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
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ISBN 92-5-104982-3

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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.

M. Wulf Killmann
Director
Forest Products and Economics Division
Forestry Department
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 Dipopoundji and Boute-Mbombo in the Central African Republic; Boundzanga, Boute and Matingau 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.
# TABLE OF CONTENTS

**FOREWORD**  
**ACKNOWLEDGEMENTS**  
**ABBREVIATIONS**  
**PREFACE**  

## 1 INTRODUCTION

1.1 Purpose  
1.2 Approach  
1.3 Scope  
1.4 Role of partners  
1.5 Design and structure of the Code  
1.6 Impact of harvesting in a regional context  
  1.6.1 Potentially damaging practices  
  1.6.2 Environmental and social impacts

## 2 SUSTAINABLE MANAGEMENT OF PRODUCTION FORESTS

2.1 Forests and their multiple functions  
2.2 International context  
2.3 Planning sustainable management and forest harvesting  
  2.3.1 Strategic (long-term) management plan  
  2.3.2 Tactical (mid-term) management plan  
  2.3.3 Annual plan of operation or coupe

## 3 PRE-HARVEST PLANNING

3.1 Mapping tools  
3.2 Geographic Information System - a management tool  
3.3 Harvest survey  
  3.3.1 Survey criteria  
  3.3.2 Description of the pocket inventory  
  3.3.3 Description of the inventory by systematic survey lot  
  3.3.4 Impact of survey activities on the forest  
3.4 Non-harvest areas  
  3.4.1 Delimitation  
  3.4.2 Special precautions  
3.5 Tree spotting and marking – planning and optimizing the extraction layout  
  3.5.1 Layout of the secondary road network  
  3.5.2 Preparing the harvesting block – planning and layout of skid trails and landings  
3.6 Producing the operational harvesting map
## 4 Planning and Construction of Road Network, Drainage Structures and Water Crossings

### 4.1 Road classification

### 4.2 Characteristics of the road network

### 4.3 Road characteristics
- **4.3.1** Cross section
- **4.3.2** Horizontal alignment
- **4.3.3** Longitudinal profile

### 4.4 Road construction
- **4.4.1** General rules
- **4.4.2** Layout
- **4.4.3** Clearing
- **4.4.4** Blading (earthwork)
- **4.4.5** Sunlight exposure
- **4.4.6** Roadway compaction and improvement

### 4.5 Drainage: drains, outlets, culverts and box drains
- **4.5.1** Avoiding water penetration
- **4.5.2** Evacuation of rainwater runoff: side drains, outlets and culverts
- **4.5.3** Drainage of roadway structure

### 4.6 Crossing watercourses: drifts and bridges
- **4.6.1** Drifts
- **4.6.2** Bridges

### 4.7 Road maintenance
- **4.7.1** Regular maintenance
- **4.7.2** Resurfacing
- **4.7.3** Other maintenance operations

### 4.8 Impact of road construction

### 4.9 Recommendations

## 5 Implementing Harvest Operations

### 5.1 Controlled felling
- **5.1.1** Preparation
- **5.1.2** Controlled felling techniques
- **5.1.3** Felling safety
- **5.1.4** Felling impact
- **5.1.5** Recommendations

### 5.2 Tapping and butt trimming
- **5.2.1** Tapping
- **5.2.2** Butt trimming
- **5.2.3** Recommendations

### 5.3 Extraction
- **5.3.1** Extraction techniques
- **5.3.2** Characteristics of skid trails
- **5.3.3** Construction of skid trails and landings
- **5.3.4** Extraction impact
- **5.3.5** Recommendations

### 5.4 Cross-cutting, marking and preserving
- **5.4.1** Cross-cutting
<table>
<thead>
<tr>
<th>13 RELATIONS WITH LOCAL COMMUNITIES</th>
<th>112</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.1 Present situation</td>
<td>114</td>
</tr>
<tr>
<td>13.1.1 Institutional framework</td>
<td>114</td>
</tr>
<tr>
<td>13.1.2 Expectations of local communities</td>
<td>114</td>
</tr>
<tr>
<td>13.2 Practical recommendations</td>
<td>114</td>
</tr>
<tr>
<td>13.2.1 Steps for developing social aspects of sustainable forest management</td>
<td>114</td>
</tr>
<tr>
<td>13.2.2 Prerequisites</td>
<td>115</td>
</tr>
<tr>
<td>13.2.3 Key factors for successful collaboration</td>
<td>115</td>
</tr>
<tr>
<td>13.2.4 Consultation of the local community: social study</td>
<td>116</td>
</tr>
<tr>
<td>13.2.5 Coordinating committee</td>
<td>116</td>
</tr>
<tr>
<td>13.2.6 Proposed rights and obligations</td>
<td>117</td>
</tr>
</tbody>
</table>

GLOSSARY 118

BIBLIOGRAPHY 125

SOURCE LIST 134
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-Foret
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-Foret)

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 out-migration;
- 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.
1.1 PURPOSE

This 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.

<table>
<thead>
<tr>
<th>No. of stems extracted/ha</th>
<th>Africa</th>
<th>America</th>
<th>S-E Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>2-5</td>
<td>6-20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commercial volume extracted (m³/ha)</th>
<th>Africa</th>
<th>America</th>
<th>S-E Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-30</td>
<td>10-50</td>
<td>50-150</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damaged stand (%)</th>
<th>Africa</th>
<th>America</th>
<th>S-E Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>25-40</td>
<td>50-60</td>
<td></td>
</tr>
</tbody>
</table>

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.
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
1.6.2 Environmental and social impacts

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

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

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:
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
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 erosional 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 of 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 m³/ha provides a more comprehensive picture of improvements that can be attributed to RIL.

<table>
<thead>
<tr>
<th>Impact indicators</th>
<th>Impact reduction from RIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of skid trail</td>
<td>- 57 %</td>
</tr>
<tr>
<td>Length of trail per m² harvested</td>
<td>- 20 %</td>
</tr>
<tr>
<td>Average gradient of trail</td>
<td>- 16 %</td>
</tr>
<tr>
<td>Soil area exposed</td>
<td>- 49 %</td>
</tr>
<tr>
<td>Area affected</td>
<td>- 38 %</td>
</tr>
<tr>
<td>Trees damaged</td>
<td>- 29 %</td>
</tr>
</tbody>
</table>

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.

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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 biomoss, 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 at 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 woodedlands;
• enhancing the protection, sustainable management and conservation of all forests, and the greening of degraded areas, through rehabilitation, reafforestation, 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 apted 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 impartment, 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.

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 rack, type of soil, above which on area becomes unharvestable;
- wetlands and flood-prone areas;
- obligatory or impassable 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.

Identifying the resource
Two key chapters deal with mapping, photo-interpretation and forest stratification.
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 contiguous 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.
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 quod maps with or without contour lines (40 m intervals);
- 1:200 000 thematic maps: hydrography, geology, pedology, morphology, vegetation;
- 1:50 000 quod maps with contour lines (20 m intervals);
- 1:50 000 LANDSAT or SPOT satellite imagery;
- 1:200 000 rador 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;
- savannas;
- 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.

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 marking of skid trails and landings
- Marking of trees next to skid trails and around harvestable trees

Harvesting:
- Cleaning 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
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 plat system;
- forest mensuration, flora, fauna and environment data gathered from sample plats 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 coupses, 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 porcelling 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 crap 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.
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 1:5000 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 gauge) 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 shape correction, by plastic tape, 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
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 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: Okaumé; 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.

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**Figure 3** Inventory by systematic survey lot

**Figure 4** Organizing the survey
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 point 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:

<table>
<thead>
<tr>
<th>Watercourses:</th>
<th>Width of sensitive area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width &lt; 10 m</td>
<td>10 m on each bank</td>
</tr>
<tr>
<td>Width &lt; 20 m</td>
<td>20 m on each bank</td>
</tr>
<tr>
<td>Width &lt; 40 m</td>
<td>30 m on each bank</td>
</tr>
<tr>
<td>Gully</td>
<td>10 m on each side</td>
</tr>
<tr>
<td>Creek or backwater</td>
<td>5 m on each side</td>
</tr>
<tr>
<td>Swamp</td>
<td>10 m from edge</td>
</tr>
</tbody>
</table>

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.
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:
- 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

---

**Figure 5** Watercourses and sensitive areas
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 black – 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 crisscrossed 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 (crass, 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 lag fram 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
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 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 same 25 to 40 years later. Construction standards and resilience can therefore be lower than for public roads;
- same 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.

<table>
<thead>
<tr>
<th>Minimum radius</th>
<th>Recommended radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentle terrain</td>
<td>40 m</td>
</tr>
<tr>
<td>Steep terrain</td>
<td>20 m</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Radius of curve</th>
<th>Widening</th>
<th>Adjustment length</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 m</td>
<td>2.5 m</td>
<td>20 m</td>
</tr>
<tr>
<td>50 m</td>
<td>1.0 m</td>
<td>30 m</td>
</tr>
<tr>
<td>100 m</td>
<td>0.5 m</td>
<td>30 m</td>
</tr>
</tbody>
</table>

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.

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.

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Braking distance (m)</th>
<th>Visibility distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>20 m</td>
<td>40 m</td>
</tr>
<tr>
<td>50</td>
<td>45 m</td>
<td>90 m</td>
</tr>
<tr>
<td>60</td>
<td>60 m</td>
<td>120 m</td>
</tr>
</tbody>
</table>

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.

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 dawndrive gradients. The following maximum road grades should be observed:

<table>
<thead>
<tr>
<th>Travelling laden</th>
<th>Travelling unladen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentle terrain</td>
<td>4 %</td>
</tr>
<tr>
<td>Steep terrain</td>
<td>8 %</td>
</tr>
</tbody>
</table>

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<td>Steep terrain</td>
<td>8 %</td>
</tr>
</tbody>
</table>
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 maved 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 far 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 stranger 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 road line 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 sail 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 layer, 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](image)

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;
- on 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 cluyey 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 lagging 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 evocuated 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 compaction 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](https://example.com/figure14.png)

**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 on 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 30° 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.

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, an 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 far safety reasons. A bridge should never be built an curve;
• the bridge should be placed where the current is as regular as possible;
• it should be built on solid foundations, an 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
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 water flow.

The substructure: abutments and piers
The abutments support and anchor the bridge deck.

a) Abutments made of log stocks

Bank abutment
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.

Canadian log crib abutment
Where necessary, to raise the bridge deck to a higher level or to improve the anchorage of the abutment, the logs are stocked in right-angled layers (cribings) 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.

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:

<table>
<thead>
<tr>
<th>Span between stringers*</th>
<th>10 m</th>
<th>12 m</th>
<th>14 m</th>
<th>16 m</th>
<th>17 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congotali</td>
<td>58 cm</td>
<td>66 cm</td>
<td>74 cm</td>
<td>81 cm</td>
<td>85 cm</td>
</tr>
<tr>
<td>Bilinga</td>
<td>63 cm</td>
<td>71 cm</td>
<td>79 cm</td>
<td>86 cm</td>
<td>90 cm</td>
</tr>
</tbody>
</table>

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:

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 end 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 soil or debris likely to narrow the river bed or restrict water flow 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 (shaats, 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 substrato, 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.
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:

- 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.

Figure 20 Harvesting map

- 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.
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 lianes, 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 bockcut 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 end safe fall;
• applying an undercut (scarf) and a bockcut (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](image)
a) Determining felling height
Trees should be cut as close 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.

(iii) 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:

(j) 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 25** Diagram of the principle of chainsaw 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 comp 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 decampose 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.
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 ofts 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.
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](image-url)
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 ond, 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.

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](image-url)
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.

![Skid trail](image)

**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).
5.4 CROSS-CUTTING, MARKING AND PRESERVING

5.4.1 Cross Cutting

A felled tree has to be converted at felling or landing site to obtain a merchantable or transformable product. End use will determine which parts of the stem will be cross-cut into logs. Most timber from tropical forests is transformed into rotary cut veneer which requires straight cylindrical logs. Secondary qualities and species less in demand on the global or domestic market are usually left in the forest, thus significantly lowering harvesting intensity and timber recovery and posting a high impact for each cubic metre of extracted timber. Low harvesting intensity in West and Central Africa therefore contrasts with harvesting impact, in terms of cleared surface area and damage to the remaining stand and soil (specific impact).

