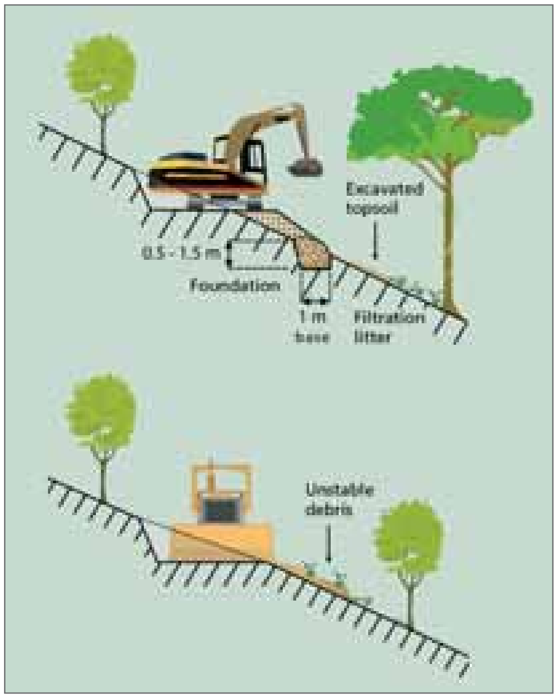

Figure 13 *Road construction with excavator and bulldozer*

Cut-and-fill roads should never have a lateral earth berm that could block downslope water runoff.

On flat ground, lateral berms or heaps of stump, crown and clearing debris should be kept to a minimum and openings cleared every 100 metres for the passage of small game.

All trees of harvestable species, size and quality that are felled for road construction should be recovered, processed and marketed.

4.4.5 Sunlight exposure

Surface evaporation depends directly on the exposure of the roadway to sunlight and aeration. Crowns of large trees growing beside the subgrade, prevent sunrays from reaching the ground and the road from drying. Their removal lengthens sunshine exposure and improves aeration.

Clearing for sunlight exposure or lateral lighting of a roadway is done by chainsaw.

Felling is not directional and trees are moved by tractor to the sides of the right-of-way. A felling crew can clear 1 000 to 1 500 metres of roadside per month along a 10 to 30 m strip without undergrowth.

It is important to remember that:

- clearing for sunlight exposure should always be much broader upslope than downslope;
- an East-West road near the Equator receives the necessary sunlight exposure from a narrower clearing than that needed for a North-South road;
- a roadway with clayey soil will need broader clearing than one of sandy soil;
- a main road must always be more broadly cleared than a secondary road.

In areas that are relatively safe from erosion or where the road does not need drying after rainfall, canopy bridges should be maintained at regular intervals as these provide uninterrupted plant cover and thus aerial passage for certain monkey species. It is worth mentioning that while regular openings in roadside berms and heaps of debris and canopy bridges facilitate the movement of wildlife, they also provide hunters with ideal vantage points to shoot and snare game.

4.4.6 Roadway compaction and improvement

Forest roads are usually made of natural soil, compacted and where possible, upgraded with a layer of aggregate. Once the topsoil has been removed and the earth bladed, the natural soil is usually sufficient to serve as roadbed. Many types of soil are suitable provided that they are compactable and relatively stable when wet.

In favourable circumstances, the natural soil can serve as both carrying layer and surface course, as in the case of laterite soils that have a high percentage of gravel. Natural soils of mediocre bearing capacity because of high clay content will require an extra thick layer of aggregate, especially on vulnerable stretches.

In tropical areas, the aggregate is usually all-purpose laterite from local quarries containing a mix of fine clay particles and coarser materials. Good distribution of particle size facilitates stabilization after compaction. Gravel larger than 30 to 40 mm should be avoided to facilitate grading, to prevent surface scouring and to enhance vehicle stability and safety. The aggregate layer should have a thickness of 10 to 25 cm before compaction.

Any natural soil used as roadbase must first be stabilized. Its bearing capacity needs to be strengthened to make it operable under wet conditions, which can be done either through compaction alone or by adjusting the granulometric range (adding required fractions, then compacting).

Straightforward compaction from rainfall and the passage of earthwork machinery, trucks and compactors is the usual form of stabilization of forest roads. Once the earthwork is complete, the natural soil profile is shaped by grader and its surface compacted. The road is then left untouched for a period of natural compaction from rainfall. Finally, before use, the base course is re-graded, wearing-layer aggregate added and the roadway compacted by roller. Any well managed logging company will therefore have its roads in place at least one year before harvesting.

The action of light rollers – whether vibrating rollers, sheep foot rollers or rubber-tyred rollers – is limited to packing the soil by making two to four runs to obtain a surface course of about 10 cm. This will consolidate the wearing layer and seal the surface to allow rainwater run-off. While compaction reduces soil porosity and facilitates water evacuation, some soils, especially clayey soils, also need to be properly drained to keep soil humidity well below the plasticity threshold of clay fractions.

4.5 DRAINAGE: DRAINS, OUTLETS, CULVERTS AND BOX DRAINS

Protecting unpaved roadways against water-caused deterioration of bearing capacity, is a constant concern of concession holders. Traffic on a roadway with impaired bearing capacity causes surface distortion, ruts and potholes that cannot be repaired until the end of the rainy season, incurring major operational constraint and added cost. However, with appropriate structures, water can be rapidly evacuated and roadways only superficially soaked and thus able to dry off within hours and sustain logging traffic. Penetration of water subsequent to maximum compaction must therefore be prevented. Road degradation is usually caused by reduced stability of terrain or roadway from the action of water. Measures should be taken to:

- avoid rainwater penetration of roadway and capillary absorption;
- ensure rainwater is evacuated by runoff;
- ensure the different roadway layers are sufficiently drained;
- facilitate surface aeration.

4.5.1 Avoiding water penetration

Rainwater penetration is limited by reduced permeability of upper road layers after compaction. The compactness and cambered shape of the roadway reduces surface absorption, as water flows immediately to the side drains before being able to soak into the substrate. The roadway is cambered by grader after earthwork. Maintenance at regular intervals restores the cambered profile and avoids water puddling. The cross-slope of the roadway has to be a trade-off between a sufficiently steep gradient to permit rapid water evacuation and a sufficiently gentle gradient to avoid washout and thus gully formation, and to ensure vehicle safety. The most effective crossfall gradient is thought to be 3 to 5 percent.

4.5.2 Evacuation of rainwater runoff: side drains, outlets and culverts

Rainwater evacuation by **drains** should be as swift as possible. The side drains serve to collect roadway water and take it to outlets from where it can be discharged without damaging the road. The bottom of the drain should be at least 60 cm below the road surface to avoid infiltration into the roadway. A drain full of water permeates the roadway and seriously impairs its resistance. This is easily spotted from the deposits of mud or sand sediment.

Deposits blocking a drain and erosion threatening roadbed stability need to be avoided. A light longitudinal gradient prevents drain deposits, staying within 5 percent to avoid washout. When draining steep roads, small waterbars can be laid to check waterflow and restrain gullying, and to hold back sediment.

When a road is built in a cutting or on cut-and-fill sloping ground, it is often advisable to dig a catch drain above the cutslope to prevent runoff reaching the road. The catch drain has to be placed sufficiently far from the top of the cutslope (4 to 5 m) to prevent infiltration that could destabilize the slope.

Side drains are generally traced by grader after the earthwork, but can sometimes be dug or opened manually.

Figure 14 *Road drainage on flat terrain*

Outlets evacuate side-drain waters towards natural valley lines. Their number and spacing will be based on direct ground observation. However, high outlet frequency is needed where:

- side drains have a low gradient (below 3 percent) and therefore slow water flow;
- side drains have a steep gradient (above 5 percent) and thus rapid water flow and an attendant risk of gully formation.

The drainage outlets, opened by bulldozer during earthworks at the same time as the side drains, follow the natural slope draining the roadside area. Their construction must meet certain requirements:

- they must actually discharge onto lower terrain (a requirement often ignored, producing the opposite effect of outlets retaining water);

- their width and depth must be at least the same as those of the side drain they are servicing so that waterflow is equal or faster than that of the side drain;
- their slope must be the same or if possible greater than that of the side drain;
- they must lead off from the side drain at a relatively gentle angle of less than 30o to permit maximum waterflow;
- they must be positioned at least 50 m from watercourses to prevent the intrusion of sediment.

On cut-and-fill sections of road where outlets cannot be inserted into the cutslope, the side drain can only be discharged by means of **culverts** that take the water across the roadway. If a road is to be in service for more than a year, a culvert has to be placed at each low point along the longitudinal profile. In the case of a hillside road, a culvert is required at each thalweg.

Road class, expected life span and available resources will determine the materials used. Using three logs to form a chute should be avoided as such a channel easily becomes obstructed.

