

Forest Management Plan

Tain Tributaries Block II Forest Reserve,
Ghana



Form international
Hatter, May 2016



Client

| | |
|----------------|--|
| Name | Form Ghana Ltd. |
| Contact person | W. Fourie |
| Address | P.O. box SYI 211 Sunyani Brong Ahafo, Ghana |
| Telephone | +233 (0)544 441 440 |
| Email | formghana@yahoo.com |
| Website | www.formghana.com |

Consultant

| | |
|------------------|--|
| Name | Form international B.V. |
| Contact person | M. Tollenaar |
| Address | Bevrijdingsweg3 8051 EN Hattem Netherlands |
| Telephone | +31(0) 38 444 8990 |
| Fax | +31(0) 38 444 8991 |
| Email | info@forminternational.nl |
| Website | www.forminternational.nl |
| Authors | P. Westerlaan & M. Tollenaar |
| Document version | V3 |
| Date of document | 23-5-2016 |
| Reference | MP-TAIN-V2 |

CONTENTS

| | |
|--|-----------|
| Contents | 3 |
| Foreword | 6 |
| List of abbreviations | 7 |
| 1. Introduction | 8 |
| 1.1 <i>Form international</i> | 8 |
| 1.2 <i>Ghana's forest and timber industry</i> | 8 |
| 1.3 <i>Reforestation by Form Ghana</i> | 8 |
| 1.4 <i>Management of timber plantation in Tain II FR</i> | 9 |
| 1.5 <i>Report structure</i> | 11 |
| 2. Company | 13 |
| 2.1 <i>Sustainability</i> | 13 |
| 2.2 <i>Corporate Social Responsibility</i> | 14 |
| 2.3 <i>Legal compliances</i> | 15 |
| 2.4 <i>Organisational structure</i> | 16 |
| 2.5 <i>Infrastructure</i> | 17 |
| 3. Characterisation of the environment | 18 |
| 3.1 <i>Physical environment</i> | 18 |
| 3.1.1 <i>Climate</i> | 18 |
| 3.1.2 <i>Soils</i> | 19 |
| 3.1.3 <i>Topography</i> | 20 |
| 3.1.4 <i>Hydrography</i> | 20 |
| 3.1.5 <i>Vegetation</i> | 21 |
| 3.1.6 <i>Fauna</i> | 23 |
| 3.2 <i>Socio-economic environment</i> | 24 |
| 3.2.1 <i>Household size, age and occupation</i> | 24 |
| 3.2.2 <i>Housing and transportation</i> | 25 |
| 3.2.3 <i>Ethnicity and religion</i> | 26 |
| 3.2.4 <i>Village facilities</i> | 26 |
| 3.2.5 <i>Level of education</i> | 28 |
| 3.2.6 <i>Health</i> | 28 |
| 3.2.7 <i>Farming</i> | 29 |
| 4. Forest management | 30 |
| 4.1 <i>Objectives</i> | 30 |
| 4.1.1 <i>Ecologically sustainable plantation management</i> | 31 |
| 4.1.2 <i>Economically sustainable timber plantation management</i> | 31 |
| 4.1.3 <i>Social benefits for employees and surrounding communities</i> | 32 |
| 4.2 <i>Consequences on land-use</i> | 32 |
| 5. Organisation of managed areas | 34 |
| 5.1 <i>Localisation and limits</i> | 34 |