Cross-cutting is one of the most important operations for optimizing efficiency and reducing specific impact. Maximum timber recovery per felled tree keeps harvesting to a smaller surface area for a given level of production, raises productivity and reduces disturbance to remaining stand and soil. The aim when cross-cutting is therefore to maximize the volume and value of timber processed from a felled tree.

The first operation is to eliminate parts of the stem that have no commercial value. Removal of major defects is usually done at the felling site, but care should be taken not to spoil potential raw material by eliminating minor defects or defects that only refer to one specific end-use. Caution is also needed with top-logs which might offer poor recovery of sawn timber but be suitable for peeling if cylindrical.

The second much more complex bucking operation is to cross-cut the stem into logs of varying length to facilitate transport and gain maximum economic returns.

Placing and making these cross-cuts should only be done by highly experienced operators, since maximum commercial value applies to the entire tree, not a single log.

Some tropical forests have a high proportion of trees with internal defects that cannot be spotted when standing, with the result that significant volumes of timber are left abandoned in the forest. There are no processing facilities for forest by-products and steps should be taken to improve marketing opportunities for secondary species and qualities (market surveys and integrated processing).

Cross-cutting site

Cross-cutting is done at the tree stump, at the intermediate landing or at the roadside landing, depending on the size of the tree, the topography and the equipment used for extraction.

At the stump:
- subsequent extraction is made easier by the reduced weight of the log;
- monitoring timber recovery is difficult;
- undetected cross-cutting errors or defects reduce product quality;
- there are higher risks of splitting, since compression and tension in the stem are difficult to evaluate and control;
- working under difficult conditions is more dangerous.

At the landing:
- easier operations and better supervision and monitoring on a prepared site;
- better identification of defects;
- easier marking of cross-cuts, therefore improved quantity and quality of yield;
- easier securement of boles for cross-cutting and therefore less risk of splitting;
- possibility of applying a steel bond before cross-cutting for species prone to splitting (e.g. Longhi, Limba).

Working technique

a) Preparing the log (securing or shoring)

A bole to be bucked is never fully on the ground. At any section, one side may be under tension and the other under compression. To avoid greater workload during cross-cutting and the risk of the chainsaw pinching, a log often has to be secured by inserting snipped or tapered pieces of wood underneath or by using a manual log jack.
b) Cross-cutting

About one-third of the diameter is first cut from the compression side, then the remainder is cut from the tension side.

When bucking in the middle of a log resting on both ends, first cut from above into one-third of the diameter, then continue the cutting sequence with a plunge cut toward the centre (cf. Figure 34).

In the case of a log resting on its central part with one end in overhang, this end must first be secured and the cut started from below. The chainsaw is then applied in plunge fashion, first to cut the bottom, then the top.

To prevent the chainsaw from pinching, a (non-iron) wedge can be placed next to the saw, taking care to avoid splitting. The ground below the cross-cut should be cleared to prevent the chain hitting the ground and being damaged by grains of silica or laterite.

Cross-cutting rules

Log lengths are often determined by defects to be removed, transportation requirements or customer preferences. In the case of direct supply to processing unit, the mill may impose a series of lengths, for example multiples of length at balts for rotary cutting. The aim should always be to yield the best value by following certain rules:

- a qualified operator determines where the cross-cuts are to be made;
- serious defects that reduce timber grade or yield should be identified on the basis of industrial end-use;
- the longest possible lengths should be sought; short logs and maximum lengths should be determined by safety and transport capacity restrictions;
- volume and weight limits of extraction and haulage machinery should never be exceeded;
- best possible external presentation should be sought by eliminating localized serious defects;
- maximum length should be retained if acceptable localized defects have little impact on quality grade;
- efforts should be made to «rectify» a bent bole by bucking the section with greatest bend, thus obtaining two straight logs on both sides of the former crook.

Safety rules

- always evolute the distribution of tension and compression at the cross-cutting point before applying the cut, and position yourself on the compression side;
- always be aware of the risk of the guide bar jamming on of the log rolling or snapping towards the operator at the end of the cut;
- never stand on top of a trunk being bucked;
- on sloping terrain, never make the final cut downslope from the trunk;
- avoid bucking with the tip of the guide bar to reduce the risk of kickback.

Recommendations

Reduced impact harvesting practices for bucking:

- use appropriate working techniques to avoid timber wastage through shattering or splitting of the trunk;
- give clear instructions on qualities, lengths and diameters for bucking at felling site and conversion at landing;
- do not cross-cut the base of a trunk to remove buttresses; cut these lengthways to obtain a cylindrical contour of log;
- cross-cut logs not only from the tree trunk but also from large limbs in the crown to recover maximum timber volume and value.

Figure 33 Cross-cutting according to stem diameter, (1) without and (2) with wedges
5.4.2 Log marking

Certain regulatory markings need to be applied to the stump, the felled trunk and the cross-cut logs. These markings will vary from one country to another and will be recorded in the harvesting register. They enable logging operators, service providers and customers to locate and control all harvesting and extraction activities over space and time.

Each log should display:
• the number of the tree;
• the number of the log within the tree 1, 2, 3, etc. or A, B, etc.;
• the stamp of the logging operator;
• the original concession area.

The content and format of a harvesting register are generally determined by the authorities. The register normally includes:
• the tree number;
• the species;
• the date of felling;
• the diameter and length of the tree;
• the number and size of logs produced (length, diameter, volume);
• the date of extraction;
• reasons for abandoning a tree or log.

Ground staff or supervisors are also required to complete monitoring sheets each day to track a tree's harvest history, with dates of felling, skidding and transfer of logs. This systematic recording prevents trees or logs from being overlooked and helps control intervals between operations. The data are then fed into databases at the central office to:
• compare survey and harvest figures;
• determine the recovery level (ratio between volume of logs and volume of bole);
• check the workflow of felling, extraction and transport;
• assess available timber stocks at every stage of harvesting.

In short, the harvest register data provide comprehensive technical and economic documentation of harvesting activities.

5.4.3 Log preservation

At the felling site, a tree’s bork gives effective protection against insect attack and fungal decay, often for several weeks. After extraction, however, some of the bark will be torn or damaged and thus provide less protection. Some form of chemical treatment is therefore needed to boost protection against insects and fungi. Some species even require early debarking at the landing.

Chemical treatment is only applied to the log surface to constitute a continuous, impenetrable toxic barrier between wood and environment. To be effective this treatment has to be done immediately after bucking and in dry weather so that it does not wash off, no matter whether the logs are debarked or not.

Uninterrupted protective cover is paramount as poorly applied treatment is worse than no treatment at all. The chemical should be sprayed over the whole log surface, including cross-cuts, with special attention to splits or bark damage which are particularly prone to attack. Log faces should be sealed with an anti-crocking product to prevent splitting. The appropriate quantities will depend on the season and species. Logs of susceptible species that are due to be floated should be debarked and treated with an
indissoluble product before launching.

Booster treatment is recommended when logs have been stored for long periods in harbours or mill yards.

The chemical products used for preservation should be environmentally friendly, or at least as non-polluting as possible, and should be applied carefully and in moderate quantities.

Recommendations
Reduced impact logging practices for log preservation:

- rapidly evacuate logs after felling to shorten the period of transfer from forest to mill; only apply chemical protection where rapid transfer is not possible;
- limit chemical protection to species liable to fungal or insect attack;
- employ products and quantities that are as innocuous to the environment as possible;
- apply treatment in such a way that the environment is not harmed during log transport.
5.5 LOADING AND TRANSPORT

5.5.1 Loading

Boles are converted into merchantable logs at the roadside landings where they are moved around for bucking, classifying, sorting and storing on roughly bladed, levelled and generally uncompacted ground. They are then ready for loading onto trucks for onward haulage.

There are a number of constraints associated with loading and transport:

- significant unit masses — generally 3 to 15 tonnes;
- loading sites are relatively uneven and often humid terrain;
- dispersed loading sites require mobile equipment;
- need for the rapid loading of 20 to 35 payloads trucks, which in the case of low density species, such as Okamé, means significant volumes;
- limited monthly and therefore daily production rates — a few thousand m³ per month.

Winching system

A two-drum winch is fitted behind the truck cabin. Each drum drives a cable that is wound around the sawlog placed parallel to the side of the truck and ends at the top of the side stanchion. By winch traction the sawlog is then winched up the ramp onto the truck deck.

Advantages:

- autonomy of truck for loading and unloading;
- easy recovery of isolated logs;
- the load is secured by winch cable.

Drawbacks:

- relatively slow process since cables and ramp have to be put in place and the truck has to be parked alongside each log;
- excessive power required for loading large logs;
- weight and volume of the loading equipment reduce truck carrying capacity.

The winching system is ideal for small and medium concessions. Attached to small and medium-size trucks fitted with decks for extra volume, it is good for loading light sawlogs and hauling them over short distances.

The crawler tractor

The truck is placed alongside a loading bay or in a pit (with truck deck at ground level) and the tractor blades each log onto the truck. Wooden log skids are used for the second and third tiers.

Advantages:

- an efficient loading technique, especially with very heavy logs.
- use of already existing machinery, generally an old tractor track chains with flat plates can be used to cause less soil damage.

Drawbacks:

- slow method if there are many logs to be loaded;
- the loading process damages truck suspension;
- to be avoided in the rainy season (flooding pits, rutting, poor traction).

This method is suitable for low production levels of large sawlogs. The only practical way of loading logs weighing more than 15 tonnes is by pit, unless a very powerful front-end loader is available.

Articulated wheeled front-end loader

This is the most frequently employed procedure. The loaders are earthwork engines on an articulated chassis and mounted on wheels. They are fitted with a log fork and sometimes an upper arm to carry several logs. The most common models have an engine power output of 200 to 270 HP.

Advantages:

- good for positioning lags properly and distributing truck deck load evenly (provided the operator is well trained);
- great mobility, able to cover several kilometres to service different landings at the same time;
- great versatility, able to accomplish many functions in a variety of operations (handling different materials, including for road construction);
- outstanding productivity.

Drawbacks:

- requires considerable room to manoeuvre and place the load;
- high purchase price.
This is the only suitable loading equipment in concession areas with large accumulated log volumes at landings.

Recommendations

Reduced impact logging practices for loading:
- pre-plan a regular network of roads and landings to facilitate log extraction and concentration;
- establish landing sites in dry areas (ridge tops or terraces), on gentle slopes that will dry off quickly, outside protected areas and at least 30 metres from buffer zones;
- keep total landing area within 1000 m²;
- deposit loose earth and plant debris separately and make sure that heaps and mounds do not hamper drainage of the landing site and are at least 10 metres from runoff zones;
- remain at a safe distance of at least 20 metres from timber trucks during loading;
- stack logs an cross-bolts to facilitate handling by loaders and to delay or restrict insect or fungal attack.

5.5.2 Transport and unloading

Log transport always begins with road haulage, either directly from worksite to point of delivery or combined with water or railroad transport.

5.5.2.1 Road transport

The most conventional form of log haulage is by road tractor and semi-trailer. This is the appropriate transport equipment for all sorts of sawlogs and can also be used to transport a layer of shorts placed on one or several tiers of long logs.

These timber trucks have three, four or five axles, with one, two or three power-driven axles on the tractor. The five-axle truck with two tractive axles (6 x 4 tractor) is the most common and has a payload of 15 to 35 tonnes and a gross weight of 25 to 50 tonnes. Timber harvesting operations also use flat-bed trailers for the transport of processed products (sawn timber, plywood, etc.) to points of delivery or export, and for supplying worksites with materials, spare parts and fuel supplies.

Rules for road transport
- the load must be firmly secured against log slippage or fall by means of stanchions, chocks, cables or chains and binders serving as lashing to prevent log movement during transport;
- the stanchions should be perfectly upright after loading;
- each log should be secured by at least two cable or chain binders;
- these have to be tightened before transport, and logs of the upper tier should have half their diameter below the top of the stanchion or adjacent log;
- low-pressure tyres should be preferred as these throw up less roadway material during haulage;
- for cost and especially safety reasons, vehicle brakes and steering should be in good technical condition and regularly checked and serviced;
- trucks should never be loaded in excess of payload

Figure 35 Securing a timber truck load
Road transport is usually required before water transport to convey the sawlogs to the landing pier, loading pond or barge. Paint of delivery has to be on a firm bank where there is sufficient and preferably year-round water flow.

Minimum draught will depend on the diameter of the largest logs handled - 1.5 to 1.8 m - and the draught of the tow boats - 0.8 to 1.5 m.