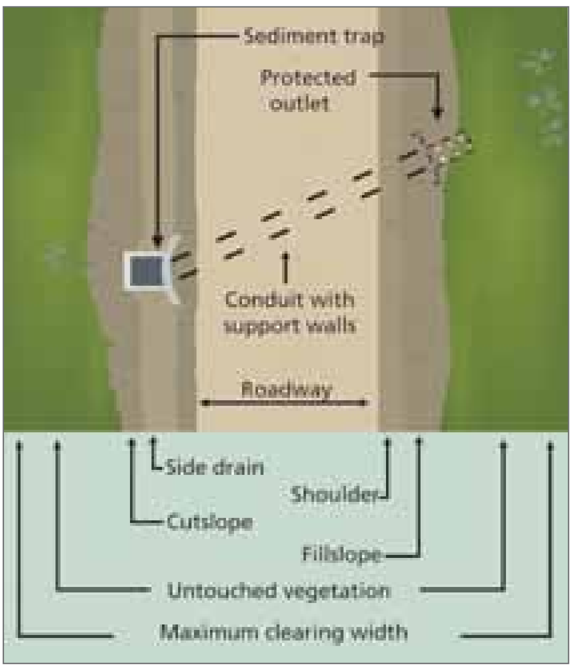

Figure 15 *Positioning a culvert*

Hollow trees: large-diameter hollow trees can be used, always placing the narrower opening upstream to avoid obstruction.

Planks: a trench is dug across the road and 50 x 50 cm or 60 x 60 cm wooden frames are placed at 1.50 to 2 m intervals. The frames serve as stanchions for the plank casing. The trench is then filled with earth and compacted.

Cement or metal culvert pipes with a diameter of more than 60 cm and as much as 2 m (it is better to install one single 1 m culvert than two parallel 60 cm culverts). Soldered end-to-end, 200-litre drums may be converted to inexpensive metal culvert pipes.

Cement culverts can be made locally using plank or sheet metal casts. They should be covered with at least 60 cm of earth and should rest on a carefully levelled bed of light concrete. Earth has to be carefully packed around the culvert to avoid crushing and water infiltration. Installing metal culverts requires special precautions:

- a foundation of natural soil with good bearing capacity. If the soil is loose, additional foundation is required, using non-scourable materials that are carefully compacted. A flexible culvert pipe should never rest on a hard rock or concrete base;
- a culvert will stay in place if the surrounding earth is firm and uniformly compacted in successive 25 cm layers;
- a proportionate layer of earth should be placed above the culvert: (50 cm of earth for a 60 cm culvert and 70 cm for a 200 cm culvert).

Culverts should have a cross-gradient of 1 to 3 percent to facilitate waterflow, but no steeper to avoid scouring at outlet. If necessary, protection works (riprap, masonry or gabions) can be used on highly erodible terrain to limit erosion at culvert point of entry and exit.

4.5.3 Drainage of roadway structure

Permanent drainage is required when a roadway is infiltrated with water from precipitation, from flooded side drains or from upward capillarity from deep water tables:

- side drains should be built in such a way that their base lies at least 60 cm below roadway level, thus

preventing prolonged water seepage to the lower road strata even with stagnant water in the drain;
- on terrain where the water table is close to the roadway surface, a thin, draining and highly permeable layer should be inserted between the subgrade and the roadbed to block capillary rise and evacuate water from the roadbed. A 10 cm layer of sand and gravel usually works well. A layer of geotextile fabric is also suitable and should be laid on a fascine or sapling bed to avoid contact or mixing with subjacent soil.

4.6 CROSSING WATERCOURSES: DRIFTS AND BRIDGES

Watercourses can be crossed by drift or bridge, the latter being far more common in the region.

Temporary crossings for the passage of construction machinery can be made by placing hardwood logs on the river bed in the direction of waterflow:
- the width of passage should be limited to 4 m;
- passage should follow the line of the road or structure to be built;
- disruption to vegetation in the buffer zone, on river banks and along the river channel should be kept to a minimum;
- logs and accumulated debris should be removed as soon as passage is no longer needed.

4.6.1 Crossing by drift

A watercourse can be crossed by drift when:
its banks are lower than one metre;
the approach gradient is less than 10 percent;
river depth above the drift is less than 0.5 metre;
the river bed is solid gravel or rock.

Any intervention to improve the crossing entails:
- minimal movement of materials, earthwork and impact on river bed;
- protection against scouring upstream and downstream from the drift;
- easy removal (e.g. of gravel used for reinforcement) once the crossing is no longer needed.

4.6.2 Bridges

Forest bridges are usually built of hardwood with long natural durability. They do not need chemical protection and, if built properly, can last 10 years or more. They are generally designed for one-lane traffic of 50-tonne, five-axle timber trucks.

Choice of bridge site

Choosing the site of a bridge requires knowledge of watercourse regime as:
- the bridge needs to be passable in all seasons, so its deck should be at least one metre above the highest water level ever recorded to permit passage of trunks and debris in floodwater;
- floodwater level will indicate the maximum width of river bed and thus the length of the bridge;
- the bridge should be as short as possible to avoid inserting intermediary supports (piers);
- it should be positioned at right angles to waterflow;
- its approach should be in a straight line of at least 50 metres for safety reasons. A bridge should never be built on a curve;
- the bridge should be placed where the current is as regular as possible;
- it should be built on solid foundations, on a firm, non-scourable bed (e.g. rocks), if necessary at the expense of minimal length;
- the positioning of the bridge determines road alignment, not vice-versa.

Figure 16 *Correct siting of a bridge*

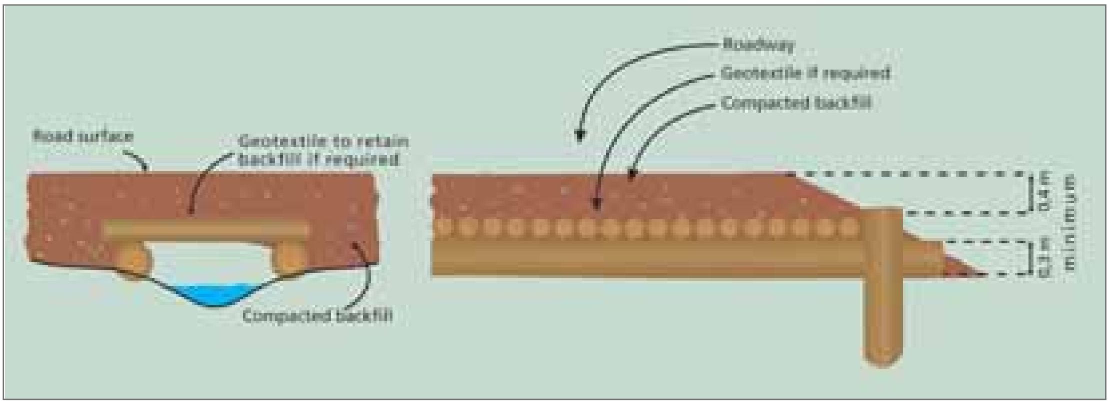

Figure 17 *Bank abutment*

Choice of bridge type

This will depend on several factors:

- available workforce, materials and equipment;
- type of traffic projected: weight, length and width of vehicles;
- density of traffic;
- physical location (steep banks and terrain relief may impose a type of bridge);
- size of watercourse, floodwater regime and volume of debris carried by the current.

The bridge will have a single span if its floodwater width does not exceed 17 m. Intermediary supports may be envisaged in the case of stagnant waters as these will not obstruct waterflow.

The substructure: abutments and piers

The abutments support and anchor the bridge deck.

a) Abutments made of log stacks

<u>Bank abutment</u>

A simple bank abutment is made of one or two 70 to 100 cm diameter head (sill) logs placed across an earthfill and laid flat on firm levelled ground to support the stringers. This type of abutment is used where the bank is sufficiently stable to preclude rockfall or subsidence. If the terrain is not sufficiently firm, the head logs are placed on a crib of round or squared logs, thus dispersing the load and reducing the pressure on the soil to an acceptable level.

<u>Canadian log crib abutment</u>

Where necessary, to raise the bridge deck to a higher level or to improve the anchorage of the abutment, the logs are stacked in right-angled layers (cribbings) and bound together. Most are covered by the backfill providing access to the bridge. This type of abutment, of which there are many variations, is known as a bridge pier or Canadian log crib.

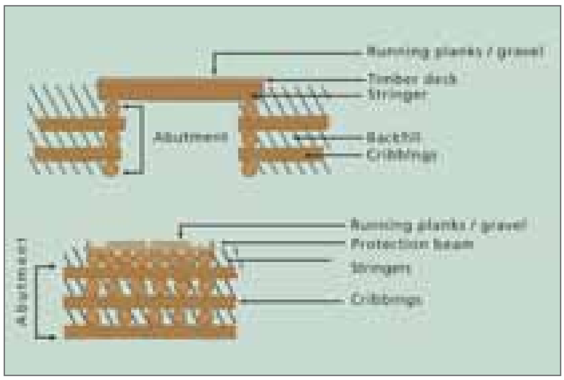

Figure 18 *Bridge pier or Canadian log crib abutment*

b) Concrete or masonry abutment

For larger structures the abutments can be built of stone or concrete. They also serve as retaining walls and have to be stabilized against lateral earth pressure. This may be done by giving the abutment wall a stepped profile, creating successive setbacks in the wall so that the weight of earthfill on each step helps stabilize it. Another way of increasing abutment stability is to give the wall face a 1/10 slant. The width at the top of the wall should never be less than 1.5 m.

c) Intermediary supports or piers

Intermediary supports or piers are required where the watercourse is too wide for a single span. These are similar and require the same types of foundation as the abutments.

They can be built on dry ground (e.g. rock bed) for easier construction, or in the water. Piers do not have to be placed on the main river bed; on the contrary, it is usually better to leave the river flood bed clear.