| | | |
|------------|---|-----------|
| 5.2 | <i>Plantation infrastructure</i> | 35 |
| 5.2.1 | Roads | 35 |
| 5.2.2 | Communication | 35 |
| 5.3 | <i>Plantation organisation</i> | 35 |
| 5.4 | <i>Field planting program</i> | 35 |
| 6. | Tree species selection | 37 |
| 6.1 | <i>Teak</i> | 37 |
| 6.1.1 | Climate and soil conditions | 38 |
| 6.1.2 | Provenances | 38 |
| 6.2 | <i>Other commercial tree species</i> | 38 |
| 6.3 | <i>Buffer vegetation</i> | 39 |
| 6.4 | <i>Forest type allocation</i> | 39 |
| 7. | Tree nursery | 40 |
| 7.1 | <i>Tree nursery practices</i> | 40 |
| 7.1.1 | Seeds | 40 |
| 7.1.2 | Stumps | 41 |
| 7.2 | <i>Transport to planting site</i> | 41 |
| 7.3 | <i>Annual planning</i> | 41 |
| 8. | Silvicultural system | 42 |
| 8.1 | <i>Management strategy</i> | 42 |
| 8.1.1 | Rotation overview | 42 |
| 8.1.2 | Yield tables teak | 42 |
| 8.1.3 | Expected teak yield from Tain II FR | 43 |
| 8.2 | <i>Silvicultural treatments</i> | 43 |
| 8.2.1 | Ground preparation | 43 |
| 8.2.2 | Plantation establishment | 44 |
| 8.2.3 | Weeding and singling | 44 |
| 8.2.4 | Climber cutting | 44 |
| 8.2.5 | Thinning | 44 |
| 8.2.6 | Pruning | 45 |
| 8.2.7 | Final harvesting | 45 |
| 8.2.8 | Maintaining the positive effects of plantation establishment throughout the project cycle (several rotations) | 46 |
| 8.3 | <i>Seed stand management</i> | 46 |
| 9. | Risk management | 47 |
| 9.1 | <i>Prevention of illegal activities</i> | 47 |
| 9.2 | <i>Fire management</i> | 47 |
| 9.2.1 | Fuel load reduction | 47 |
| 9.2.2 | Fire breaks | 47 |
| 9.2.3 | Fire squad | 47 |
| 9.2.4 | Awareness raising | 48 |
| 9.3 | <i>Control of pests and diseases</i> | 49 |
| 10. | Social plan | 50 |
| 10.1 | <i>Oversight body</i> | 50 |

| | | |
|------------|--|-----------|
| 10.2 | <i>Stakeholders' committee</i> | 50 |
| 10.3 | <i>Benefit sharing</i> | 50 |
| 10.4 | <i>Intercropping</i> | 50 |
| 10.5 | <i>Employment and training</i> | 51 |
| 11. | Environmental management | 52 |
| 11.1 | <i>Soil and water</i> | 52 |
| 11.1.1 | Water quality management | 52 |
| 11.1.2 | Soil management | 52 |
| 11.1.3 | Policy for use of chemicals | 53 |
| 11.2 | <i>Biodiversity</i> | 53 |
| 11.2.1 | Buffer vegetation management | 53 |
| 11.2.2 | Wildlife | 53 |
| 11.2.3 | Harvesting non-timber forest products | 54 |
| 11.3 | <i>High Conservation Value Forests</i> | 54 |
| 11.3.1 | Conclusion | 54 |
| 11.3.2 | Management implications | 55 |
| 11.3.3 | Future | 55 |
| 12. | Monitoring and evaluation | 56 |
| 12.1 | <i>Plantation monitoring</i> | 57 |
| 12.1.1 | Forest growth and condition | 57 |
| 12.1.2 | Biological diversity | 58 |
| 12.1.3 | Rainfall, soil and water protection | 59 |
| 12.2 | <i>Economic aspects</i> | 60 |
| 12.2.1 | Timber | 60 |
| 12.2.2 | Carbon credits | 60 |
| 12.3 | <i>Social aspects</i> | 61 |
| 12.4 | <i>Utilization of study findings</i> | 61 |
| 13. | Operational management plan | 62 |
| 13.1 | <i>Annual planning</i> | 62 |
| 14. | References | 63 |
| | Annex A. List of Protocols | 64 |
| | Annex B. stand sheets | 66 |
| | Annex C. Overview map of Tain II | 68 |
| | Annex D. Yield tables Ivory Coast | 69 |

FOREWORD

Form Ghana is proud with the acquisition of the land lease covering nearly 15,000 hectares in Tain II Forest Reserve. This allows an expansion of her reforestation activities in partnership with Ghana's Forestry Commission. We can build upon the experience gained from the reforestation of Asubima and Afrensu Brohuma Forest Reserve that was realised between 2008 and 2012. Form Ghana now aims at reforesting 20,000 ha of degraded Forest Reserves in Ghana.