The logging operator prepares the loading piers which usually have ramps reinforced with billets placed perpendicularly to the bank. The logs are launched into the water where they are retained by a cabled cordon of logs before the log raft is assembled.

Stream driving in rafts (rafting)

Floating logs are assembled into rafts using methods dictated by custom and requirements.

a) Rafts assembled in the direction of river flow. These are held together by:
• hardwood poles, 15 to 20 cm in diameter, laid across the logs and connected by cable and ring cramp;
• cables only, passed through successive ring cramps.

The rafts are made of rafts of logs of varying lengths placed end to end. On the Congo and its tributaries, long logs are placed crosswise at each end to form a rectangular cradle with the flanking logs. There are also small rafts that may be pushed if assembled firmly enough.

b) Logs placed at right angles to river flow (Gabon)
The raft is assembled by cable running along the middle through iron ring cramps driven into each log. Several 60-80 log units are then assembled to form a raft which is pulled by tug boat. Logs with a density of close to one will not float but can be transported by water if assembled with lighter buoyant logs.

Lighters and barges
Sinker logs and processed timber can be transported by lighter (inside the hull) or by barge (on the deck). The second is the most frequent. The timber is usually loaded crosswise onto the deck by crane or other lifting device.

Figure 36 Position of load on truck deck

capacity; loads should be well distributed and balanced, with more load on the tractive axle to avoid difficult driving and risk of tilting over;
• the load should be adopted not only to the truck but also to the bearing capacity of roads and road infrastructure, which is often regulated;
• tawing trucks out of aquagires or across unstable sections of road by crawler or skidder should be strictly forbidden. The environmental and financial costs of such octian ore enormous;
• such problems can only be avoided by creating a first-rate, pre-planned road network backed by consistent application of a wet-weather barrier regime;
• far reasons of efficiency and safety, the semi-trailer unit should be loaded onto the tractor before travelling unloaded;
• driving articulated vehicles is difficult, demanding work that should only be done by qualified, well-trained personnel in full possession of all their faculties;
• the transport of passengers and especially gome is strictly forbidden.

5.5.2.2 Water transport

Water transport is generally an inexpensive option, at least over large distances, but has to be incorporated into the entire upstream and downstream transport system. Its specific characteristics also have to be taken into account: inconvenience and cost of interrupted chain of transfer, delays in conveyance, and unavailability of watercourses during low-water periods.

Copyrighted material
Rules for water transport

- Launch and landing piers should be regularly cleared of bark, pieces of cable, cramps and other waste. It might be advisable to dig diversion ditches to prevent runoff spilling directly into the river;
- Riverine areas with brackish water and mangroves should be avoided for storage;
- Never tow rafts upriver, and, in estuaries, wait for a favourable tide;
- The raft will drift with the current, the tug boat serving to steer and guide it according to wind and current;
- The tow line needs to be long enough to slacken and sink below the water surface, thus avoiding sudden tautening;
- The towboat should be lighter than the towed load so that it can quickly reverse on a swell and avoid breaking the towline during critical manoeuvres;
- Tow- or push-boats should have enough power to control the speed and direction of the convoy at all times.

Recommendations

Reduced impact logging practices for transport and unloading:

- Pre-plan a regular network of roads and landings to facilitate transport;
- Never load timber trucks beyond their payload capacity;
- Secure the load with chains and binders at each end and additional chains at regular intervals;
- Evacuate timber within two months, especially timber vulnerable to insect or fungal attack;
- Observe speed limits;
- Make sure all stanchions are firmly in place before removing cable or chain binders prior to unloading;
- Stay at least 20 metres from a truck during unloading;
- Never carry passengers on a timber truck.

Impact of transport on the environment

Major impact is undoubtedly caused by road construction. Timber trucks can be the source of:

- Accidents causing casualties and physical damage to people and equipment;
- Pollution of varying origin (exhaust fumes, fuel and lubricant leakage);
- Illegal transport and trade of bushmeat and other products.
POST-HARVEST OPERATIONS

6.1 REHABILITATION OF SKID TRAILS AND LANDINGS

Skid trails

The heavily compacted surface of main skid trails should be loosened by ripper to slow water runoff and erosion and thus enhance plant regeneration.

All temporary watercourse crossings should be cleaned up.

Any logs used to facilitate watercourse crossing and to protect banks should be removed, if possible with the help of an excavator, and placed at least 10 metres from the bank.

Banks and environmentally sensitive areas should be restored.

Cross-drains should be placed manually or by ripper on sloped skid trails to prevent gullies forming from overly rapid runoff. These drains run obliquely (45° to 60°) to the skid trail and have 30 to 50 cm banks that deflect the water to undisturbed areas. They should have a gradient of 1 to 4 percent and be placed at each abrupt change in slope, at the approach to a watercourse or whenever dictated by terrain.

Post-harvest drainage of secondary roads and skid trails to reduce soil erosion

Secondary roads on steep terrain are vulnerable to erosion, which should be prevented by laying cross-drains at regular intervals as indicated below:

<table>
<thead>
<tr>
<th>Gradient of road or trail</th>
<th>Stable Soil</th>
<th>Erodible soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4 %</td>
<td>not required</td>
<td>100 m</td>
</tr>
<tr>
<td>5-9 %</td>
<td>100 m</td>
<td>50 m</td>
</tr>
<tr>
<td>10-19 %</td>
<td>60 m</td>
<td>35 m</td>
</tr>
<tr>
<td>20-24 %</td>
<td>20 m</td>
<td>15 m</td>
</tr>
<tr>
<td>25-29 %</td>
<td>15 m</td>
<td>12 m</td>
</tr>
<tr>
<td>&gt; 30 %</td>
<td>10 m</td>
<td>10 m</td>
</tr>
</tbody>
</table>

Table 13. Cross-drain frequency on secondary roads and skid trails after use

Landings

Landings should be cleared of all debris, offcuts, bucking waste and bark after harvesting. This waste is often burnt or buried, depending on national laws and local conditions. However, it is recommended not to conceal unused timber in an attempt to bolster recovery levels but, rather, to leave it to decompose on the landing site.

The soil on the landing site should be loosened by ripper to facilitate regeneration, especially in Okoumé forests. Ripping should be crossways to slope gradient.

All areas prone to water ponding should be levelled or drained adequately.

6.2 CLOSURE OF ROADS

After harvesting, all roads not to be used until the next rotation should be closed to all traffic to prevent the incursion of unauthorized vehicles—especially poachers. Road closure can be done by:

• placing a large log across the roadway;
• digging a ditch across the roadway by excavator.

The height and width of these barriers should make them totally impassable to off-road vehicles.

6.3 CLEANING OF WATERCOURSES

All debris from harvesting operations should be removed from buffer zones and banks.

All obstacles blocking waterflow under bridges e.g. culverts or box drains should be removed.

Figure 37 Post-harvest cross-drain on a skid trail after use
WILDLIFE MANAGEMENT

The forests of West and Central Africa, where the majority of timber concessions are managed, still harbour a wealth of large mammal species whose survival is threatened by human population growth and timber harvesting. Managing wildlife is therefore an integral part of sustainable tropical forest management and practical solutions to the many attendant problems need to be found.

Consumption of bushmeat is deeply rooted in the culture of West and Central Africa's forest communities. Domestic animals roaming around villages are more symbolic in nature, serving as barter, gifts or food for special occasions, such as weddings and funerals.

However, pressure on wildlife has been seriously aggravated by human population growth and increased local demand. Employment opportunities are scarce and hunting has become a primary source of income. Demand for bushmeat is high in urban areas where prices for meat from domestic livestock are not competitive with those of bushmeat. In Cameroon, the four major markets of the copitol, Yaoundé, trade more than 2 300 kg of bushmeat each day (Klein and V.D. Wal, IUCN 1998).

To supply towns and cities, previously untouched forests have been invaded by professional hunters and poachers who have extracted huge quantities of game. The installation of forest camps and the rapid extension of infrastructure have not only disturbed wildlife habitats, but have also facilitated the development of commercial hunting. The road network built in a concession area allows a hunter to enter a forest, shoot game and return to market within a short time. Workers in logging camps and their families also have easy access to this source of income if no restrictions are imposed by the forest concessionaire.

Thanks to the work of environmental NGOs, stakeholders are becoming increasingly aware of the means and mechanisms required to integrate wildlife into the management of forest concessions. In some countries, forest enterprises have already implemented a wildlife management system, with varying degrees of success, but the underlying principles still need to be consolidated and promoted on a broader regional level.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>IUCN Classification</th>
<th>CITES Appendix</th>
<th>Protection in Gabon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-nosed monkey</td>
<td>Cercopithecus nictians</td>
<td></td>
<td>Not protected</td>
</tr>
<tr>
<td>Moustached monkey</td>
<td>Cercopithecus cephus</td>
<td>II</td>
<td>Not protected</td>
</tr>
<tr>
<td>Sun-tailed monkey</td>
<td>Cercopithecus solatus</td>
<td>II</td>
<td>Not protected</td>
</tr>
<tr>
<td>Black colobus</td>
<td>Colobus satanas</td>
<td>Vulnerable [VU] II</td>
<td>Not protected</td>
</tr>
<tr>
<td>Mandrill</td>
<td>Mandrillus sphinx</td>
<td>I</td>
<td>Partially protected</td>
</tr>
<tr>
<td>Rodents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bush-tailed porcupine</td>
<td>Atherurus africanus</td>
<td></td>
<td>Not protected</td>
</tr>
<tr>
<td>Grasscutter</td>
<td>Thryonomys swinderianus</td>
<td></td>
<td>Not protected</td>
</tr>
<tr>
<td>Pangolins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant pangolin</td>
<td>Smutsia gigantea</td>
<td>II</td>
<td>Protected</td>
</tr>
<tr>
<td>African tree pangolin</td>
<td>Manis tricusps</td>
<td>II</td>
<td>Not protected</td>
</tr>
<tr>
<td>Artiodactyles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bush pig</td>
<td>Potamochoerus porcus</td>
<td></td>
<td>Partially protected</td>
</tr>
<tr>
<td>Water chevrotain</td>
<td>Hyemoschus aquaticus</td>
<td></td>
<td>Protected</td>
</tr>
<tr>
<td>Blue duiker</td>
<td>Cephalophus manilcola</td>
<td>II</td>
<td>Not protected</td>
</tr>
<tr>
<td>Bay duiker</td>
<td>Cephalophus dorsalis</td>
<td>II</td>
<td>Not protected</td>
</tr>
<tr>
<td>Peter's duiker</td>
<td>Cephalophus callipygus</td>
<td></td>
<td>Not protected</td>
</tr>
<tr>
<td>Reptiles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough-backed crocodile</td>
<td>Osteolaemus tetraspis</td>
<td>Vulnerable [VU] I</td>
<td>Partially protected</td>
</tr>
<tr>
<td>African dwarf crocodile</td>
<td>Crocodylus niloticus</td>
<td>Data deficient [DD]</td>
<td>Partially protected</td>
</tr>
</tbody>
</table>

Table 14. Most hunted species in Gabon
Effective wildlife management requires a permanent body, grouping representatives of:

- the local population;
- the forest company;
- the workers of the forest company;
- the authorities;
- the environmental NGOs;
- professional hunters and bushmeat traders.

The members of this body work closely to ensure that hunting is effectively controlled and that alternative sources of animal protein are made available (e.g. chicken rearing, hedgehog breeding, fish farming) to communities living within the sphere of the concession area.

Wildlife legislation and regulations have to be respected (hunting seasons, protected species, authorized methods and protected areas). However, while legislation to protect wildlife has been enacted in countries of the region, it bears little relevance to the situation on the ground.

Measures to control the negative impact an wildlife are three-pronged:

- excessive hunting is dealt with by combating poaching and making other sources of animal protein available;
- road construction by logging companies is designed to prevent the fragmentation and isolation of animal territories (canopy bridges, corridors, etc.);
- company planning is improved to avoid environmental disturbance (zoning of protected areas, blocked access to abandoned cutting units, concentration of harvesting activity in a small area).

The problem of excessive hunting can be overcome by farming a wildlife management committee that will consensually determine and apply appropriate measures. This committee can include representatives of:

- the local population;
- the logging company holding the concession;
- the company workers requiring a regular source of animal protein;
- the authorities responsible for controlling hunting, notably the Forest Service;
- NGOs with specific knowledge and know-how.