Superstructure: stringers, trusses and decking

a) Stringers

Stringers are support beams made of whole, sap-cleared or squared trunks. Since the bridges are constructed for one-way traffic, four beams (two on each side) are sufficient to form a 3.5 m roadway if placed under the vehicle wheel tracks. The respective stringer diameters of Letestua durissima-Congotali (high tensile strength) and Nauclea trillesii-Bilinga (lower tensile strength) to support 50-tonne five-axle vehicle traffic are:

Span between stringers*	10 m	12 m	14 m	16 m	17 m
Congotali	58 cm	66 cm	74 cm	81 cm	85 cm
Bilinga	63 cm	71 cm	79 cm	86 cm	90 cm

Table 12. Diameter of stringers

*An additional diameter of 4 cm for 1 m extra span is required for spans over 17 m.

b) Decks

Planks are the best and lightest material for building decks. There are usually two types of superimposed, cross-aligned deck, each serving a particular purpose:

- the trusses (weight distribution deck), which are laid at right-angles to the stringers, spread the carrying load equally among the superstructure. They are not connected so as to facilitate rainwater runoff;
- the wearing deck, also referred to as the flooring, is intended to withstand the constant wear of heavy vehicle passage and is ideally made up of half planks laid at 45o to the bridge axis.

Laterite decking: where stringers cover the entire width of a bridge, 2 to 3 cm diameter saplings can be laid in the gaps between the stringers; then the deck is formed by covering the whole structure with a layer of laterite. Ideally, the litter of saplings and the layer of laterite should be separated by geotextile fabric. Although this technique has the advantage of being simple, it also has certain drawbacks:

the laterite adds an extra 3 to 5 tonnes per linear metre;

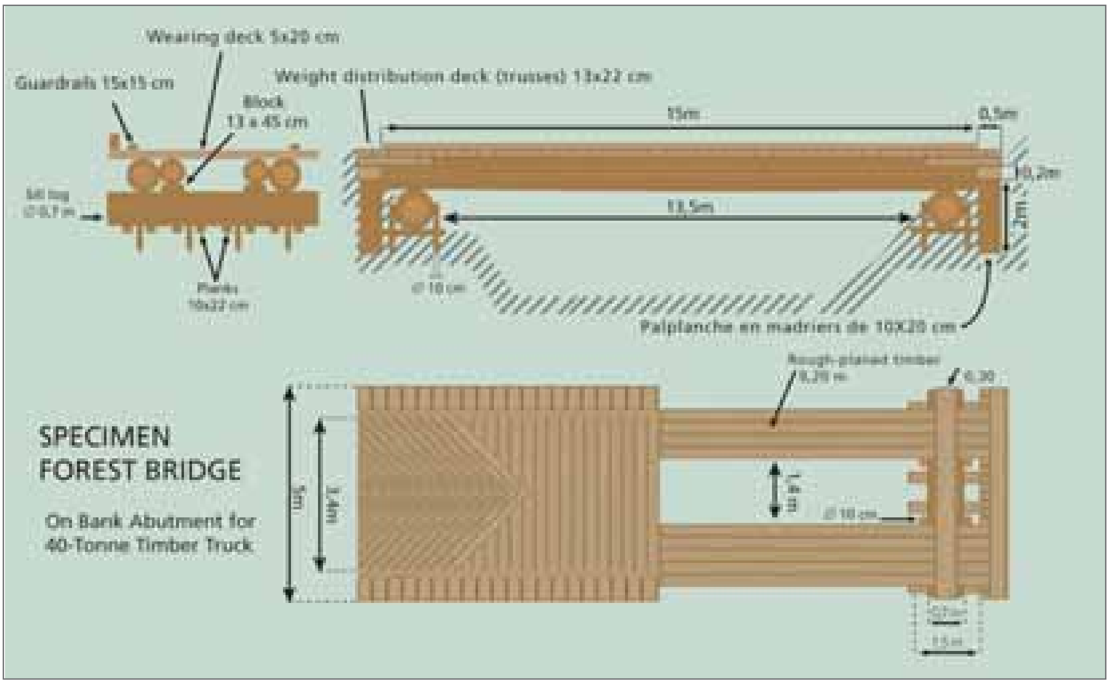

Figure 19 Specimen forest bridge

- it retains moisture which is conducive to wood decay;
- it is more difficult to spot the transition from road to bridge and to check the condition of the bridge at night, which has implications for traffic safety. Laterite decking is however frequently used.

4.7 ROAD MAINTENANCE

Vehicular traffic and bad weather cause deterioration of roadway and drainage structures which has to be controlled by means of regular maintenance and timely repair.

4.7.1 Regular maintenance

Reshaping road surface

This is necessary to counter the impact of traffic:

- road wear and washboarding in the dry season;
- rut formation and washout in the rainy season.

The constant passage of vehicles tends to produce greater compaction along the wheel track than the rest of the roadway. Truck wheels shear off gravel from the surface course and cast it outwards. Together, these two actions produce ruts and ridges that block lateral runoff of rainwater to the side drains.

Maintenance involves early intervention to eliminate pre-rut surface scouring. Ejected materials are replaced on the road and the road profile is restored, preferably by grader. The most effective strategy is to repair road deterioration promptly in order to pre-empt serious, permanent distortion. The blade should only be used to remove rippling ridges and shoulder berms, and should never cut into firm and stable roadway layers. Care must also be taken to avoid leaving sidecast along the roadside.

It is very important to choose an appropriate day for reshaping a road surface as the soil needs to have optimal moisture content (which will depend on its clay composition) for compaction after grading. Soil with too much moisture tends to become plastic and thus unsuitable for reshaping or compaction.

Filling potholes

Potholes should be removed on sight, first drying them, then filling them with laterite. Filling without drying is ineffective as the water will soak into subjacent road layers and undermine bearing capacity. Using laterite stones or pebbles to fill a pothole is also ineffective as these will be pushed down into the soft layers, leaving the problem unresolved.

Water runoff and drainage structures

The road maintenance crew should also keep constant watch over the state and function of runoff structures: drains, outlets and culverts. Inlets and outlets should be kept free of debris so that water can run freely.

This also applies to bridge abutments and piers. Any wood or debris likely to narrow the river bed or restrict waterflow needs to be removed. Bridge support beams need to be checked regularly, as does the state of the wearing and distribution decks, renailing or changing planks as necessary.

4.7.2 Resurfacing

Despite regular maintenance, a road can become worn from loss of materials. New materials may therefore eventually be needed to reinforce and restore the roadway. Theoretically the only roads that require resurfacing are those in permanent use, which means adding laterite at regular intervals. This will however be determined by traffic intensity, quality of road materials, weather conditions and quality of regular maintenance.

4.7.3 Other maintenance operations

Certain sections of road will not be very stable, with regrading required in cut areas with frequent rockfall or landslip. This has to be cleared quickly, preferably by excavator or front-end loader, and the side drain restored. A slope can be considered sufficiently stable when loose soil stops falling. It is less expensive to clear fallen rock or soil than to embark on expensive earthworks during road construction, to obtain a gentler sideslope gradient.

4.8 IMPACT OF ROAD CONSTRUCTION

There are two main types of impact:

a) The environmental impact on the forest, with road construction clearing all vegetation and topsoil from the roadbed. It takes several years after road closure for nature to recover and repair the damage; the road will gradually cover over, first with herbaceous vegetation (grass, climbers, etc.) then with shrubs (shoots, seedlings, etc.) and finally with trees.

b) The social impact, which may either be positive or negative:

Positive:

- access of local populations to resources (wood and non-wood forest products) and relief from economic and social isolation;
- emergence of petty trade, markets and artisanal activity along the roadside;
- improved living conditions for local populations (education, health).

Negative:

- easier forest access for poachers and illegal loggers;
- disruption of social structure.

4.9 RECOMMENDATIONS

Reduced-impact practices in road construction:

- plan the road network with due attention to protected areas, avoiding as far as possible environmentally sensitive areas and heritage trees;
- seek to align roads along ridgelines on gentle to moderate terrain to facilitate drainage and uphill skidding;
- opt for an excavator rather than a crawler tractor for cut-and-fill profiles to reduce volume of earthcut and the risk of erosion and landslip;
- avoid moving earth into watercourses;
- keep sunlight exposure to the minimum necessary, according to class of road, topography and type of soil of subgrade and base layers;
- retain canopy bridges and intersperse lateral earthwork with openings for the passage of certain species of monkey and game;
- construct and maintain appropriate drainage structures for the collection and evacuation of water, avoiding any deterioration of roadway substrata, erosion of side slope and influx of sediment into watercourses;
- avoid disruption to vegetation near watercourses, in buffer zones and on river banks and beds during construction works;
- remove all plant debris from buffer zones for burial in pits or earthfills.

CHAPTER 5

«The intention of preparing this document was to concentrate on harvesting since it is the component of industrial forestry that is most often subject to complaints relating to environmental damage associated with forestry operations, especially in developing countries.» (FAO Model Code of Forest Harvesting Practice, 1996)

IMPLEMENTING HARVEST OPERATIONS

IMPLEMENTING HARVEST OPERATIONS

This chapter deals with actual harvesting practices, from tree felling to loading and transport of logs.

Objectives of the Code

- to minimize detrimental impact on remaining stand, soil and water;
- to optimize harvesting efficiency, in particular recovery level;
- to safeguard forest yield and regeneration capacity;
- to promote stand increment in volume and value;
- to employ competent and experienced personnel at all levels;
- to adopt and apply appropriate safety standards.