Figure x.1. Overview Tain II Forest Reserve.

I am pleased to present you this management plan for the areas in Tain II Forest Reserve managed by Form Ghana. In the near future, FSC certification as well as VCS verification will be strived for, like is now the case for the reforested areas in Asubima FR managed by Form Ghana. Therefore, in Tain II FR we will adopt responsible and sustainable practices from the start. I am confident that this management plan forms a solid basis to establish a sustainable forest plantation.

Our major challenge now is to work on establishing and maintaining good relations with surrounding communities.

Form Ghana Ltd.,

Mr. Willem Fourie
Managing director

LIST OF ABBREVIATIONS

| | |
|-------|---|
| DBH | Diameter at Breast Height |
| FC | Forestry Commission |
| FORIG | Forestry Research Institute of Ghana |
| FR | Forest Reserve |
| FSC | Forest Stewardship Council |
| FSD | Forestry Services Division (part of FC) |
| Ha | hectares |
| Kg | kilogram |
| M | meter(s) |
| Mm | millimetre(s) |
| NTU | Nephelometric Turbidity Unit |
| PPP | Public Private Partnership |
| PSP | Permanent Sample Plot |
| Pt/Co | Platinum and Cobalt scale |
| VCS | Verified Carbon Standard |

1. INTRODUCTION

Form Ghana has commissioned Form international to elaborate a management plan for the company's reforestation activities in Tain II Forest Reserve, Brong Ahafo Region. This chapter starts with a brief introduction of Form international, followed by the context of Ghana's forest and timber industry. Then, the company Form Ghana Ltd. is presented and the structure of the management of the Tain II FR. This chapter ends with an overview of the report structure.

1.1 Form international

Form international is a Dutch consultancy firm established in 1992. It offers high quality advice on forest management, certification and technical assistance to plantation establishment and management. Form international (Form) has extensive experience in tropical forest management, mainly in West and Central Africa and is also active in Europe on Chain-of-Custody (CoC) certification and PEFC conformity assessments.

Form advises branch organizations, international timber and forest companies, NGO's and many other organizations that play a role in the direct or indirect amelioration of forest management. Using a pragmatic approach, Form's knowledge and experience in the field of sustainable forest management and certification is translated into a concrete advice ready to be implemented in the day-to-day forest operations of her clients.

1.2 Ghana's forest and timber industry

Ghana's forest area has been reduced over the last decade, due to over-exploitation and encroachment of its forest reserves. Ghana's present forest resources sustain a maximum annual allowable cut of about 1 million m³ of timber, while the export-oriented wood industry has an installed capacity of around 3.7 million m³ and local demand for firewood will reach about 3 million m³ by 2020.

Forest Reserves are managed by the Forestry Services Division of the Forestry Commission. Harvesting is carried out under logging concessions by private companies. The forestry sector is reported to contribute to 2.8% of the Gross Domestic Product (2011) and is characterised by excess capacity relative to the availability of raw material. Ghana has made considerable efforts towards bringing her natural forests under sustainable management. The National Forest Plantation Development Programme (NFPDP) aims at reforestation of degraded Forest Reserves and private lands via multiple strategies, among others through land leases and benefit sharing agreements with private investors.

1.3 Reforestation by Form Ghana

Form Ghana Ltd. is owned by Sustainable Forestry Investments the Netherlands (SFI NL) and based in central Ghana. The company was established in 2007 and has since then been active in the north of the Ashanti Region, near Akumadan, where the company had started to reforest the highly degraded Asubima and Afrensu Brohuma Forest Reserves in 2008 and 2011 respectively.

For the Tain II Forest Reserve, a Public Private Partnership (PPP) has been established between Ghana’s Forestry Commission, the local landowners and Form Ghana (the private investor). The goal of the PPP is to increase the amount of commercial reforestation in the degraded forest reserves of Ghana. A lease was obtained from the Forest Service Division of the Forestry Commission for 14,596 hectares of degraded forest land in the Tain II Forest Reserve that are favourable for growing teak.