The local population

Measures to improve wildlife management:

- active participation of the local population in the wildlife management committee grouping the forest company, its workers, the forest authorities and relevant NGOs;
- guaranteed continuity of traditional community hunting methods and rights within the concession area. This means that hunting for subsistence cannot be prohibited if conducted in compliance with the law, but hunting outside traditional grounds will be discouraged;
- formulation of a participatory wildlife management plan for the defence of protected species, the observance of closed seasons and the establishment of wildlife management areas, demarcating a buffer zone around villages for traditional hunting and an area under total protection;
- raising local awareness of the need to use wildlife resources sustainably;
- awarding incentive prizes or premiums to students, classes, villages or farmers for exemplary performance in wildlife and forest conservation. Journalists should be invited to award ceremonies in order to involve the media;
- professional hunters, bushmeat traders and village inhabitants should respect the law. Legal and illegal hunters from outside the village should be identified as the first step of a strategy to deal effectively with poaching.
Concession company
a) Overhunting of wildlife
The logging company should apply measures to discourage and limit illegal hunting, establishing internal regulations that include the following provisions:

- prohibition on all workers from possessing and/or transporting firearms, bushmeat and/or hunters in company vehicles, even outside the concession area, and a ban on betting or facilitating hunting;
- prohibition on all workers from hunting illegally. Transgressors will be severely punished and reported to the local police and to the Forest Service for prosecution;
- prohibition on all workers from hunting outside demarcated hunting areas;
- prohibition on all workers from hunting protected animals;
- prohibition on all workers from using snares;
- prohibition on selling bushmeat (in commercial quantities) in company camps and worksites;
- prohibition on trading in live protected animals;
- severe sanctions for the violation of these prohibitions;
- pasting of company regulations and an official list of protected animals with pictures in prominent places (camp, company store, recreation areas, offices);
- awareness-building for workers on the importance of protecting wildlife (in cooperation with NGOs and the Forest Service);
- blocking abandoned forest roads with deep ditches or large logs (unless this creates problems with villagers);
- installing monned barriers at all points of access to an active concession;
- making animal protein available to workers and their families by selling chicken, turkey, pork and frozen or smoked fish in the company store at reduced prices or prices competitive with bushmeat;
- establishing a hunting area around the camp for workers owning a rifle, a firearm permit and a hunting licence, as stipulated by existing legislation. A special area may be demarcated around the camp for hunting on non-working days and during the daytime only;
- placing a ban on entering the worksite with a rifle, on carrying a firearm or slaughtered game in a company vehicle and on hunting more game than needed for family subsistence (quantity limits);
- placing a ban on the sale of snares and wire at the company store.

The presence and activity of poachers should be discouraged by all legal means:

- prohibiting access to concession areas;
- prohibiting lodging in the logging camp;
- prohibiting the setting-up of camps in the concession area;
- prohibiting persons or goods from company vehicles;
- prohibiting access of suspect carriers (collective toxis) to concession areas;
- reporting infractions to the authorities (police, forest services);
- collaborating with a specialized NGO might be necessary, especially for companies with no experience in or means of recruiting specialized supervisory staff.

b) Fragmentation of wildlife areas
Fragmentation affects tree-living animals as forest roads obstruct their movement. Prevention measures are almost all in the hands of the logging company:

- inconclusive experiments have been conducted with aerial bridges. Better results might be obtained with more appropriate locations (for example, on ridgelines where water is easily evoked and where shade has least impact on roadway surface);
- road width should always be kept to a minimum; artificial bridges could be built along secondary roads by bending small trees across the road (blocking traffic, temporary semi-aerial bridge used until young trees restore a closed canopy);
- in relatively flat areas, the blocking of watercourses by installing excessively small bridges or culverts or by building dikes will create swamps and lakes that will restrict the movement of land animals and have a significant hydrographical impact; in such cases good upstream drainage is essential;
- genuine old growth forests are rare. Harvesting leaves significant quantities of food for animals in secondary forests, especially those feeding at ground level (e.g. elephants). With regard to remaining pockets of old growth forest (often on steep slopes), the management plan should include the retention of corridors between pockets, where
there will be no harvesting or where harvesting will be sensitive to the environment.

c) Disturbance from harvesting
Harvesting activities undoubtedly disturb animals, causing many to flee.
- The land-use plan should indicate sensitive areas and density of key species. Adequate management practices need to be adopted in these areas and, if necessary, the company should be prepared to refrain from all disturbing activity;
- harvesting should be restricted to certain seasons determined by the reproduction cycles of animals under threat. Zoologists, NGOs and research institutes should be contacted for advice;
- harvesting blocks should not be too large and felling should be concentrated in the shortest possible time, which will benefit the logging operator as much as the animals (limited period of disturbance).

Company workers
Company workers have to comply with hunting regulations and company restrictions. They should also be involved in projects to develop alternative resources: stock raising, cropping, collecting food (see Section 7.2 Identification and Development of Alternative Resources).

Authorities
The State has a special role in:
- training ranger teams: paramilitary training, use of maps, GPS and compass, knowledge of flora and fauna, etc. Rangers should be provided with a firearm permit and a pair of handcuffs and should be sworn in before taking up duty;
- establishing checkpoints at concession boundaries and deploying mobile squads;
- rating illegal activities, visitors, arrivals and departures through checkpoints, etc.;
- having the police withdraw driving licences (collective taxis) for the transport of poachers;
- helping logging companies uphold law and order (arrest of suspects);
- ensuring a regular and visible presence of Forest Service agents and police officers in the concession area.

Environmental and social NGOs
These should be involved in awareness raising, training and specialized assessments, and their expertise made available to the wildlife management committee whenever needed (wildlife inventory, livestock or cropping projects, awareness-raising in adjacent villages).

7.2 IDENTIFICATION AND DEVELOPMENT OF ALTERNATIVE RESOURCES

Balanced food intake requires a versatile and varied diet. If it is to prevent its workers from hunting for bushmeat, a concession company must make other food resources available:
- availability of smoked fish, canned meat, beans, dried milk, etc.;
- encouragement of fishing and collection of caterpillars and snails (in sustainable quantities);
- promotion of activities that provide vegetable or animal protein and are adapted to the tropical forest environment.

With regard to plants, pulses (beans, peas) can be grown although these are often highly vulnerable to disease. Agricultural services such as the PNVRA in Cameroon and NGOs should be contacted to identify suitable crops.

As regards livestock, domestic breeds adapted to local forest conditions should be selected (preferably animals resistant to sleeping sickness: Ndama cattle and local breeds of pig and goat). Technical fact sheets are available from agricultural extension agencies.

Another potential source of animal protein is the breeding or domestication of wild animals. This is best done on a small scale to remain within the scope of local breeders (backyard animal production). There have been successful examples of breeding snails, hedgehogs and Gambio (pouched) rats. Although subject to constant updating, related manuals are available.

A third option is fish farming, where costs are relatively low and yields can be high in the early production cycles. Again, technical manuals on fish farming are available from agricultural extension services.
7.3 PILOT PROJECTS

Several timber companies in Central Africa have already committed themselves to sustainable wildlife management in and around their concession areas.

Their management systems share the following features:

- establishment of a wildlife management committee with representatives of the local population, the authorities, environmental NGOs, company workers and management;
- cooperation, even formal agreements, with the authorities (Forest Service, Hunting Authority, Police) and environmental NGOs on awareness-raising, violations, control and education;
- implementation and enforcement of internal rules and measures;
- conduct of wildlife inventories throughout the concession area;
- formation of a team of rangers trained in forest control and surveillance.

Experiments in breeding wild animals

Since the 1980s, trials have been carried out in breeding wild animals for meat production. This involves domesticating animals preferably caught young and kept in pens.

The aim is to have many regular litters, so that the most docile and fertile individuals can be selected. Most species are aggressive and nervous in the wild, but several projects have shown promising results, with reproduction brought under control and higher productivity. Species include hedgehags, porcupines, Gambian rats, pythons, boars, various kinds of antelope and snails.

However, breeding wild animals in a forest environment is not necessarily feasible because of competition from a saturated bushmeat market whose prices might be lower than production costs. Another consideration is that breeding involves species that are extensively hunted without becoming decimated, for example rodents hunted to protect field crops. To be economically feasible, breeding needs to be of species that are in demand and vulnerable to hunting for example: various species of antelope.
Camps need to be carefully planned as they house many different structures: administrative buildings (offices), technical facilities (workshops, garage, sawmill), commercial buildings (company store, small business activities), social facilities (dispensary, school, video room, church) and accommodation for workers and their families.

The first decision will be whether to have a single settlement covering all technical, social and administrative functions or to have a smaller base camp supplemented by one or more satellite camps nearer to the harvesting areas. This will depend on topography, distribution of commercial timber stock, configuration of concession area and the spatial order and pace of harvesting.

The location of the timber processing site also has to be decided, after careful terrain survey. Earthwork plans, preferably drawn up by experts, are needed to configure the different activity zones and associated facilities. Some form of landscaping with ornamental and fruit trees should also be envisaged.

The chosen site should be healthy, aerated, if possible on a hill top for panoramic views, and close to a spring or permanent watercourse.

Construction
All buildings on concessions committed to sustainable forest management should be made of solid materials (cement, bricks, stane, processed hardwood) and designed with comfort and convenience in mind.

Camp roads should be lit at night and equipped with drinking water points (stand pipes).

Worker living quarters should have:
- clean running water;
- lighting and a power socket;
- sanitary facilities (shower and toilet) draining to a septic tank.

A camp located at some distance from the social, school and commercial facilities of a town or village should have:

- a dispensary with treatment and recovery rooms for basic medical assistance, and equipped with basic medical supplies. There should be an evacuation procedure (rescue chain) for severe accidents and emergencies, with rescue equipment available;
- a primary school;
- a company store offering basic goods at competitive prices, with ample stocks of meat, poultry and fish to reduce pressure on local wildlife (hunting);
- social and cultural facilities: club, video room, church.

Logging camps should be supplied with clean water that should be duly tested on a regular basis. Any necessary filtering and treatment should be provided at the source.

Disposal of wastewaters and refuse
Each camp should have a basic sewerage system of septic tanks and/or drainage sumps located at least 100 m from the nearest source of clean water. Wastewaters should not discharge into a watercourse but be buried.

Each camp should have a refuse site that is:
- separated from runoff water;
- located at least 50 m from a stream or water point and located well above the water table;
- physically inaccessible (by barrier or fence) to animals and children.

Several pits should be dug for different kinds of refuse. Combustible household waste should be burnt on a regular basis.

Each home should be equipped with a refuse bin with lid. Refuse should be collected at least twice a week.

Waste from the dispensary should be given special treatment and protection.

Metal waste should be buried under at least 30 cm of earth. Tyres and bulky waste (e.g. carcasses of derelict machinery) should be kept separately and their recovery negotiated with suppliers.
A number of general principles apply:
• preference should be given to regular, annual and steady employment, as opposed to casual, short-term work;
• recruitment of personnel should be based on work profiles that reflect the organizational structure of the concession company;
• special attention should be paid to safety, given the element of risk in forest harvesting work;
• all harvesting jobs and operations should comply with international standards and national labour codes;
• employers should only assign workers to jobs that correspond with their age, physical capacity, state of health and vocational qualifications;
• remuneration should no longer be based solely on productivity. Financial incentives (e.g. bonus system) should be introduced to encourage workers to observe safety regulations, to reduce negative impacts and to maximize timber recovery;
• in situations of equal qualification and experience, priority should be given to national personnel over expatriate personnel and to workers from nearby villages over workers from other districts.

One major constraint to harvesting in dense tropical forests is the lack of skilled personnel (masters, technicians and skilled workers) to plan, execute and supervise harvesting operations and road construction.

There is also inadequate supervisory and managerial capacity. Companies should therefore consider the supreme importance of staff training at all levels in order to:
• minimize damage to the forest and the environment by implementing RIL in an effective and efficient manner;
• make staff fully aware of the social and environmental impacts of harvesting;
• increase work productivity, quality and safety;
• reduce harvesting losses as well as direct costs and production costs.

The simplest and least expensive way to develop skills is through on-the-job training by company supervisors and managers. However, at least for certain staff categories, this usually has to be supplemented by regular (generally annual) RIL technical courses run by external vocational trainers. Developing staff capacity should focus on:

Planning and inventory:
• mapping and GIS;
• species recognition and quality choice;
• harvesting inventory;
• location and layout of roads and bridges.