Merchantable trees in the tropical forests of Central and West Africa are irregularly distributed and are limited in number and volume. Preliminary planning is therefore paramount to facilitate harvest operations; «facilitate» in the sense of minimizing negative impact and making operations safer and more efficient. However, planning is meaningless if not applied. A plan must therefore be intelligible to ground crews so that they can apply it without difficulty and operate in consonance with reduced-impact logging principles.

Interlinking planning with operations involves two actions:

- general and constant use of the harvesting map that provides an overall picture of the area to be harvested and shows the approximate position of each tree to be harvested, as well as significant features of terrain (rivers, gullies, swamps, rocks). It also indicates roads, landings, bridges and skid trails.

Figure 20 *Harvesting map*

- on-site briefing and instructions: the map serves as a point of reference for felling and extraction crews, enabling them to operate according to rules and regulations. Each crew should receive a copy of the harvesting map, together with clear instructions on operational details and necessary precautions.

Unless supervisors make sure that ground crews fully adopt the planning provisions shown in the harvesting map and actually put them into practice, this planning document risks being no more than an other useless, costly piece of paper.

SECTION 5.1

Objectives:

- tto limit damage to the remaining stand, especially to potential crop trees, heritage trees and regeneration;
- tto minimize timber loss during felling and optimize quantity and quality of timber harvested per tree;
- tto facilitate extraction by placing the log into a favourable position;
- tto maximize safety by applying appropriate standards, devices and equipment.

CONTROLLED FELLING

5.1 CONTROLLED FELLING

Felling is one of the activities that can cause serious damage to the remaining stand. The correct working technique has to be applied in order to recover the most precious parts of a trunk. At present, trees are often felled without a proper undercut or hinge, causing them to fall at random with resulting damage to the trees themselves and to the remaining stand. Chainsaw operators often fell trees at chest height without first removing buttresses, even where the trunk has merchantable timber at its base. Such technically inadequate and poorly planned practices result in low timber recovery and impact negatively on the remaining stand, in spite of the low harvesting intensity of tropical moist forests of West and Central Africa.

Felling is physically demanding, especially when making the backcut, with the weight, heat, vibrations and noise of the chainsaw causing high physiological workload. Operators often have to use chainsaws without any safety device and are not provided with personal safety equipment. It is therefore imperative that logging personnel be trained in correct working techniques in order to ensure maximum safety.

5.1.1 Preparing controlled felling

Using the harvesting map, the felling supervisor inspects the area to be harvested and assigns each feller a number of trees to be cut in a day or week. Fellers working at the same time need to work in areas sufficiently apart to avoid danger. After reaching a tree and checking and recording its harvest number marked on the trunk or attached tag, the feller has to carry out certain observations and actions regarding the tree and its immediate vicinity in order to:

a) Decide whether to fell

Any dead or hollow tree has to be discarded. Trees showing signs of decay at their base need to be probed by machete or chainsaw. The decision to fell and the selection of felling direction are up to the feller who cannot be obliged to fell a tree that he considers dangerous. The feller has to identify potential crop and heritage trees reported by the spotting crew and decide how to avoid damaging them. Where this is not possible, and unless harvesting is taking place in a stand with an abundance of crop trees, the feller should desist.

b) Determine the direction of tree fall

Before making this decision, the feller examines:

- the verticality of the trunk;
- the estimated gravity centre of the crown (weight distribution within the crown in relation to trunk axis);
- the position of heavy branches;
- the risk of lodging onto adjacent trees;
- the risk of crashing onto a ground obstacle (rock, gully bed) or against a large tree in the line of fall;
- any attachment to the crown of a neighbouring tree by liana, where visible;
- wind direction and speed.

Where the preferred direction of fall deviates significantly from the natural lean of a tree, all these factors imply that directional felling without auxiliary means is extremely difficult, if not impossible in practice.

Felling can be considered «controlled» if conducted by experienced, well-trained crews. Controlled felling means that the tree has to be harvested:

- in the safest possible manner for the crew;
- for the efficient recovery of the felled trunk;
- without damage to the remaining stand and soil;
- for greatest ease of subsequent log extraction.

The feller determines the direction of fall on the basis of the most likely line of natural fall determined by weight distribution between stem and crown, and the direction of fall required to minimize damage and facilitate extraction.

Where these two directions are different, the feller has to note the natural lean of the tree and, where possible, manipulate the fall by applying appropriate techniques. The extent to which a tree can be felled in a direction other than its natural lean depends on the degree of lean, the weight of the tree and its species (mechanical wood properties). A range of 30 degrees each side of the imaginary line of natural fall is generally considered feasible. Beyond this, felling «against the lean» is considered impracticable and dangerous to crew safety. Using a tractor and winch as auxiliary means is made difficult by the density and poor visibility of tropical moist forests.

c) Prepare the tree for felling

The feller and his assistant have to carefully:

- clear the area around the tree of all obstructions (low branches, brush) in order to create a comfortable working space;
- scrape off the bark at the butt of the trunk by machete to remove pebbles or other objects that could damage the chainsaw;
- if necessary, cut all visible and accessible climbers around and next to the tree.

Several authors (Dykstra, Heinrich, Sist et al.) advocate liana cutting at least six months before felling, especially in Asia. In Africa, however, it is often difficult to spot lianas in the forest canopy because of the abundance of species and the vertical structure. Very few studies have been carried out on this subject in Africa, and the only significant ones question the utility of the practice.

Further research is therefore required. This costly activity should only be undertaken when there is a clearly visible dense web of lianas connecting the crowns of harvestable trees to adjacent trees.

d) Ensure the safety of the felling crew

The feller should:

- check for the presence of dead and potentially dangerous branches;
- check for the nearby presence of dead trees that could shatter under the impact of the felled tree;
- prepare two escape routes, cleared over a sufficient distance and designed to enable rapid withdrawal during tree fall. These routes should be at an angle of 135° to the supposed line of fall as a felled tree can sometimes slide back on its stump along the axis of fall. The felling crew should only start to withdraw when they can clearly see the direction of fall.

5.1.2 Techniques for controlled felling

The objectives of controlled felling are:

- to avoid damage to potential crop trees, regeneration and soil;
- to ensure maximum safety for the felling crew;
- to use as much of the felled tree as possible;
- to facilitate favourable log position for ease of extraction.

Controlled felling involves:

- making an undercut and a backcut to create a hinge and predetermine direction of fall to within 30° of either side of natural lean and thus guarantee a low-impact, efficient and safe fall;
- applying an undercut (scarf) and a backcut (main felling cut) as close to the ground as possible to obtain maximum volume of the most valuable part of the bole;
- removing buttresses and thus reducing the basal area of the trunk in order to proceed more quickly with the felling cut and avoid wood wastage (torn fibres from premature fall).

The tool most commonly used for commercial logging in Africa is the chainsaw. Currently employed models have a power rating of 7 to 9 HP and a guide bar length of 70 to 90 cm. The actual felling operation consists of four successive phases:

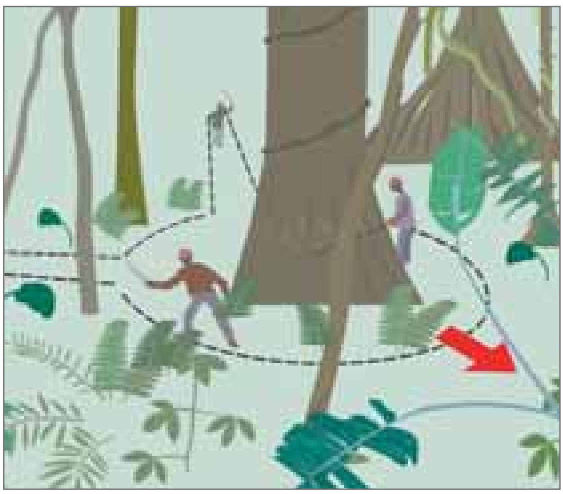

Figure 21 *Escape routes and clearing around tree base*

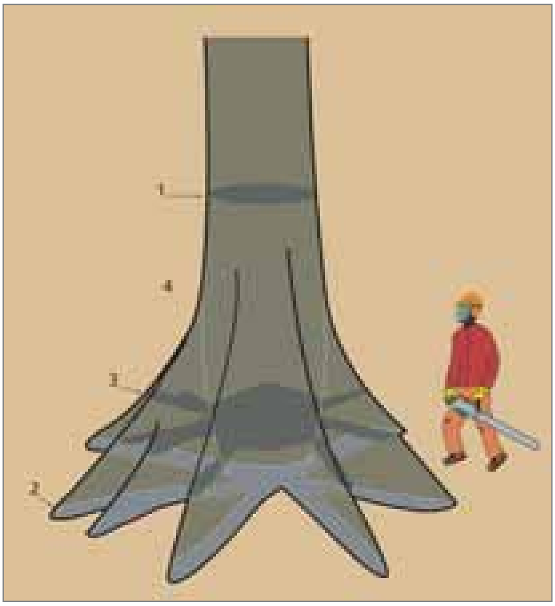

Figure 22 *Trunk cylinder (1), basal area (2), cutting height (3) and conical part (4) of a trunk with plank buttresses.*

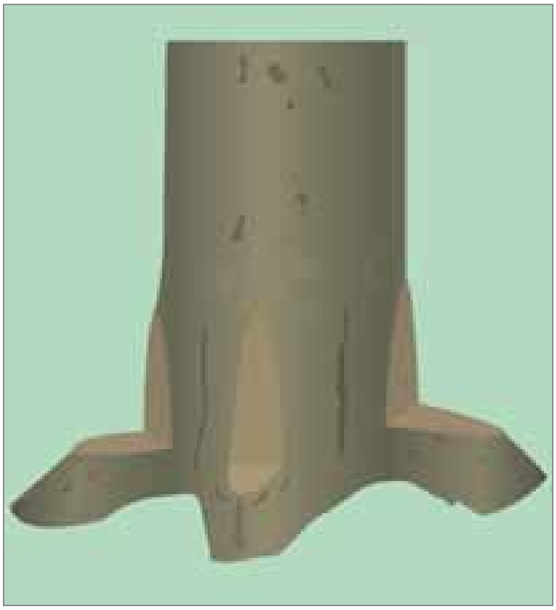

Figure 23 *Removing buttresses*

a) Determining felling height

Trees should be cut as close as to the ground as possible. Trees with few or no buttresses can be felled 30 cm above the ground. Otherwise the buttresses have to be removed for easier cutting at a height permitting maximum timber recovery at the base of the trunk.