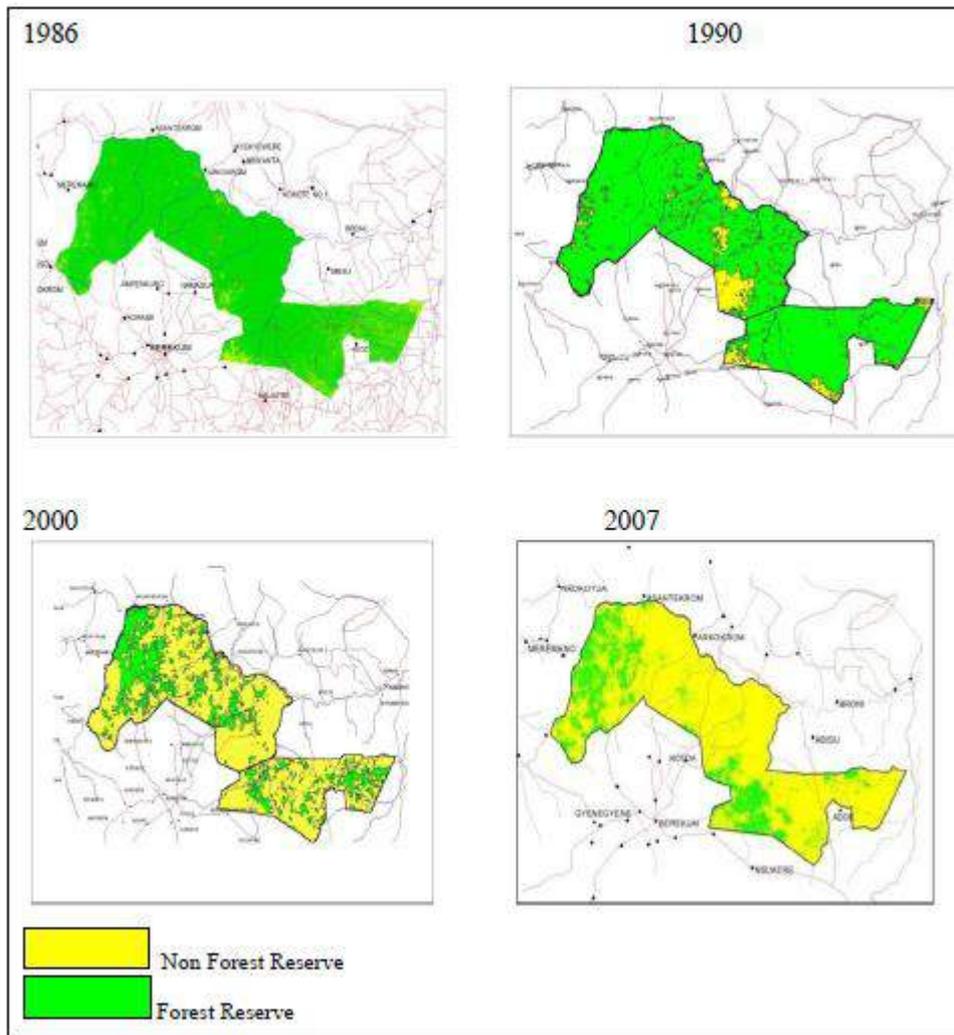


Figure 1.1. Forest cover Tain II FR from 1986 – 2007. Source: Kosoe, 2012.

Within the partnership, every party has their own specific responsibilities. The Forestry Commission provides assistance on specific activities such as demarcation, mapping, fire sensitization of communities, yield marking and monitoring. The local landowners provide access to land and the private investor is responsible for the provision of all further financial, management and technical inputs of the plantation establishment.

A benefit sharing agreement has been signed between the three parties in the PPP, see section 10.3.

1.4 Management of timber plantation in Tain II FR

Management plan

Form Ghana Ltd. (Form Ghana) has elaborated a reforestation plan for the establishment of a commercial timber plantation in the Tain Tributaries Block II Forest Reserve (further referred to as Tain II FR), which after submission has been approved by the Forestry Commission of Ghana. However, since the reforestation plan is too general to work with in the field, Form Ghana has commissioned Form international to elaborate a management plan for the company's reforestation activities in Tain II Forest Reserve.