Use and maintenance of equipment:
• chainsaws;
• crawler tractors, excavators, graders, etc.;
• articulated wheeled skidders;
• transport and haulage equipment.

Harvesting methods and techniques and associated works:
• controlled felling;
• careful pre-skidding and skidding;
• efficient bucking;
• safety standards and measures;
• control, monitoring, and evaluation of harvesting.

Practical on-site training modules should be designed and applied as a matter of priority for inventory, felling and skidding crews.

Ground workers operating heavy machinery (crawler or wheeled equipment) should be specifically trained in personal safety and safety in team work. This will help to convey the specific role, relevance and responsibilities of each crew member.

There should also be mandatory staff training in preventing and fighting fires so that everyone knows how to react in the event of a fire breaking out on company premises or in the forest.
Preliminary remarks

Most of the recommendations in this chapter are drawn from 1998 International Labour Office publication Safety and Health in Forestry Work, which should be referred to as necessary.

A certain number of recommendations have been incorporated into the technical chapters to which they intrinsically belong.

10.1 GENERAL PRINCIPLES

As harvesting tropical forests is still a mostly high-risk activity practiced under difficult conditions and requiring significant physical effort, concession companies must consider safety management as a top priority.

They must understand their responsibilities in this regard and actively promote health and safety at the work place. Policy should be developed to:

- eliminate risks;
- control risks at the source;
- minimize risks by focusing on safety of work methods and organization;
- provide personal protective gear, equip all machinery with safety devices and make sure these are used.

10.2 OBLIGATIONS AND RESPONSIBILITIES

Obligations of forest authorities

The authorities should:

- design and adapt legislation and regulations to ensure the safety of workers in the concession area. This should be supplemented by technical standards and operating directives;
- make sure all forest workers receive the same level of protection, whatever their professional status.

National legislation should stipulate that:

- concession companies bear primary responsibility for the safety of forest operations;
- employers are expected to adapt work systems and methods that offer maximum safety;
- companies are responsible for training workers so that they have the necessary skills to carry out their assigned work in complete safety;
- managers and supervisors should ensure that worksites are safe and not dangerous to health;
- workers collaborate in ensuring that safety standards and measures are respected and are expected to apply all measures designed to ensure their own personal safety.

Obligations and responsibilities of the employer

The employer is responsible for safety at work and should take every possible step to minimize the risk of accident at the forest worksite.

The employer should comply with all laws, regulations, standards and directives dealing with occupational safety, and should institute and uphold a corporate policy of safety.

The employer should enable workers to participate actively in the improvement of safety rules and measures.

Workers should only be assigned tasks that correspond to their age, physical ability, state of health and skills.

The employer should strive for workforce stability and low staff turnover.

The employer should make sure that all equipment, tools and materials needed to work under conditions of safety are provided and kept in good state of repair; and should provide safe and appropriate forms of transport for personnel and equipment to and from the worksite.

The employer should arrange regular medical check-ups for all employees, especially those exposed to occupational disorders. Basic medication and vaccines should be made available when not provided by the public authorities, and there should be first-aid and emergency rescue services.

Obligations of works supervisors and chiefs of harvesting operations

Chiefs of harvesting operations and all supervisory personnel should make sure that the company's safety policy is applied on the ground.

Supervisors should ensure that operators understand and apply all safety standards and rules.

The chief of harvesting operations and supervisors should ensure that the work is
planned, organized and executed in such a way as to minimize risk of accident. Supervisory staff should see that:
• safety regulations are observed;
• safe working methods became and remain standard practice;
• personal protection and safety devices are always used.

Rights and responsibilities of the workforce:
• the entire workforce should collaborate with the employer in promoting safety;
• workers should consciously take care of their personal health and safety;
• workers should, under pain of sanction, comply with all occupational health and safety provisions;
• workers should immediately inform line supervisors of situations they consider hazardous to themselves or their surroundings.

10.3 GENERAL SAFETY MEASURES

Employment conditions
The occurrence of hazardous situations and thus risk of accident is fomented by high staff turnover. Stability of workforce should therefore be fostered. Working hours should not exceed the number stipulated by national law or collective agreement. Working hours should include adequate periods of rest:
• short breaks during working hours;
• breaks for meals;
• periods of rest during the day and night;
• weekly rest.

Safety requirements for tools, machines and hazardous chemicals
All tools, machines and products used in forestry should:
• meet existing safety standards;
• only be used for their intended application or purpose;
• only be used or operated by workers with appropriate skills and qualifications.

Equipment should be designed for easy and safe maintenance. Workers should be trained in maintenance and minor repairs.
Workshops and equipment for repair and maintenance of harvesting machinery should be available on or near the camp. The use of maintenance vehicles or mobile workshops in the field, ideally next to the worksite itself, is strongly recommended.

Work clothing and personal protective equipment
Clothing appropriate to tropical conditions should be used to avoid excessive thermal insulation and allow body ventilation.

The employer should assess protective equipment requirements according to job and circumstances and keep sufficient stocks for the workforce.
Clothing should be in bright or fluorescent colours that stand out in forest surroundings.

First aid and emergency rescue
Forest workers should ideally be given first-aid training as they are generally dispersed in crews operating over wide areas.

Clearly marked and serviceable first-aid kits should be available on all worksites.
Arrangements should be made for the rapid evacuation of workers in emergency situations.
Crews working in remote areas (e.g. far inventory) should be connected to base by radio and should have permanent access to radio contact with an emergency vehicle operator.
The camp should have a special rest area where sick or injured personnel can await evacuation.

10.4 SAFETY RULES FOR HARVESTING OPERATIONS

10.4.1 Felling with chainsaw
Organization
Felling areas allocated to each crew should be no closer than twice the length of the tallest tree to be felled.

Only felling and marking crews should be authorized to enter the felling area. Any other person should only be allowed to enter after announcing his intention to, and receiving permission from, the foreman of the felling operation.
Apart from the feller’s assistant, no other person should approach the feller within twice the height of the tree being felled.

Special care is required during felling on steep terrain: no worker should be allowed to operate downhill from a felling area.

Under normal conditions, no one should be allowed to operate a chainsaw in isolation.

The wearing of personal protective equipment is obligatory, under penalty of sanction for operator and supervisor.

Equipment
The power output of the chainsaw should match the size of the trees to be felled. The chainsaw should be as light as possible and equipped with a guide bar of appropriate length. The most commonly used chainsaws are in the 7 to 9 HP range and have a guide bar of 70 to 90 cm.

Chainsaws should have the following safety devices:

a) separate handles for each hand;
b) an on/off switch close to the throttle control;
c) a throttle control lock-out preventing the chainsaw from accelerating unexpectedly;
d) a rear handle guard to protect the right hand;
e) an anti-vibration system between the engine block and the handles;
f) a chain brake activated manually by front handle guard and automatically in the event of kick-back;
g) a chain catcher;
h) a spiked bumper to help the operator transfer weight and vibrations of the saw to the log while cutting;
i) a front handle guard to protect the left hand;
j) a chain guard to avoid injury during transport.

Operating a chainsaw
Chainsaw work should be limited and interspersed with other tasks to reduce the health hazards associated with this tool. The sequence of work with displacement from one tree to another, refuelling, and other activities generally ensures this.

The carburettor should be adjusted so the chain is at standstill when the engine is idling.

Before starting the chainsaw, the operator checks that no one is close by. He then places it on the ground and secures it by foot through the back handle.

The saw should never be used above shoulder height because of the risk of kick-back projecting the guide bar backwards.

Chainsaws should always be switched off and the chain brake engaged when operators move to another workstation.

Smoking when refuelling is strictly prohibited.

10.4.2 Cross-cutting with chainsaw

The equipment is the same as for felling, but the guide bar is generally longer.

Before cutting, logs should be carefully examined for risk of rolling, sliding or bouncing.

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Figure 38 Chainsaw safety devices
when certified

The blade reduces functioning according to the guide on mounted Falling

10.4.3 Extraction by skidder

Skidders should be fitted with an internationally certified Roll Over Protection Structure (ROPS) and Falling Object Protection Structure (FOPS) mounted according to manufacturer’s instructions.

Seats and safety belts should be fitted according to international standards.

The rear of the cabin should have a metal mesh protection.

The skidder should have an accessible and functioning fire extinguisher.

The operator should always be facing the cab when getting in or out.

Cross-slope extraction should be avoided as it reduces the stability of the vehicle.

The rear of the skidder should be aligned with the load to reduce lateral hauling.

The skidder brakes should be engaged and the blade placed in low position for winching.

The cable or chokers should be positioned relatively close to the end of the log to reduce the distance between winch and log.

The load to be hauled should be well within the tractive capacity of the winch and the maximum tensile breaking strength of the cable.

A minimum of three turns of cable should always be left when unreeling the cable from the winch drum.

The cables should have the appropriate size and strength for the loads to be hauled: wire ropes generally manufactured of bright steel, composed of preformed strands in scale construction and cross lay, with a diameter of 7/8 to 11/8 inches and a tensile breaking strength of 180 to 220 kg/mm².

The load should be hoisted up as close as possible to the rear butt plate of the skidder.

Workers should avoid walking alongside the load and should always remain uphill from it.

No one should sit or stand on a moving load.

10.4.4 Loading and transport

Loading

Vehicles being loaded should be parked safely with their brakes on.

Nobody should be in the cab or on the platform of the vehicle while loading is in progress (except for winch-assisted loading).

The load should be properly balanced and secured by cables or chains that are sufficiently strong to prevent the logs from moving during transport.

Loading should comply with road regulations and vehicles should never be over loaded.

Road transport

Drivers of timber trucks should:

• hold a valid driving licence for the type of vehicle being operated;
• strictly observe traffic regulations;
• have thorough knowledge of the functioning of their vehicle;
• be able to carry out routine servicing and minor repairs;
• have final responsibility for the correct distribution and fastening of the load on the truck deck, as well as for the weight of the load.
The trucks should be properly equipped and roadworthy and comply with road safety standards.

The cabin should be protected against roll-over, falling objects and logs intruding from a poorly fastened load by an appropriate cab superstructure around the roof and between the cabin and load.

Trucks and trailers should be carefully inspected daily, with particular attention to steering, brakes, wheels and tyres.

If travelling long distances and operating in remote areas, trucks should preferably be equipped with a two-way radio.

The presence of passengers in the cabin (including company staff) should be forbidden or at least strictly regulated.

Main and secondary road networks should be fitted with safety signs indicating speed restrictions, dangerous curves, narrow sections and approaches to bridges and other road works.

All limitations, especially speed limitations, should be strictly observed.

A set of road signs guiding trucks from the entrance of a concession area to the point of loading can also enhance safety.

Water transport

Special care should be taken when preparing log launch sites.

Laws and regulations on waterway safety should be strictly followed.

Timber rafts should be towed or pushed by boats that have sufficient power to control the speed and direction of the raft.

Rafts should be properly secured by strong cable to float in total safety and prevent loss of logs.

Rafts should be clearly signalled and identifiable by day and particularly by night to avoid risk of collision.

10.5 SAFETY RULES FOR CHEMICALS AND PETROLEUM PRODUCTS

Chemicals, petroleum, oils and lubricants are highly polluting, so all precautions have to be taken for their storage, delivery and use.

Special care should be taken to prevent these products polluting watercourses, wells and surroundings.

These products should be used according to suppliers’ instructions and stored safely in containers, tanks, etc. designed to prevent leakage and accidents.

Chemical products should be stored in a dry, cool and well-ventilated building. Containers should not be placed directly on the ground but perched on pallets, for example.

The storage site for these products should be at least 100 metres from watercourses.

Fuel storage tanks should be placed on wood or concrete platforms so that spillage during delivery and supply can be recovered.

Diesel fuel supply to forest areas should be done by mobile tank fitted with a properly functioning pump.

At refilling and worksites:

- diesel fuel mixed with water for purging should be recovered in a recipient (generally a drum or half-drum);
- diesel too dirty to be used as fuel should be stored in a separate container and returned to the workshop for other uses (cleaning engine parts, additive);
- all used oils should be recovered in appropriate recipients and either used for lubrication or for maintenance purposes on the ground, or sent to the workshop for storage before return to the supplier for recycling;
- fuel and lubricant for chainsaws should be delivered in closed, waterproof recipients with pouring spouts to avoid spillage.

These recipients will be refilled from closed, waterproof drums or jerry cans fitted with spigots.