Trees whose basal area does not have sufficient hinge wood to guide the tree during its fall (rotten wood or species with a conical base and pronounced plank buttresses) should be felled at a height where the stem has enough healthy wood in the central cylinder to form a sufficiently strong hinge. Whatever technique is applied, the operator should be able to keep both feet firmly on the ground and maintain a stable working position throughout the felling process.

b) Removing buttresses

Many tropical tree species have buttresses that should, whenever possible, be removed to obtain a cylindrical bole shape, reduce the basal area and enable the backcut to be completed before the tree starts to fall.

The complete removal of buttresses before felling presents a number of advantages:

- the cylindrical base of the bole makes it easier to apply the undercut and backcut as close to the ground as possible;
- the direction of fall is easier to control as the undercut can be placed in the central area of axial fibres;
- there is less risk of fibre splitting, since the backcut can be conducted more quickly;
- it permits the recovery of timber at the base of the stem that would otherwise be left on the stump.

With regard to its implications for felling practices, we distinguish three different situations:

- trees with cylindrical base and moderate buttresses (i);
- very large trees with cylindrical base and pronounced buttresses (ii);
- trees with conical base and buttresses in the form of high thick planks (iii).

(i) Moderate buttresses are removed in such a way that the base of the tree becomes a cylindrical bole by applying a horizontal and a vertical cut that join in a straight line. The horizontal cut should never exceed the cutting plane of the vertical cut.

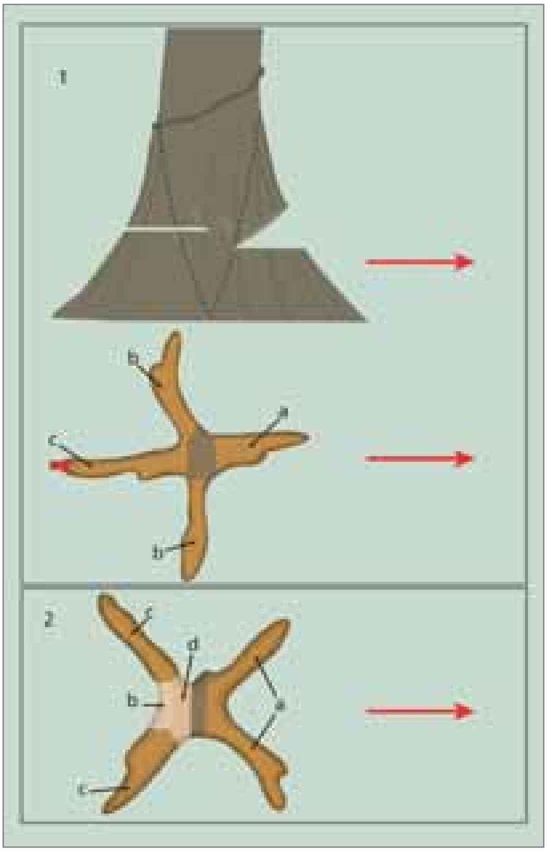

__Figure 24__ Configuration and sequence of cuts when felling trees with buttresses and conical base, (1) with and (2) without wedge.

(ii) In the case of trees with a very large diameter and a cylindrical base, it may be necessary not only to remove the buttresses but also to reduce the diameter of the trunk in order to apply the felling cuts. The trunk is trimmed with two 45° cuts or, if necessary, three cuts leaving more room to manoeuvre the chainsaw. Another option is to raise the felling height to a level where the trunk size is easier to handle for the chainsaw operator, although this implies considerable loss of timber.

(iii) The buttresses are not removed where they exist as high thick planks and where the conical base cannot provide enough hinge wood to hold the weight of the tree. Since the effort required in such cases to remove the buttresses is not justified by better timber recovery or working safety, the felling cuts are made with the buttresses in place (see Figure 24).

c) Making the undercut

The undercut or felling notch forms one part of the pivotal hinge around which the tree will tilt and fall to the ground. This hinge has two purposes: it determines the direction of fall and breaks the last uncut fibres by free flexion. The felling notch performs this dual role through its orientation and angle of aperture.

The felling notch has to have the following specifications:

- a depth of 1/5 to 1/3 of stem diameter;
- An angle between top cut and bottom cut of 30° to 45°, with the lower cut horizontal;
- a straight chord (without overlapping cuts), its perpendicular indicating the direction of fall.

The direction of fall is determined by the orientation of the felling notch. Because of the particular size characteristics of tropical trees, the undercut can only manipulate tree fall to within 30 degrees either side of natural lean.

The undercut comprises two cuts, one horizontal and the other at an angle of between 30 and 45 degrees. The first is applied horizontally into the side of the fall to a depth of one-fifth to one-third of the diameter of the stem base. The second cut is slanted at an angle of 30 to 45 degrees with the horizontal cut which it should meet along a straight line (chord) perpendicular to the direction of fall.

The line where the top and bottom cut meet (the chord or hinge edge) must be perfectly straight and perpendicular to the line of fall. The top and bottom cut forming the edge of the hinge should not extend beyond their intersection, if the hinge is to function properly. If the base of the undercut is not horizontal, the bending stress causes significant tension which can lead to fibre tearing.

With fragile species (Okoumé, Mahogany, Limba), any buttress in the line of fall should be removed to prevent it from acting as a wedge against the stem base and causing it to burst.

The greater the lean of tree, the deeper the undercut has to be to reduce the risk of splitting in the butt end. The straighter and more balanced a tree, the more the undercut can be restricted to one-fifth of the apparent diameter.

d) Making the main felling cut or backcut

The main felling cut or backcut has to be higher than the undercut. During its fall, the stem has to be able to rest on the rear of the stump so that the feller working behind the tree can operate in complete safety.

The best results are obtained when there is a 15 to 30 cm difference in height between the bottom of the felling notch and the backcut. In the case of species with sapwood tending to split, a shallow cut should be made on either side of the hinge.

The backcut should proceed in such a way that the hinge (the uncut wood between the chord of the felling notch and the line of the backcut) remains symmetrical to the direction of fall. By guiding the chainsaw from one side of the stem to the other, the feller tries to cut parallel to the notch chord in order to achieve the necessary symmetry.

There are different backcut techniques for different trunk diameters:

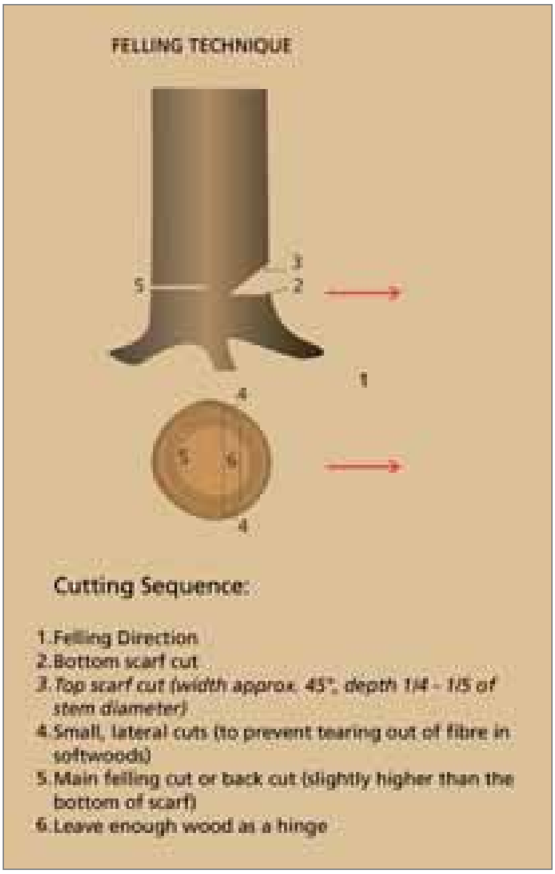

Figure 25 *Diagram of the principle of chainsaw felling*

(i) If the diameter is bigger than the length of the guide bar, the cut begins on the right side (looking towards the direction of fall) and then moves in various stages around the trunk towards the left. There are two opportunities to check that the back of the hinge forms a straight line: after starting the backcut and when reaching the opposite side.