This Management Plan describes the management system of Form Ghana Ltd., based on the FSC Principles and Criteria, includes the following topics:

- An overview of the physical environment (climate, water and soil condition, biodiversity, etc.) and social-economic environment (village facilities, occupation, level of education, housing and transportation etc.) of Asubima and Afrensu Brohuma FR.
- The forest management objectives, elaborating on each of the three sustainability pillars (ecological, economic and social) and it describes the way land-use is impacted on the long-term
- The organization of the managed areas including the plantation infrastructure and field planting program
- The tree species selection and forest type allocation
- Tree nursery practices
- The various silvicultural practices that will be carried out during the entire plantation rotation cycle
- Risk management, including prevention of illegal activities, fire management and control of pests
- A social plan that covers the involvement of stake-holders, benefit sharing, employment and intercropping by local farmers
- Environmental management, concentrating on soil and water, biodiversity and High Conservation Value Forests
- The various monitoring activities

A number of studies and reports was used as input for this Management Plan, each based on relevant preliminary studies of the area:

- The Reforestation Plan of Tain II Forest Reserve
- The Social and Environmental Impact Assessment (SEIA) report for Tain II Forest Reserve
- The High Conservation Value Forest analyses of Tain II Forest Reserve

Management procedures and stand sheets

Complementary to the Management Plan, Form Ghana uses a system of separate protocols that describe the processes of environmental and social management. A list of the protocols is included in Annex A of this Management Plan. Throughout the management plan, reference will be made to these protocols.

Also, there are stand sheets which are filled in or updated every planting year. These stand sheets form the basis of the operational management plan (see chapter 13). They describe the area planted per year and the way in which that area will be managed specifically. They are important to keep track of the stands and to conserve information through time. For an example see Annex B.

Monitoring

Management is a continuous process. This means that it will be adapted over time as a consequence of changes in the field or new insights. To keep track of these management changes, Form Ghana applies a monitoring system which involves annual information gathering on plantation growth and condition, social impact, soil and water protection and biodiversity (see chapter 12).

The effectiveness of management is checked annually through monitoring activities. The Management Plan and Protocols serve as input for the monitoring system. Findings from monitoring activities are fed back into the management system through the adaptation of protocols or management plans. The process of evaluation and adaptation will lead to further fine-tuning of the management plan. The relations between the various documents is described in the schedule below (figure 1.2).

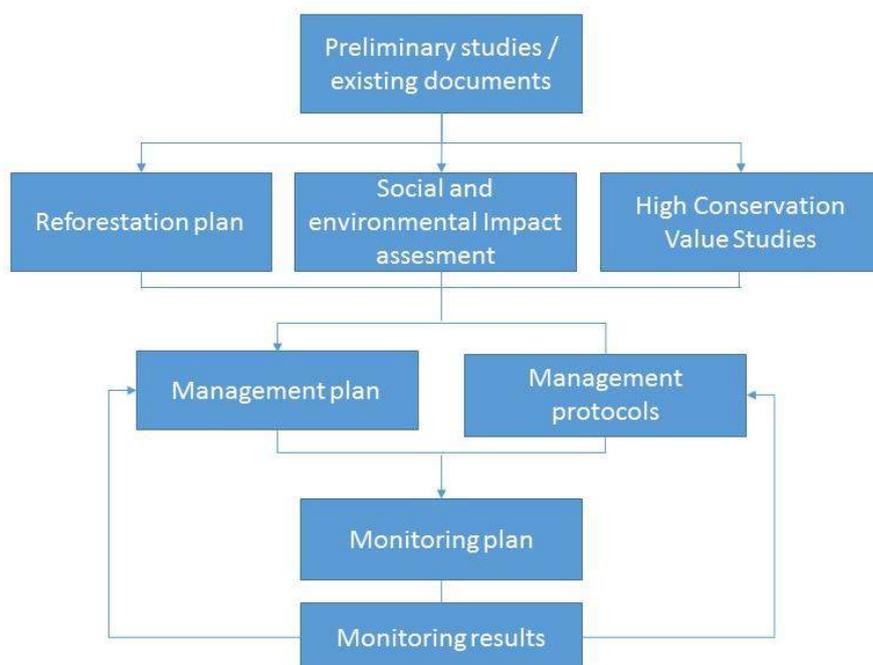


Figure 1.2. Links between various documents

Validity of management plan

As is mentioned in the section above, the management plan is updated every year to incorporate new information from the field. Every year during the dry season, the plan is closely compared with the current situation in Tain II FR. If the field situation has changed, the management plan is adapted accordingly. Likewise, information from monitoring is used to update the management plan (if the nature of the information dictates so).