Chemical and petroleum products should never be spilt into watercourses. The cleaning of equipment containing or used for these products in watercourses is strictly forbidden.

Workers using or applying chemical products should receive special training in associated risks, use of protective equipment and first aid. They should wear adequate protective clothing.
Monitoring and assessment of harvesting provides systematic verification that operations have followed the annual harvest plan and achieved its technical, financial and environmental objectives, while at the same time adhering to the management plan guidelines. Monitoring and assessment are thus key elements of sustainable forest management for which the harvesting manager is responsible. These may be conducted:

- during harvesting through the monitoring and control of harvest operations;
- after harvesting by means of internal and external assessment.

Monitoring and assessment permits real-time assessment of worker and equipment productivity and efficiency, so that necessary improvements can be introduced.

Post-harvest assessments serve:

- to check whether operations were performed according to harvesting and management plans;
- to estimate the impact of harvesting on the environment;
- to prepare or confirm the sustainability certification of a forest concession.

Such assessments have to be conducted at each hierarchical level, using ground surveys, GIS data and management databases. The findings are recorded in periodic operational and summary reports that are forwarded first to the harvesting manager, then to company executives and finally to the forest authorities.

11.1 CONTROL AND MONITORING OF HARVESTING

Daily records provide the management with an increasingly clear idea of production quantity and quality, and of productivity trends of workers and equipment throughout harvesting. Daily production sheets completed by operators enable crew leaders to draw up daily reports on operations under their responsibility:

- felling: number of trees felled, identification numbers, species, volume;
- extraction: number of stems or logs extracted, species, volume, distance;
- bucking: number of logs, species, volume, quality;
- loading and transport.

Similar records are kept for each machine:

- number of machine hours;
- consumption of fuel and lubricants;
- spare parts and consumables used;
- periodic servicing.

With these daily records, the chief of operations can prepare a weekly report for the harvesting manager, summarizing the information, providing maps and indications of logging sites and appraising the thoroughness and quality of work of harvest crews.

These weekly reports are then condensed into monthly reports by the harvesting manager who inserts data on:

- worksite administration and accounts (operating, supervision and management costs, etc.);
- personnel (wages, bonuses, health expenses);
- workshop expenditures (consumption, spare parts);
- forest-related activities as determined by the harvesting and management plans.

The monthly reports are transmitted to the company management for calculation of direct staff and equipment costs, operating costs and, on the basis of marketing data (sales prices), overall returns and profit margin. The technical part of the report may be forwarded to the forest authorities, together with any other documents required by law.

11.2 INTERNAL AND EXTERNAL ASSESSMENT

These are normally post-harvest assessments. They are usually carried out a few weeks (verification of stumps, felling damage, etc.) to almost one year after harvesting in order to assess:

- the canopy opening after harvesting;
- the area affected by the skid trail network;
- the level of recovery at felling and conversion;
the damage caused by felling and extraction to the remaining stand and soil;
- the extent of eroded area and level of regeneration.

The internal assessment can have several purposes:
- annual assessment of adherence to reduced impact logging standards and management plan guidelines;
- control of corporate efficiency, timber recovery level, productivity and cost of operations, traceability of the chain of custody from inventory to market or processing;
- five-year and mid-term revision of the management plan to introduce any changes and improvements needed.

The first of these objectives, which should be an ongoing corporate concern, is generally carried out by a small assessment or research-evaluation team, headed by a senior forest technician or engineer and tasked with conducting:
- follow-up studies and research on forest harvesting (inventory revisions, forest structure and regeneration, harvesting impact, ecology and wildlife);
- evaluative work as such.

Assessment will generally be based on ground surveys of a proportion of the harvested area and existing data (maps, inventories, harvesting reports). Ground surveys focus on remaining stands in randomly selected harvesting blocks and their skid trail network.

The team will conduct a number of appraisals of the quality of harvesting activity on the plot, using pre-defined core indicators:
- stump identification, checking the marking;
- searching for overlooked stems;
- assessing the quality of felling, measuring felling damage and felling waste;
- assessing the quality of bucking, evaluating timber yield;
- estimating the damage caused by felling and extraction (canopy opening, affected surface, attention paid to future crop trees and damage caused to remaining stand);
- assessing damage to the soil from erosion and compaction;
- checking the quality and efficiency of the skid trail network.

The external assessment serves a variety of purposes and objectives. It can be instigated independently of the logging company, either by the forest authorities to see that concession terms and conditions are respected or by a donor to monitor compliance with loan conditions. It can also be arranged by the company itself to initiate the process of certification of concession sustainability. Such external assessments are carried out periodically by external teams that are totally independent of the company.
MAINTENANCE AND REPAIR OF EQUIPMENT

12.1 WORKSHOP AND GARAGE

Workshop and garage buildings should be located more than 50 m from any water source or stream.

In order not to discharge toxic waters into the environment, waste water from workshops or garages should be evacuated to and recovered in sewage ponds where it will undergo purification. Residual waste recovered from purification should be burnt.

The use of products containing toxic substances should be strictly limited. Wherever possible, these should be replaced by biodegradable products.

12.2 STORAGE OF FUEL AND LUBRICANTS

Fuel and lubricant storage should be:
• in well drained areas at least 50 m from the nearest watercourse;
• at least 100 m from living quarters.

Diesel fuel recovery ditches (if possible cemented) should be built around fuel drums or tanks and have a retention volume of at least twice storage capacity.

Drainage from storage areas should be towards sumps set in stable dry ground at least 50 m from the nearest watercourse.

If fuels and lubricants have to be stored on a river quay or wharf:
• the storage area should be as far from the water as possible;
• tanks should be encircled by a protective ditch from which spilled fuel can be recovered.

12.3 ON-SITE SERVICING

As far as possible, in-forest servicing and repair of machinery should be done from mobile workshops accompanying the harvesting and road construction works.

Refuelling or lubrication of machinery should be from mobile tanks or specially equipped trucks.

Mobile workshops and refuelling tanks and trucks should be:
• on flat well-drained areas such as landings or crossroads;
• at least 50 m from watercourses.

Special care should be taken to avoid spillage or loss of fuel when refuelling machinery or chainsaws on the worksite.

No engine oil or diesel fuel considered unfit for further use should be poured onto the soil, but should always be recovered in drums and returned to the central workshop.

12.4 HARVESTING WASTE

As a general principle, all waste from harvesting activities should be recovered, stored, destroyed or removed, as appropriate.

Non-toxic solid waste, especially metal waste (cables, chains, pulleys, machinery parts) and derelict equipment should be buried in pits and covered with at least 50 cm of earth, or collected for recycling by manufacturers or suppliers. The lower pit level should be at least 1 m above the water table. Waste materials should never be left abandoned on the roadside, on landings or in the forest.

Refuse bins should be available for used filters and returned to the central workshop when full. The filters should be compressed to remove contents, the fuel and oil recovered and the empty filters burnt before placed on the waste disposal site.

Used tyres should be kept at the central workshop for return to the manufacturer for retreading or destruction.

Batteries should be neutralized and their acid recovered and removed.

Paper, wood and board should be burnt on the disposal site.
An integrated approach to forest management is essential for sustainable and reduced-impact harvesting. Unless relations with workers and local communities are taken into account, sustainable forestry will clearly be more difficult to implement successfully. The sustainable management of natural resources therefore requires the comprehensive integration of all technical, ecological, socio-economic and institutional factors.

This chapter suggests how the social aspects can be integrated into sustainable forest use. However, such aspects exist in many forms and cannot be universally covered. The recommendations put forward are therefore by way of indication only and need to be tailored to the specific circumstances of each worksite or forest management unit. An evaluation grid is suggested as a basic work tool for developing the social dimension of a project, but this cannot be successful without involving the communities living in or near the forests to be managed and harvested.

13.1 PRESENT SITUATION

13.1.1 Institutional framework

Forests in West and Central Africa have varying but generally low population densities. Nevertheless, this human presence can present problems for forest management.

Furthermore, forests in West and Central Africa are generally under State control and thus share the same political and legislative framework, a potentially significant characteristic for sustainable forest management throughout the region.

13.1.2 Expectations of local communities

Social aspects directly concern the inhabitants of villages within or adjacent to concession areas, who are in some way affected by forest management or harvesting activities.

The objectives of management and harvesting are often left unexplained and thus remain unclear to local populations who have the right to engage in agriculture, hunting and other subsistence activities, but whose land tenure rights are not always recognized.

These problems can be overcome by involving local communities in forest management. The concessionaire must also promote more comprehensive development, focusing on a culture of dialogue, allowing communities to participate and share benefits and setting up a management committee. Training and education programmes are required to enable local populations to participate in forest management, to organize themselves better and to defend their rights.

13.2 PRACTICAL RECOMMENDATIONS

Some of the recommendations may already be included in regulatory provisions for sustainable management planning. A socio-economic study and a zoning plan are usually required by the administration.

13.2.1 Steps for developing social aspects of sustainable forest management

- Understand the local context: seek input from other actors and concessions in the area, information on NGOs, churches, teachers, traders, target population, etc. This avoids raising false expectations of special favours to certain individuals;

- conduct a social study on the local population and take findings into account when setting up the zoning plan;

- create a coordinating committee to be associated with the local population in forest management;

- on the basis of the multi-resource zoning plan, draw up agreements with the local community on rights and obligations that are integral to the management plan;

- discuss with local communities the different stages of the collaborative process and decisions taken, particularly matters relating to restitution;

- create a basic social framework for sustainable forest management so that social issues can be further developed in the future.
13.2.2 Prerequisites

Two key factors are decisive for the successful integration of social aspects into sustainable forest management:

Credibility
Each employee has to display exemplary behaviour. Credibility largely depends on employees observing regulations. Agreements reached with local populations should be integrated into company internal regulations which should also apply to subcontractors.

Collaboration
Cooperation with the local population requires expertise and sociological studies that only specialized organizations or scientific institutes can provide. The concession company should develop all necessary partnerships with national environmental NGOs, local development organizations and donors.

To ensure that agreements are known to and accepted by the community members concerned and to avoid misunderstandings, a protocol of collaboration should be signed by all partners and distributed to all concerned.

The company management should appoint a liaison officer to oversee cooperation between the company and the local community. This person will be in direct contact with local partners and NGOs, will sensitize company workers to the importance of cooperation arrangements and will relay information on social aspects to the management. He or she could be given special training for this new task.

13.2.3 Key factors for successful collaboration

Several factors have to be considered if the local population is to participate actively in the concept of sustainable harvesting policy. These factors are referred to as 'the five Cs':

Confidence
Forest harvesting often makes local partners feel suspicious about the concession company. These suspicions can be overcome if ongoing and intended forest management is shown and described in a completely transparent way. This however, implies maximum transparency of management goals and activities.

Commitment
People used to living in conditions of abundance sometimes forget that resources can become depleted and scarce. Sensitization to the sustainable use of forest resources is needed, especially among the young who are more receptive to new concepts.

Communication
Communication with local partners should be well organized and structured with a special focus on transparency. Good communication of results among partners helps build mutual confidence and resolve problems.

Compensation
Target groups will only commit themselves to collaboration if this helps protect their interests. Traditional rights of local communities have to be safeguarded. In cases where these cannot be guaranteed, satisfactory and reasonable compensation should be offered.

Collaborative management
Certain responsibilities should be placed in the hands of local stakeholders, for example the management of forest areas surrounding the village (agriculture and other land-use zones demarcated in the management plan) or matters related to hunting, but also the social and functional organization of the village. Effective collaboration is extremely difficult to achieve in the absence of an organizational structure in which the main village groups are represented.
13.2.4 Consultation of the local community: social study

Preliminary social studies and surveys Knowledge about the biological resources of the forest is acquired by inventory, whereas the social environment is determined by socio-economic study. The resulting report should cover:

- the various uses of forest products;
- the other services forests provide to the local community (e.g. water);
- the productive activities of the local population (processing of forest products, marketing) and village contacts with the outside.

As part of Rapid Rural Appraisal, the local population will be interviewed on:

- the settlement of the population associated with same kind of property title to the forest and likely demographic expansion, especially if living within the forest;
- customary products gathered from the forest (products and zones of socio-economic interest to the local population, e.g. concentration of Moabi, hunting grounds);
- spatial expansion of crop plantings and forest land and future expansion needs;
- rules and traditional rights governing the use of natural resources (hunting and fishing);
- aesthetic and cultural values of local inhabitants (conservation of sacred areas, sites of worship, cemeteries, etc.);
- expectations from forest management, interest in temporary or permanent employment;
- level of current and potential income from the management of products under the ownership of local inhabitants (after deduction of management expenses imputable to them as beneficiaries);
- exchanges with the outside (product flux, trade); other interested parties, the State, NGOs, traders, neighbouring villages, poachers/hunters from towns, tourists, etc.