If the trunk is equal to or more than twice the length of the guide bar, a plunge cut is required from the side of the felling notch in order to sever the centre of the trunk. The fanlike felling cut explained above is then applied.

5.1.3 Felling safety

Felling in closed tropical forests is very dangerous for the operator, as the density of undergrowth obstructs visibility and retreat during tree-fall. Torn or dead branches falling off the crown as well as decaying or rotten trees are another potential cause of serious accident.

Risks when felling in tropical forests where trees are intertwined and their crowns interlaced with lianas are:

- falling trees often bring other trees down;
- branches of falling or adjacent trees break and fall or kick backwards;
- lianas are torn and cause whiplash.

Important rules for preventing accidents during tree felling:

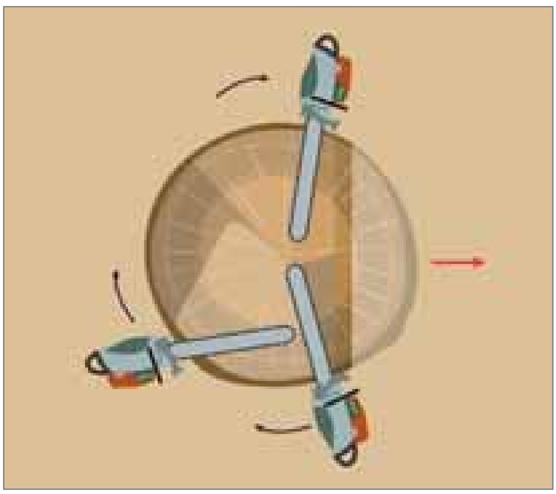

Figure 26 *Fanlike felling cut (trunk diameter bigger than length of guide bar)*

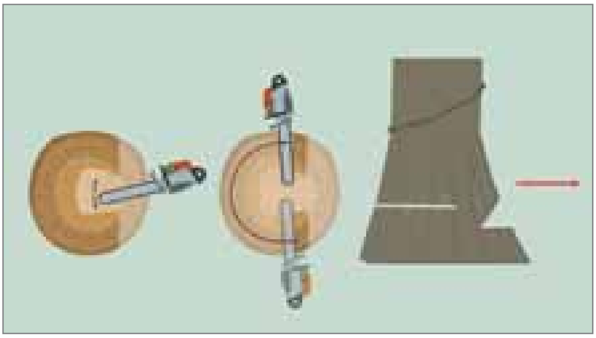

Figure 27 *Plunge backcut (trunk diameter equal to or more than twice the length of guide bar)*

- felling should only be done by skilled, trained and healthy workers who use chainsaws fitted with all safety devices (including anti-vibration systems and chain brakes activated manually and automatically in the case of kickback), the shortest possible guide bar and personal safety equipment;
- never move around with the saw chain in motion;
- a properly sharpened chain makes work easier and raises productivity and safety. Mechanical sharpening of chains at the camp workshop is recommended, with the feller depositing the used set of chains in the evening and picking up a new set of sharpened chains for the next day. The chains are better and more quickly sharpened this way than having the chainsaw operator sharpen them himself at the felling site;
- workers should dispose of and wear appropriate safety equipment:
  - a safety helmet and protective footwear are essential, although some fellers still prefer to work barefoot;
  - face shields (visors) and ear muffs are also essential, although uncomfortable in a tropical climate;
  - safety trousers in fluorescent colours are recommended;
- just as dead branches and large lianas have to be spotted before felling, care is also needed over crowns or branches broken by the falling tree, whether from the felled tree or from adjacent trees;
- the feller should always give a warning shout before starting the backcut and should only proceed on hearing no response;
- once the felling of a tree has been started, it must be completed;
- lodged or hung-up trees must always be brought to the ground by skidding tractor winch and cable. Never cut adjacent trees or the tree holding the lodged tree to make it fall. Never work below a hung-up tree and never buck the stem nor climb on it to bring it to the ground.
- tree felling should be suspended under windy conditions as the wind can affect the direction of fall.

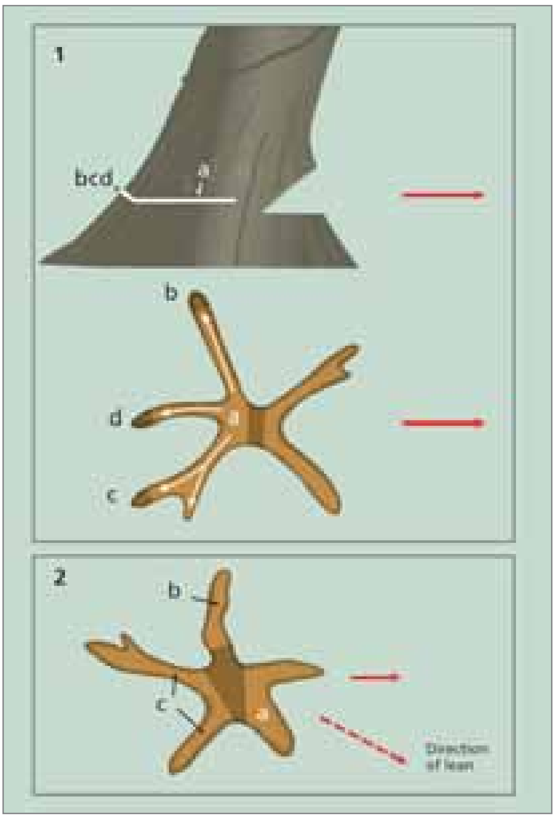

Figure 28 *Configuration and sequence of cuts for felling trees with a (1) forward and (2) sideward lean*

5.1.4 Felling impact

Poorly conducted or controlled felling can have the following negative impact:

- extensive damage to the remaining stand (broken branches, topped or uprooted trees);
- financial implications as damage (ring shakes, splits, cracks) incurs significant loss of timber;
- risk to life and health of workers.

5.1.5 Recommendations

Reduced-impact harvesting practices in felling:

Controlled felling techniques are used to have trees brought down into already existing gaps, along skid trails or onto the crown of an already felled tree to break its fall and avoid damage to the remaining stand.

Where possible, tree-fall should be at an angle of 30° to 60° to the skid trail to facilitate extraction.

The felling of a exploitable tree could break or damage several close future crop trees because of its direction of lean. In such cases, the head of the spotting crew should inform the harvesting supervisor who decides whether the stem in question should be felled or not.

Trees should not be felled downwards on hilly terrain, unless this is unavoidable. Felling in parallel to contour lines reduces the risk of breakage to felled and adjacent trees.

Felling should cause minimum damage to soil and watercourses, and particular care should be taken to avoid bringing trees down across watercourses. Where this occurs, trees should be extracted carefully, causing the least possible damage to banks and debris should be removed from sensitive zones.

Trees beside a sensitive zone should be felled outwards from the zone.

Crowns and branches should not be moved or extracted from the forest, but left to decompose on site.

Controlled felling reduces timber loss and harmful impact, raises productivity and safety, and facilitates all subsequent operations. It is therefore essential to give felling crews specialized basic training in controlled felling practices, followed by periodic refresher training.

SECTION 5.2

Objectives:

- to ensure maximum safety by applying recommended cutting techniques;
- to maximize timber recovery from felled tree;
- to trim the log for more efficient and careful extraction.

TOPPING AND BUTT TRIMMING

5.2.1 Topping

The crown is always separated from the trunk at the felling site. Crown removal or topping is normally done under the first large limb. It can be done by the feller himself immediately after felling, by a special crew operating a few days or several weeks after felling, as dictated by the species (many loggers prefer this practice which allows the tree to settle before extraction, to release sap pressure and thus to eliminate or reduce the internal tensions that can trigger splitting) or at the time of extraction by a chainsaw operator working alongside the skidding crew.

In the case of fragile species, the work has to be done quickly to provide freshly felled timber and to reduce the risk of insect or fungal attack and thus avoid chemical treatment.

5.2.2 Butt trimming

The stem base is trimmed whenever its weight or shape could hamper extraction. Butt trimming takes place at the same time as topping. It is not necessary if the buttresses have been cornered before felling or when the operator removes them before skidding to facilitate movement and recover an extra section of timber.

5.2.3 Recommendations

Topping and butt trimming are done in the forest under difficult conditions of work and visibility (the trees often lie in awkward positions, cutting sites are not very accessible, the distribution of tensions is difficult to gauge), so experienced crews trained in RIL techniques and safety measures are required.

Reduced-impact harvesting techniques for topping and butt trimming:

- create conditions for the marketing of hitherto abandoned grades and dimensions (timber from the flexuous parts of the bole and the large limbs);
- give clear instructions to felling crews on required grades, lengths and diameters;
- top beyond the first large branch, to the extent possible;
- again to the extent possible, recover trunk butts with buttresses by cutting lengthways to obtain a cylindrical shape.

It may be useful to do the topping and butt trimming at the same time as the extraction, as combining these activities helps recover more wood and enhances safety for the chainsaw operator, as it clears the cutting site that may otherwise be obstructed by tangled branches.

On the other hand, it means the crawler tractor has to enter the clearing, which causes more serious damage than if it were only to winch the pre-topped trunk or position it for extraction.

This method should therefore only be adopted where a tractor is absolutely vital to ensure safe and efficient topping, and to avoid wastage of timber. Before engaging in heavy extraction entry, all other necessary measures should be taken to ensure maximum safety and recovery, training of crews in cross-cutting techniques (cf. 5.4.1) and encouragement of routine implementation through monetary incentive (see Chapter 9).