1.5 Report structure

This management plan first introduces the company Form Ghana Ltd and the sustainability approach taken (Ch. 2). Then, in chapter 3 an overview is presented of the physical environment (climate, water and soil condition, biodiversity, etc.) and social-economic environment (village facilities, occupation, level of education, housing and transportation etc.) of Tain II FR.

Chapter 4 states the forest management objectives elaborating on each of the three sustainability pillars (ecological, economic and social) and it describes the way land-use is impacted on the long-term. The organisation of the managed areas is presented in chapter 5 including the plantation infrastructure and field planting program. The tree species selection and forest type allocation is described in chapter 6, followed by the tree nursery practices in chapter 7. Chapter 8 gives a full description of the various silvicultural practices that will be carried out during the entire plantation rotation cycle.

Chapter 9 is devoted to risk management including prevention of illegal activities, fire management and control of pests. The social plan (chapter 10) covers the involvement of stakeholders, benefit sharing, employment and intercropping by local farmers. Environmental management, concentrating on soil and water, biodiversity and High Conservation Value Forests, is covered in chapter 11. The various monitoring activities are described in chapter 12. Finally, the set up and maintenance of the operational management plan are discussed in chapter 13.

2. COMPANY

Form Ghana Ltd. was established in 2007 and has since then been active in the north of the Ashanti Region, near Akumadan, where it has reforested 3,500 ha of the highly degraded Asubima and Afrensu Brohuma Forest Reserves between 2008 and 2012. In 2013, Form Ghana expanded its reforestation activities to Tain II Forest Reserve in the Brong Ahafo region.

This chapter first elaborates on the core value of Form Ghana: sustainability. Directly linked to that, paragraph 2.2 is about the corporate social responsibility of Form Ghana. Then, in paragraph 2.3 details are given of the legal compliance of Form Ghana, the organisational structure is presented in 2.4 and the infrastructure is briefly described in paragraph 2.5.

2.1 Sustainability

Form Ghana envisions carrying out its activities in a social, ecological and economical responsible way. The figure below gives an overview of Form Ghana's unique sustainability concept that is applied in all the plantation units managed by Form Ghana.

The unique sustainability concept of Form Ghana

| Social | Ecological | Economical |
|--|---|--|
| <ul style="list-style-type: none"> • Landlease instead of purchase • Creating local employment • Intercropping by local farmers • Trainings and good working conditions for employees • Revenues partly return to local community • Stimulate outgrowing | <ul style="list-style-type: none"> • Reforestation of degraded land • >5% of the planted seedlings are local species • Conservation and restoration of bufferzones along waterways • Enhance biodiversity • Restore water and soil quality • Positive influence on global carbon balance | <ul style="list-style-type: none"> • Respond to declining supply and growing demand for sustainable timber • Boost local economy • Yield much higher and harvesting cycle shorter than natural forest • Main tree species teak is highly profitable • Periodic revenues due to annual planting • Besides timber, income generation from carbon credits |

High quality on a technical as well as on a social and environmental level is the key to success for Form Ghana. This has resulted in FSC certification for responsible forest management in 2010 and validation of a reforestation carbon project under the VCS in 2013.

On the next page, the sustainability policy of Form Ghana is presented. In the following chapters these aspects will be elaborated in detail for the Tain II FR.

Sustainability Policy of Form Ghana Ltd.

Form Ghana commits itself to manage its plantations in a responsible and socially, environmentally and economically sustainable way. To this end, it strives to operate in compliance with the Principles and Criteria of the Forest Stewardship Council (FSC™).