This inventory could lead to further thematic research on, for example, the importance of Moobi for a village or of hunting for pygmies, or the identification of plants used by villagers, their uses and methods of preparation.

Other methods might also be applied to appraise the villagers' harvest chain, to study urban markets for their products, or to record and evaluate potential and actual yield of non-wood forest products.

13.2.5 Coordinating committee

It is advisable to get local populations involved in the management of their surrounding forests and, although a concession company cannot be held solely responsible for the employment and social development of local populations in terms of medical care, schooling, access to credit, and so forth, they should respond to local interest in using resources from the concession. In this way, companies can play a significant role in helping to develop a region.
The coordinating committee is responsible for village affairs and for managing zones dedicated to agricultural use. It has a consultative role and coordinates the participation of rural communities with regard to:

- full local participation in earnings;
- local participation in decision-making;
- compensation;
- traditional rights to harvest wood and non-wood forest products;
- responsibilities;
- employment (and training);
- communication;
- monitoring of village activities and evolution of results.

Agreements should be spelt out and recorded in detail, registered at forest management unit level, and noted in the participation manual.

Organization of the coordinating committee
The coordinating committee should have a representative of each village clan, together with representatives of some of the more vulnerable target groups: women, pygmies, minorities and the young. The representatives meet under the guidance of a neutral party. The committee works on the basis of an internal written code of conduct presented in the participation manual. Agencies specialized in rural organization (e.g. development NGOs) often supply model rules of procedure. A national NGO could be contacted, preferably one operating in the area, to help the local population organize its coordinating committee and to brief its members.

Agreements and regulations determined by the committee will be recorded in a participation manual available to all stakeholders.

Arbitration committee
In principle, existing rules and regulations should be observed by all participants. However, it is recommended that an arbitration committee, independent of the coordinating committee, be set up to settle disputes before these reach the courts. The arbitration committee should be led by a neutral chairperson and be made up of respectable persons of exemplary moral character.

13.2.6 Proposed rights and obligations

The measures taken as relations between local partners evolve will determine the rights and obligations of all partners, as well as the institutions to be contacted and procedures to be followed in the case of dispute.

Actions and methods integral to the participatory approach should be carefully explained in a written document, from initial contact to final monitoring and evaluation (participation manual), and minutes taken of all meetings of partners, with a copy distributed to each party. The following instruments and procedures should be stated in the participation manual.

The responsibility of all partners
The local population should try to establish a system of sustainable resource management on its territory. Just as the logging operator is expected to seek successful collaboration, so too the village communities are expected to play their part.

Respect of traditional rights
Rights and obligations will be recognized and set out in the participation manual. The traditional rights of the local population will be respected. These will be incorporated into the management plan and indicated on the harvesting map.

Indemnities and compensation
Several countries have legislated compensation and indemnities (per tree, hectare or other). Regulations should be included in the participation manual for reference in the event of dispute.

Participation in benefits
Local communities can be strongly motivated to participate if made aware of the many potential benefits from doing so.
This glossary presents the forestry terms used in the text and illustrations of this publication but does not pretend to establish definitive terminology which can only be done through a process of international consultation.

**Annual allowable cut (AAC)**
Volume of timber that can be harvested from a given forest area in a year. From the perspective of industrial harvesting, the AAC needs to be set at a level that provides the largest harvest possible, but without compromising future crops. If we take the impact of timber harvesting on non-wood forest products into account, it is usually better to revise the APC downwards. This will however depend on existing complementarity or competition between timber harvesting and non-wood forest products. Similarly, consideration of the potential role of forests in terms of the environment and provision of services also tends to downscale the AAC.

**Annual coupe**
Precise extent of forest to be harvested during a year. Depending on the underlying criterion (surface or volume to be harvested), we distinguish between surface area coupe, volume coupe and surface area coupe with regulated volume.

**Biocoenosis**
Association of living organisms in a relatively homogeneous and well-defined biological environment, forming a closely integrated community.

**Biodiversity**
Variety and variability of living organisms and the ecological communities in which they live. There is diversity of ecosystem, diversity of species and genetic diversity. It is assessed by means of structural, population, physiological and genetic indicators. As indicators of biodiversity are difficult to measure and require high expertise, relatively few conclusions exist as to the impact of forest harvesting an biodiversity in general. However, it is widely recognized that harvesting infrastructure and activity beyond a threshold which is still not exactly definable, are harmful to biodiversity, fragmenting forests, eliminating or endangering certain vulnerable species, and thus reducing variety and variability of living organisms. However, it is also widely acknowledged that moderate canopy opening that avoids harming the remaining stand and soil holds good potential far promoting the regeneration of certain species and increasing structural and biological diversity of the forest.

**Bole**
A tree stem that has sufficient diameter to provide sawlogs, veneer logs or large poles.

**Bolt**
Term used as a synonym of «log» which also designates roundwood of intermediate size used for the construction of bridges and loading facilities.

**Buffer strip**
Area of forest usually bordering protected zones, watercourses and lakes where all timber harvesting is forbidden.

**Buttress**
Ridge of wood above the ground between the main lateral roots and the base of the tree stem. These buttresses, which develop on many species of forest trees in the region, should as far as possible, be cut before felling, in order to facilitate controlled felling and to maximize the recovery of timber from the base of the stem.

**Buttress removal**
This operation consists of removing the buttresses from a tree before felling. This highly recommended practice facilitates controlled felling and maximizes timber recovery from the stem base.

**Cable**
Flexible steel rope made up of numerous wire strands that are twisted helically around a core of wire, wire rope, fibre, plastic or other material.
**Canopy**
More or less continuous and vertically structured forest cover made up of tree crowns creating environmental factors that determine the living conditions of forest biocenoses. A dense canopy with an abundance of forest strata and borders, harbours a wide variety of biotic communities.

**Canopy opening**
Reduced density of forest crown cover resulting from harvesting. The opening of the canopy favours the regeneration of light-seeking species that tend to eclipse the shade-demanding species through their exuberant growth. The shade-demanding species then successfully recover ground when the forest closes. Moderate canopy opening is considered favourable to regeneration and production of plant material. Regeneration capacity and the growth dynamics of species is however still not sufficiently understood to determine the most appropriate canopy opening for the forest stands of the region.

**Chocker-setting**
The work of the extraction helper (chocker-setter) who unwinds the cable and wraps it around the log for winching it to the skid trail and then skidding it to the landing.

**Code**
Systematic compilation of directives governing practices applied in a specific domain.

**Collaborative management**
Action whereby local stakeholders are given responsibility for the management of the forest area around their villages (agricultural and other series), hunting and also the organization of village affairs. To be effective, collaborative management requires a community association in which all the main groups are represented.

**Controlled felling**
Technique employed to cut a standing tree in order to control its line of fall and guarantee maximum operator safety, avoid damage to neighbouring trees, maximize timber recovery from the tree base and facilitate its extraction.

**Conversion**
Series of operations whereby felled trees are processed into timber for milling, especially with regard to length and quality. The main operations are topping, butt trimming and cross-cutting.

**Coupe**
Specific area of forest to be harvested during a particular period of time (see AAC). In forest harvesting, this generic term is also used to designate all felling and cross-cutting operations.

**Cross-cutting (bucking)**
Operation involving the cross-cutting of a trunk, bole or large branch for subsequent recovery of timber from the felled tree, producing the log end-product of forest harvesting.

**Culvert (box drain, cross-drain)**
Transversal drainage structure for cut-and-fill forest roads, directing water from the side drain on the uphill side of a road to the downhill side. Culverts can be made of wood, cement or metal.

**Deck**
Thick wooden flooring that distributes load among stringers (distribution deck) or that protects bridge structure against constant wear from heavy vehicle passage (wearing deck).

**Diameter at breast height (DBH)**
Diameter of a tree measured at a standard height (generally 1.3 m) above ground on the uphill side, after removal of accumulated forest litter. In the case of trees with large buttresses, the diameter is often measured at a point above the main flare of the buttresses.

**Drainage**
System of water channelling and evacuation that protects the subgrade of a forest road with a natural soil surface from impaired bearing capacity caused by water. Relative dryness of subgrade is assured by cambered road profile, side drains, outlets and culverts.

**Environment**
Aggregation of abiotic factors (humidity, rainfall, temperature, wind, terrain, soil properties), biotic
factors (plant and animal) and anthropogenic factors that interact with each other and condition life in general within a certain area.

Erosion
Combined action of natural atmospheric phenomena (ablation, deflation and abrasion) on the exposed surface of the ground. There is sheet erosion, rill erosion and gully erosion. In this document, erosion refers mainly to the scouring of the soil from the action of water and to resulting damage in the form of rutting, compaction, leaching and scalping of the soil by extraction machinery (see also Sediment).

Extraction
Operation whereby trunks or logs are taken from felling site to landing by winching and skidding by wheeled tractors. We distinguish first and second extraction.

Felling or cutting cycle
Under selection (polycyclic) harvesting systems, the number of years envisaged between two successive harvests on a specific tract of forest (compare with Rotation).

Forest harvesting
All tree felling, extraction and conversion operations as far as handling (stacking, grading and storage) of logs at the landing.

Future crop tree
A tree of commercial species with DBH inferior to MHD retained during a felling entry for the subsequent cutting cycle. These trees play an important role in polycyclic harvesting systems.

Ground marking (staking, taping)
The marking of the main layout on the ground using stakes and pickets.

Harvest inventory
Survey operation whereby trees to be felled are counted and marked, and their species, diameter, status and quality recorded, together with future crop and heritage trees that need to be protected.

Heritage tree
Tree identified before and kept during harvesting, utilized by the local population for nutritional, cultural or religious purposes.

Impact
Action and effect of two elements coming forcefully into contact. Impacts refer in particular to harvesting effects on the environment (forest structure, remaining stand and soil), workforce and local communities. Impacts are assessed by means of indicators that show the extent to which activities affect the sustainability of resources, the well-being of local communities and the operational/financial efficiency of production.

Industrial roundwood
Roundwood used for industrial purposes, either in round form (electricity pales, piles, etc.) or as raw material to be processed into industrial products (sawnwood, panels, pulp, etc.)

Intermediate landing
Provisional gathering of logs on an intermediate site between felling stump and landing.

Kick-back
Sudden violent movement of a chainsaw propelled backwards towards the operator when the moving chain on the upper tip of the guide bar comes into contact with an object such as a trunk or branch. Kick-back is always a potential danger for the chainsaw operator, particularly during topping and butt-trimming when the point of the cutting attachment is often used in cantilever. It can only be properly controlled by means of an automatic chain brake using the inertia principle to activate the brake placed around the clutch housing in the event of a kick-back and thus stopping the chain immediately.

Landing
Cleared area temporarily organized for the assembly and storage of harvested timber where logs are placed after extraction for onward transport to processing mill or other final destination.
Lateral berm
Alignment of debris from road and landing construction (tree stumps, crowns and other debris) and from landing operations (offcuts, bark and sawdust) to avoid the blocking of drainage. On steep terrain where roads are cut into the slope, a row of debris from earthcut can be placed at the foot of earthfill by excavator shovel to act as a filtration litter and prevent sediment from reaching a nearby watercourse.

Lianas (climbers)
Plants that either hang freely from the forest canopy or adhere to the stems of trees by means of specialized roots. Free-hanging climbers with woody stems are often called woody climbers or lianas. They often bind several trees together as they pass from one crown to another, which can cause significant damage when one of the trees is felled. Climbers can however play an important role as source of food and habitat for animal species and should therefore only be cut where necessary to reduce felling damage.

Loading pier
Ramp reinforced with bolts placed perpendicular to the bank to facilitate the launching into the water of logs for floating in rafts, on a barge (on deck) or in a lighter (in the hull). The loading pier constitutes the point of rupture between road and water transport.

Lodged, hanging or hung-up tree
A tree that has been felled, uprooted by wind or pushed by other means against another tree, preventing it from falling to the ground.

Log
Any section cut from the bole or larger branches of a felled tree by cross-cutting.