The choice of best topping and butt trimming practice, and the decision whether to extract the timber in trunk or log form (see 5.3.5) will depend on local conditions (size and tensions of tree to be topped, accessibility of crown and topography of terrain). In any case, the action chosen will have to meet the three RIL operating criteria: maximum recovery of timber, maximum safety and minimum impacts throughout production (felling, conversion and extraction).

Wood hitherto left in the forest should be used to maximize returns from the resource and ease pressure on the forest. Tree waste at the felling site should be recovered, although this does facilitate poaching and illegal logging. Conversion offcuts should be regularly collected from landings and taken to processing plants outside the forest or processed on-site in mobile sawmills.

Cross-cutting techniques applying to topping and butt trimming are explained and illustrated in detail in Section 5.4.

SECTION 5.3

Objectives:

- to minimize damage to remaining stands, soil and watercourses;
- to minimize disturbed area between skid trail and road networks;
- to reduce soil compaction by using appropriate technology and low-pressure tyres;
- to optimize extraction productivity and safety.

EXTRACTION

5.3 EXTRACTION

Extraction is the first stage in the transport of logs from stump to sawmill log yard. Since it involves moving logs from felling site to roadside landing by means of heavy equipment, it can cause severe impact on the environment in a variety of ways.

First, the tractor clears a track to the logs to be extracted, uprooting and toppling trees along the way. The tractor blade is sometimes used to grade the soil for easier skidding.

The logs are then dragged along the ground, disturbing the soil (erosion and sedimentation of streams) and damaging trees next to the skid trail. Watercourses crossed can be contaminated by debris and leaking fuel or lubricant.

Because of their versatility crawler tractors are used much too often for skidding, causing far more damage to the remaining stand and soil than wheeled skidders.

With increasing terrain slope skidding damage increases dramatically (vast areas are cleared and disturbed by crawler tractor for levelling and pre-skidding).

Timber extraction is in two stages:

a) Pre-skidding

During pre-skidding, logs are moved up to 30 metres from the felling site to the nearest point of access of the wheeled skidder. This should, as far as possible, be done by winch and cable. Approaching a trunk by crawler tractor should be the exception, resorted to for instance, when the trunk has become stuck during winching and a tractor blade is required, or when a tree has fallen into a difficult position for skidding on rugged terrain.

Using a tractor blade should also be the exception. The direction of tree-fall should normally be the angle best suited for winching to the skid trail without the need for repositioning by blade. The cable on the crawler tractor winch should be at least 30 m long.

b) Skidding

The logs are then dragged along the skid trail to the landing for subsequent loading. Skidding is in one or two phases covering some hundreds or thousands of metres, beyond which it is more economical to build a secondary or feeder road to haul logs on trucks rather than drag them along the ground.

5.3.1 Extraction techniques

The only technique actually used in the dense production forests of tropical Africa, once monthly production exceeds 1 000 m^3, is skidding by crawler tractor and/or articulated wheeled skidder equipped with winch and cable. Other methods involving draught animals, cable yarding, balloons or helicopters are not employed.

The decision on the type of machinery to use will depend on:

- the size of the logs;
- the harvested timber volume per hectare;
- the topography and soil conditions;
- the appropriate road network density.

Crawler tractors have greater tractive power than wheeled tractors for the same weight and engine size, which is why they are preferred for skidding large logs, where high tractive power is more important than high speed of travel.

Crawler tractors:

Two main types are used: the 215 HP class and the 175 HP class.

Wheeled tractors:

Nowadays almost all models of articulated tractor are in the 190 HP class .

All machines should be equipped with a skidding winch attached to the rear. The choice of tractor model will depend on the size of logs, topography and terrain:

- in the case of rugged terrain with medium-size trees, a lighter crawler tractor with greater manoeuvrability will be preferred to a more powerful but heavier machine.
- wherever possible, wheeled tractors should be used as these are more mobile, easier to manoeuvre and less detrimental to the soil and remaining stand.

Crawler tractors cause extensive damage to the soil and their use should be restricted to the pre-skidding of logs that are too heavy to be winched by wheeled tractors under difficult conditions. Crawler tractors should always stay on the skid trail and haul logs by winch. Moving a log with the blade should only be permitted under exceptional circumstances.

On gentle terrain (gradient below 20 percent), a wheeled logging arch can be hooked to the crawler tractor. This device, which consists of a projecting arm mounted on a wheeled chassis, lifts the log at one end and thus eases the weight on the tractor. The head of the arch is fitted with four rollers that guide the winch cable to an elevated position. The advantage of using a logging arch is that it reduces ground friction and thus log resistance. It also reduces soil scouring and enhances tractive power. However, it makes the tractor more difficult to handle and can easily cause it to tilt over when lateral traction is too strong.

There are two possible extraction procedures, depending on terrain conditions, exploitable timber volume and size of trees: single-stage skidding directly from stump to roadside landing; and twin-stage skidding with conveyance interrupted at an intermediate landing halfway between stump and roadside landing.

Single-stage extraction is employed:

- on easy terrain that permits a high-density network of comparably inexpensive roads, conjugated with short skidding distances of a few hundred metres at most;
- in a forest with medium-to-high intensity timber extraction where investment in road construction can be easily recovered.

Single-stage extraction is usually by crawler tractor, sometimes wheeled skidder. Crawler tractors operate alone, while wheeled skidders generally operate in tandem with crawler tractors, the latter extracting the larger trunks, the former the smaller and lighter stems along pre-opened trails.

Twin-stage extraction applies:

- on difficult terrain where increased skidding

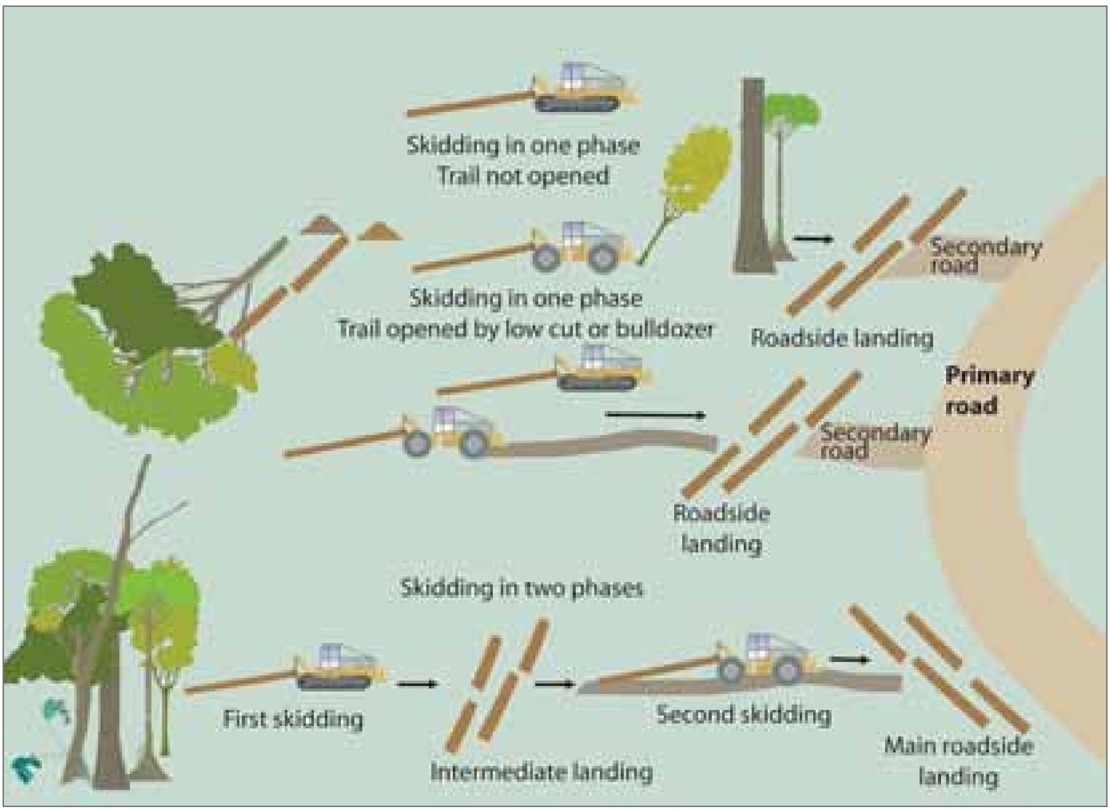

Figure 29 *Methods of tractor extraction*

distance is the necessary consequence of low road density. The respective roles of the crawler tractor and the wheeled skidder are then clearly defined. The crawler tractor travels to the vicinity of the trunk as it alone can operate on very steep and rugged terrain, blading its own trail if necessary and it alone has the capacity to extract trunks from difficult positions. The wheeled skidder is then used to move the cross-cut logs along the skid trail;
- in a forest with low extraction intensity, where two-stage skidding is an appropriate method of extracting timber with minimum investment in a road network.

Two-stage extraction comprises:
- primary skidding by crawler tractor along a few hundred metres from stump to intermediary landing where the logs are cross-cut;
- secondary skidding along 500 to 2 000 metres from intermediary to roadside landing by wheeled skidder on trails opened and, if necessary, levelled by bulldozer.