In this way, the company will contribute significantly to the environment, the Ghanaian economy and to the quality of life of people related to and in the direct vicinity of the company. High quality on a technical as well as on a social and environmental level is the key to success for Form Ghana.

Form Ghana offers its employees a safe and healthy working environment, with good employment terms, favourable insurance policy conditions and pension build-up. Besides employment, local people can benefit indirectly from the activities of Form Ghana, through revenue sharing.

Form Ghana aspires to conserve and restore biological diversity, water sources, and fragile ecosystems found in or near its plantations. Plantations will be managed in such a way that they will contribute to climate change mitigation by having a positive influence on the global carbon balance.

The production from forest plantations certified for sustainable management will ensure the enhancement of the local economy and a guaranteed timber supply for the forest industry.

Form Ghana will operate with respect to Ghanaian laws as well as the international conventions valid in Ghana.

2.2 Corporate Social Responsibility

Form Ghana aspires to continue meeting the standards of the Forest Stewardship Council (FSC). Besides technical performance, Form Ghana has a policy for the corporate social responsibility.

Corporate Social Responsibility Policy of Form Ghana Ltd.

Code of conduct

Form Ghana will uphold and / or develop cultural values by respecting local customs and maintaining good relations with the local chiefdoms.

Form Ghana will not allow any form of discrimination to take place on the premises. Discrimination based on race, sex, sexual preference, age or religion is explicitly prohibited at Form Ghana.

Employment

At Form Ghana all labour is voluntary and regulated by contracts that were negotiated in freedom. No forced labour shall take place on Form Ghana premises.

At Form Ghana there shall be no child labour. No people are employed that are less than 18 years of age.

There is a preference to employ people from the neighbouring towns and villages to stimulate the local economy. If specific expertise/ background are not available locally, Form Ghana will employ people from elsewhere. Employees are preferably housed in their own houses. The company organises the transport from a central collecting point to the nursery and the plantation. For staff living outside the area the company will provide appropriate lodging facilities.

Workers receive the training necessary to adequately perform their jobs. Most of this training is on the job and repeated annually. In some cases special schooling may be awarded when deemed necessary by the management.

Payment

Workers will receive at least the nationally agreed minimum wage. For the permanent staff this salary can be transferred to the respective bank accounts of the employees or be paid cash. For temporary workers payment will be in cash.

Form Ghana pays the SNITT for the permanent workers as is due.

Form Ghana offers a possibility for a loan to permanent workers.

Worker's unions

At Form Ghana the employees have all rights for organisation and collective negotiations.

A Consultative structure exists consisting of worker representatives who meet with management on a monthly basis.

Safety

Form Ghana has performed a health and safety analysis in the workplace. Based on this analysis a schedule of safety equipment has been drawn up. This equipment is provided to the relevant workers.

Form Ghana provides water from a tested source for its employees.

Form Ghana has a first aid centre with a trained nurse. Employees are trained in providing first aid annually. Also there is an agreement with the Holy Family hospital in Techiman and the Holy Family Hospital in Berekum, so that injured workers of Form Ghana will be admitted immediately and paperwork is arranged later. Workers who have fallen ill can have their medical expenses refunded against presentation of the bills of medicines and a doctor's order for these same medicines.

Form Ghana insures the permanent workers through the national health insurance programme. This insurance covers the medical costs of workers and their families.

Local farmers

Form Ghana collaborates with farmers through, among others, the following arrangements:

- Providing farmers with temporary access to farm land within the plantation according to specified criteria and options set by Form on a sustainable basis (this concerns intercropping).
- Allowing farmers to grow certain crops on the fire belt.
- Provide training in bush fire prevention and fighting for the fringe communities.
- Ensure high safety standards in the entire operation and access to better health care facility to the fringing communities.
- Transparent benefit sharing with relevant stakeholders.

2.3 Legal compliances

Form Ghana Ltd. is officially established in Ghana through documents CA-387,338/2421 (registration certificate), CA-37,338 (certificate of incorporation) and CA-37,338 TIN 824VO25997 (certificate to commence business).