Logging arch
Support mechanism mounted on tractor chassis or trailer serving to raise one end of the log to facilitate hauling.

Minimum harvesting diameters (MHD)
Diameter below which harvesting of a given species is not allowed. MHDs can differ from one country to another.

Minimum management diameters (MMD)
Diameters from which the management plan envisages the extraction of targeted tree species felling cycle. MMDs are determined on the basis of the forest structure, diameter distribution, increment and mortality of main species, and the rotation regime.

Manacyclic harvesting systems
Harvesting systems in which the crop trees are harvested all at once at the end of the rotation. Intermediate entries (thinnings) may be made to remove trees that are not intended for the final crop, so that crop trees receive more light and nutrients and can thus grow to a larger size.

Non-wood forest products
In this document, all biological matter other than industrial roundwood that can be extracted from natural ecosystems for commercial, domestic, social, cultural or religious purposes.

Offcut
Piece of wood from the base of a trunk cross-cut during conversion at the landing to remove the parts dirtied or damaged during skidding and to trim the log for sale or processing. Recovery level is considerably reduced when offcuts are excessively long. This habit is a major source of timber wastage and should be abandoned.

Pole
Roundwood with a smaller diameter than sawlogs, usable without further processing as electricity poles or for basic construction works.

Polycyclic harvesting systems
Harvesting systems in which crop trees are removed in a more frequent cycle of felling entries than a rotation. Such systems safeguard resource sustainability by respecting MHDs and the felling cycle. Under such systems, not all crop trees are removed during a particular felling entry; for example, trees to be felled might be those of certain species with a DBH of more than 60 cm or other selection criteria. For this reason, polycyclic systems are often referred to as selection systems.
Pre-skidding
Operation conducted by crawler tractor, that prepares the terrain and the trunk for easy access and extraction. Excessive or unskilled pre-skidding can cause considerable damage to remaining stand and soil. Careful pre-skidding seems to be the key to reduced impact harvesting in the region.

Production forest
Forest managed essentially for optimal harvest of principal wood and non-wood products. In the regional context, production usually centres on premium quality timber for the international market. Management has so far been limited to harvesting in felling cycles without optimizing biological production through silvicultural interventions (enrichment planting, thinning systems for steering growth dynamics).

Protection forest
Area totally or partially covered with forest vegetation managed essentially to retain all biotic or abiotic attributes and protect them from human-induced change; for example, minimizing erosion, regulating watercourses, maintaining water quality, stabilizing dunes and protecting wildlife species and vulnerable biotic communities.

Reduced impact forest harvesting (or RIL reduced-impact logging)
Practices aimed at optimizing operational efficiency and minimizing negative impact on environment, workforce and local population.

Resource
In this publication, any element of the natural environment that has an attributed value or utility.

Rotation
Planned number of years between the formation or regeneration of a crop of trees and the time when the same crop is felled for final harvest. The age at the time of harvest is referred to as the exploitable age when this coincides with the rotation, and as the harvesting age when not.

Sediment
The material products of erosion (soil, sand, clay, gravel and blocks) brought down watercourses and suspended in the water or deposited in outwash fans or on floodplains (see also Erosion).

Seed tree
Tree in apparent good health and conformation, marked before and retained during felling to facilitate natural regeneration and safeguard the continuity of forest species as well as their composition.

Shear plank
Length of joined and roughly squared wood driven vertically into the bank of a bridge to stabilize the verge below the access and exit of a bridge, and to anchor its superstructure to the abutment.

Skid trail
Trail along which logs are hauled. Main skid trails are planned in advance and marked on site. Tractors should always remain on skid trails during pre-skidding and extraction, therefore must be equipped with a winch and a cable long enough to reach the logs to be extracted.

Skidding
See Extraction

Skimming
Metaphorical expression designating the hyperselective harvesting of a handful of species. Skimming can jeopardize the sustainability of polycyclic systems. By utilizing a smaller volume of timber than planned, it creates a constant need for new areas, and, as market demands for new species rise, it tempts foresters to repeatedly re-enter already harvested blocks without observing the felling cycle.

Specific impact
Expression of impact where the magnitude of impact indicators is calibrated with the volume of timber harvested or extracted, thus showing the scale of impact per m³ of timber produced. Although forest harvesting in the region has a
relatively moderate impact in terms of absolute figures because of its low intensity (<10 m³/ha), specific impact figures are often high, especially those for structural impacts.

**Secondary road (Feeder road)**

Road giving access to each harvest area for a limited duration and only requiring basic construction standards. Lodings are usually located along these roads. Their prior planning and construction is a basic requisite for reducing skidding distance and thus surface area disrupted by the extraction network (roads and skid trails).

**Stanchion**

Wood or metal strut or support placed vertically on the sides of the deck of the timber truck, facilitating the stable loading of logs and ensuring that the load is properly fastened and evenly distributed during transport.

**Stem**

Main axis of a plant from which buds and shoots emerge. We talk of trunk in the case of a tree. The trunk of a large tree can also be referred to as a bole.

**Stump**

The woody base of a tree that remains in the ground after felling.

**Stringers (support beams)**

Four complete (two on each side), sap-cleared or squared trunks of considerable length and relatively large diameter resting horizontally between the bridge abutments. Together with the distribution and wearing decks, they constitute the bridge superstructure that bears the weight of traffic.

**Sunlight exposure**

Removal of trees blocking sunlight in order to clear the sides of a roadway and facilitate the drying of its surface. The width of sunlight exposure depends on soil type, terrain and exposition, but should in any case be kept to a minimum. Regular canopy bridges should be left to allow aerial passage for certain monkey species.

**Superstructure**

The main part of a bridge, made up of the stringers and the distribution and wearing decks, resting on the abutments.

**Systematic survey lot**

Harvest inventory method based on systematic porcelling of a forest using a grid of survey lines.

**Timber**

Wood that can be converted into industrial forest products. This term is sometimes synonymous with industrial roundwood and may also designate certain large pieces of sawnwood (construction timber).

**Timber recovery**

Proportion between volume of timber after and volume of timber before the production process (for example, felling and crosscutting). The recovery level is an indicator of harvesting efficiency but also of wastage of primary resources. The level under RIL should be above 60 percent but is much lower in forest harvesting in the region.

**Timber truck**

Vehicle with a payload of 15 to 35 tonnes serving to transport logs on forest and public road networks. Made up of a tractor and trailer and usually equipped with five axles (three for the tractor, including two power-driven, and two for the trailer) and with a total gross weight of 25 to 50 tonnes.

**Transport**

Transport of logs from landing to processing mill or other final destination.

**Tree spotting and marking**

The appraisal of trees identified as exploitable during the inventory, marking those that are accepted (with a set of plaques), indicating trees to be protected, staking the layout of the skid trail network and counting the number of trees to be extracted along each trail as their position is noted. This phase links pre-harvest survey with harvesting operations and prepares the ground for environmentally sound and efficient
extraction. It is therefore an essential tool for the implementation of reduced-impact practices.

**Tropical moist forests**
Natural forests with varying degree of disturbance and crown cover, located between the Tropic of Cancer in the North and the Tropic of Capricorn in the South, comprising numerous species with permanent foliage and dominated by a relatively high ambient humidity.

**Trunk**
Stem or part of the stem of a felled, topped and butt-trimmed tree. Can also refer to a very large branch processed in this manner.

**Volume**
The estimated or measured quantity of wood in a log, trunk, bole or tree, usually expressed in m³.

**Washout**
Form of erosion (removal of fragments of rock and soil) caused by waterflow in the drainage structures of a forest road and in watercourses crossed by drift and bridge, affecting stability of the roadbed.

**Winch**
A drum fitted to and powered by a tractor and serving to pay out and reel in cable so that the first phase of extraction can be done without approaching the stump and then haul the bole or log to the landing with one end raised as high as possible off the ground. The winch is considered a vital piece of equipment designed to reduce surface area affected by skid trails and soil damage by ground traction.
REFERENCES RELATED TO FOREST PRACTICES WITHIN A REGIONAL CONTEXT


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PHOTOGRAPHS AND ILLUSTRATIONS:

Figure 1  Division into blocks and pockets  Leroy Gabon
Figure 2  Survey map from pocket inventory  Leroy Gabon
Figure 3  Inventory by systematic survey lat  Thanny/TWE
Figure 4  Organizing the survey  Jean Estève
Figure 5  Watercourses and other sensitive areas  Vanuatu Department of Forests, 1998
Figure 6  Specimen harvesting map  Leroy Gabon
Figure 7  Cross section of road on flat terrain  Estève
Figure 8  Cross section of a standard cut-and-fill hillside road  CTFT, 1989
Figure 9  Standard side-drain profile  CTFT, 1989
Figure 10  Widening and adjustment of curve  CTFT, 1989
Figure 11  Visibility ledge  CTFT, 1989
Figure 12  Hillside profile  FAO, 1999
Figure 13  Road construction with excavator and bulldozer  Vanuatu Department of Forests, 1998
Figure 14  Road drainage on flat terrain  Vanuatu Department of Forests, 1998
Figure 15  Positioning a culvert  Vanuatu Department of Forests, 1998
Figure 16  Correct siting of a bridge  Vanuatu Department of Forests, 1998
Figure 17  Bank abutment  Vanuatu Department of Forests, 1998
Figure 18  Bridge pier / Canadian log crib abutment  Vanuatu Department of Forests, 1998
Figure 19  Specimen forest bridge  CTFT, 1989
Figure 20  Harvesting map  FAO, 1996
Figure 21  Escape routes and clearing around tree base  FAO/ILO, 1980
Figure 22  Trunk cylinder, basal area, ...  FAO/ILO, 1980
Figure 23  Removing buttresses  FAO/ILO, 1980
Figure 24  Configuration and sequence of cuts when felling trees with buttresses and conical base  FAO/ILO, 1980
Figure 25  Diagram of the principle of chainsaw felling  ILO, 1988
Figure 26  Fanlike felling cut  FAO/ILO, 1980
Figure 27  Plunge backcut  FAO/ILO, 1980
Figure 28  Configuration and sequence of cuts for felling trees with a lean  FAO/ILO, 1980
Figure 29  Methods of tractor extraction  CTFT, 1989
Figure 30  Trail network for skidding towards ridgeline  Vanuatu Department of Forests, 1998
Figure 31  Location of a landing  Vanuatu Department of Forests, 1998
Figure 32  Provisional crossing of a watercourse using baits  ILO, 1998
Figure 33  Cross-cutting according to stem diameter  ILO, 1998
Figure 34  Cross-cutting wood under tension  Vanuatu Department of Forests, 1998
Figure 35  Securing a timber truck load  Asia-Pacific Forestry Commission, 1999
Figure 36  Position of load on truck deck  ILO, 1998
Figure 37  Post-harvest cross-drain on a skid trail after use  ILO, 1998
Figure 38  Chainsaw safety devices  ADIE
Figure 39  Chainsaw kick-back  ADIE
Figure 40  Sustainable forest management chart  ADIE
### TABLES

| Table 1 | Estimated average impact of harvesting on stands | Schwab et al., 2001 |
| Table 2 | Damage to stands caused by felling and extraction | Fath and Arzberger, 2003 |
| Table 3 | Matrix of impact indicators | Fath and Arzberger, 2003 |
| Table 4 | Surface area affected by infrastructure and harvesting | Estève |
| Table 5 | Improvements from RIL | Balouard, 1998 |
| Table 6 | Planning documents | ATIBT, 2001 |
| Table 7 | Diagram for the planning and implementation of harvesting operations | Estève |
| Table 8 | Width of sensitive areas | Vanuatu Department of Forests, 1998 |
| Table 9 | Curve radius | CTFT, 1989 |
| Table 10 | Widening of curves | CTFT, 1989 |
| Table 11 | Visibility distance | Estève |
| Table 12 | Diameter of stringers | CTFT, 1989 |
| Table 13 | Cross-drain frequency on secondary roads and skid trails after use | Dykstra et al., 2001 |
| Table 14 | Most hunted species in Gabon | ADIE |
| Table 15 | Other Central African species threatened by hunting | ADIE |
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.

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:

i) the African “region” in a broad sense, encompassing the tropical countries of West and Central Africa and their specific characteristics;

ii) timber harvesting because of its potential damage to the environment. Some guidelines on silviculture and wildlife protection are also included;

iii) and on closed natural production moist forests, although some of the guidelines also apply to protection and plantation forests.