A skid trail carrying a large number of skidding cycles can in fact be equated with a secondary road.

Although crawler tractors are often used for the first stage of extraction (which in this case corresponds to extended pre-skidding), their use should be restricted to initial winching during pre-skidding, leaving most of the distance to be covered by wheeled skidder to lessen the detrimental impact of extraction.

Skidding should be upwards towards the ridgeline where possible, since:
- runoff waters flow towards adjacent vegetation and not onto the main trail;
- the number of watercourses to be crossed is generally lower;
- it is easier for the driver to control load and tractor, particularly on wet soil;
- it is easier for the helper to carry the log cable downwards;
- there is greater operational safety for workers and equipment.

5.3.2 Characteristics of skid trails

There are two types of skid trail:
- Main trails designed to withstand more than 10 skidding cycles. These are generally laid out along ridgelines to facilitate upward skidding and may be bladed.
- Secondary trails used for one or a few cycles whose clearing does not involve blading, except on difficult terrain.

Figure 30 *Trail network for skidding towards ridgeline*

Shrubs and small stems cut while clearing the trail should be left on the trail bed as a protective litter against compaction and erosion.

5.3.3 Construction of skid trails and landings

Objectives of this Code:
- to minimize the size of landings and thus reduce the cleared productive area;
- to build landings and trails in such a way that watercourses are safeguarded;
- to reduce damage to the soil;
- to minimize gradients and keep them within 20 percent if possible;
- to promote skidding towards ridgelines and restrict the crossing of watercourses;
- to optimize efficiency, productivity and safety of operations.

The landing and skid trail layout was already planned and ground-marked by machete or tape when preparing the harvesting area (cf. 3.5.2).

Roadside landings are generally prepared at the same time as the secondary roads. However, where the extraction process involves intermediate landings in the forest, these are cleared at the same time as the main skid trail. As a general rule, main skid trails are established before felling, while secondary trails can quite easily be laid out afterwards, provided they have been marked beforehand.

Landings

Location

The location of landings should be indicated on the harvesting map. They should be:

outside protected and environmentally sensitive areas;

- at least 30 metres from environmentally sensitive areas;
- on dry, well-drained or easy-to-drain terrain, preferably along a ridgeline or on a gentle slope to minimize cut-and-fill earthwork;
- on a site where mud, debris from cross-cutting and other waste cannot reach watercourses;
- at the entrance of one or several skid trails.

The number of landings should be kept to a minimum to reduce the area cleared for infrastructure. A landing is not needed if a trail only evacuates a few logs which can be bucked and loaded at the roadside.

However, a landing should never be placed on the side of the road opposite to that of the skid trail and tractors should not be allowed to cross a road while skidding a log, as buttress wings can cause severe harm to the roadway, and the compacted surface course can suffer damage that even prompt filling and grader resurfacing cannot repair. The result would be a road section vulnerable to potholes and infiltration of rainwater.

Size of landings

The average roadside landing covers 600 to 1 200 m². In-forest intermediary landings are generally smaller because they only serve as transit points and not as repositories of buffer stock, which is sometimes a function of roadside landings. Ideally, landings should not cover more than 1 000 m².

Construction and use of landings

Landings are levelled with the equipment used for road construction. Their utility is by nature temporary, as limited to the duration of timber evacuation. Grading should be designed to facilitate the drainage of rainwater. Earthwork berms, bucking waste, bark and sawdust should be disposed of in such a way as not to impede drainage.

Where possible, the humus layer removed during grading should be stored separately for re-laying after the completion of operations.

Levelling a landing site by tractor blade should be avoided during the rainy season to keep it operational.

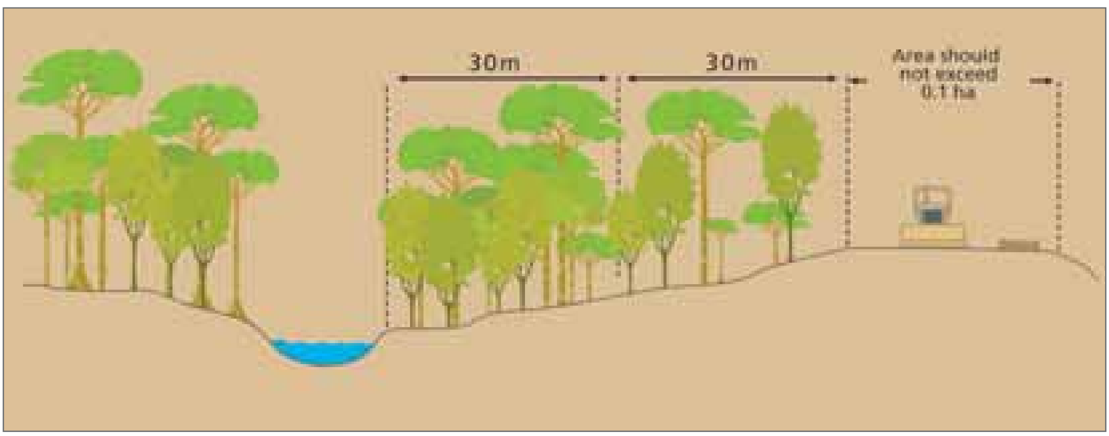

Figure 31 *Location of a landing*

Skid trails

Any skidding in protected areas is of course prohibited. Skid trails should be located:

- at some distance from watercourses and unstable terrain;
- away from environmentally sensitive areas close to river banks (any authorized felling in these areas should always be away from the stream and the trees extracted by winch and cable);
- on ridgelines to facilitate drainage;
- with due care for future crop or heritage trees.

Waterway and gully crossings should be kept to a minimum and should always be less than 4 m in width. Where unavoidable, crossings should run at right angles to the bank on a rock or gravel bed. Otherwise, the bed should be protected by logs (bolts) laid parallel to waterflow, subsequently removed after skidding to restore the water regime.

Construction

Skid trails can be opened by machete, chainsaw (low cut) or tractor.

a) The low cut is recommended for secondary trails that will only be used for one or a limited number of skidding cycles. Cut material can be left where it is to protect the soil. This is the environmentally soundest practice as crews open the trail along a marked course and clear no more than tractor width, while their daily production target is measured in length of skid trail cleared.

b) Skid trails can also be opened by wheeled skidder clearing its own trail as it moves along the path indicated by the marking crew, or by crawler tractor working for one or several wheeled tractors. Main skid trails are cleared well before extraction.

The wheeled tractor is only used for easy terrain and sparse undergrowth as it is not suited to this work, its blade being too weak and poorly positioned to clear, and much less grade a trail.

Certain operational rules need to be observed:

- no grading should be allowed on trails with a gradient of less than 20 percent;
- maximum gradients should be 25 percent for main trails and 45 percent for secondary trails;
- the maximum gradient for laying a cut-and-fill trail is 45 percent;
- cut-and-fill grading should be forbidden on secondary trails and avoided on main trails;
- cut-and-fill trails should have a cross-slope of 2 to 5 percent for water runoff;
- the maximum width should be 4 m, i.e. the width of a tractor blade;
- trails should be as straight as possible, avoiding tight curves that could damage trees beside the trail.

Figure 32 *Provisional crossing of a watercourse using bolts*

5.3.4 Impact of extraction

The following impact is always extremely negative:

- soil damage caused by the clearing of trails and landings and the passage of heavy machinery and logs: various degrees of soil compaction, rutting, leaching and scalping;
- log-caused damage to vegetation and bark wounds on trees beside the skid trail.

Precautions to reduce this impact:

- the least blading possible; clearing by machete and laying branches on the ground as protective litter;
- trails as straight and narrow as feasible;
- optimal log length according to terrain and sinuosity of skid trail;
- butted logs (without buttress wings).

5.3.5 Recommendations

Reduced impact logging practices for skidding: Opening of trails and extraction by crawler tractor should be limited to terrain with a maximum gradient of 45 percent (20 degrees), above which either other extraction techniques should be used or the area should be classified as non-harvest.

The tractor operator should stick to the flagged route and avoid opening new trails.

Trails should be as straight as possible, avoiding excessively tight curves that could damage trailside trees during skidding.

Equipment should be appropriate to terrain and load (low-pressure tyres).

Whenever possible, extraction should be by wheeled tractor, winch and cable.

With or without load, tractors should always travel with their blades raised. The driver should only lower the blade when needing ground support, as for winching.

The tractor is generally not allowed to leave the trail, particularly during pre-skidding. The trunk should be moved away from the stump by winch action and not by pushing it with the blade, which is still the general practice because drivers and helpers are inadequately trained.

The tractor should never shovel itself into the ground for winching; it is better to lock against an unprotected tree, which can then be sacrificed if necessary.

The choker-setter should know how to place the cable so the log rolls into a better position for winching.

The tractor should always winch in a straight line, i.e. the tree, cable and winch should form one line and never be at an angle.

The driver should always reel in the winch cable to the top to wedge the log under the winch and raise it as high as possible off the ground.

Workers should never stand between the winch and tree during winching. Whiplash from a broken cable can be fatal.

When skidding downhill, a driver should never allow a log to pass the rear of the tractor, much less slide along the side of the tractor.

Although maximum timber recovery requires that the whole stem be extracted for optimal bucking at the landing, a log may sometimes have to be cross-cut at the felling site to reduce extraction damage. The best course of action will have to be determined on the basis of the local situation (length and weight of log, terrain and tractive power of machinery).