In 2013, Form Ghana has obtained a lease for 110 compartments in Tain II Forest Reserve, for the duration of 50 years (renewable). These are: 30-32, 34-38, 42-52, 54-63, 65-74, 76-92, 99, 102-104, 108, 110-115, 118-126, 135, 136 and 138-140 (block A, 81 compartments), 193, 205, 207, 216-224 and 226 (block B, 13 compartments) and 150-152, 155, 157, 158, 160, 162, 182, 183, 185-188, 212 and 213 (block C, 16 compartments), see figure 5.1.

Form Ghana implements its activities according to the applicable national legislation and international conventions. Protocol P01 describes in detail how this is realised by the company.

2.4 Organisational structure

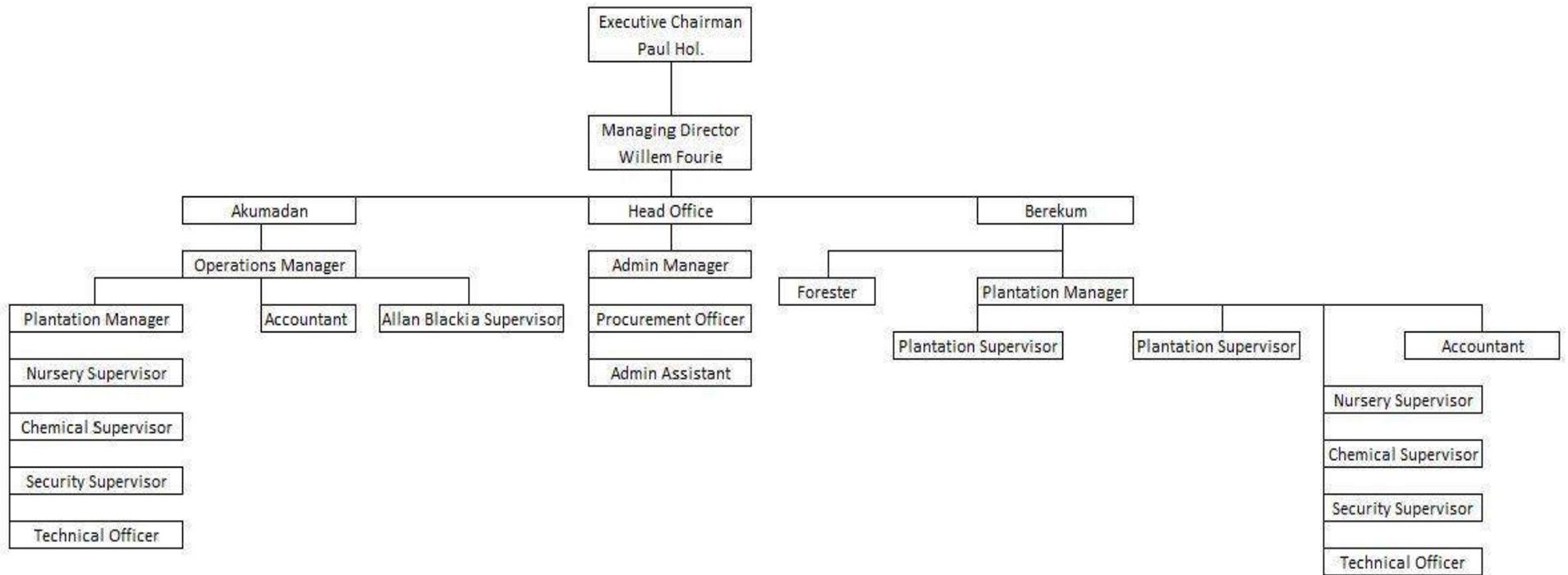


Figure 2.1. Diagram of the organisation of Form Ghana Ltd.

2.5 Infrastructure

Offices

Form Ghana has offices in three locations. One office is built in Akumadan near the plantations established in Asubima FR and Afrensu Brohuma FR. Another office is located in Kotaa near the Tain II FR. Finally, there is an office located in Sunyani.



Figure 2.2. Office in Sunyani

3. CHARACTERISATION OF THE ENVIRONMENT

In this chapter some background information is given on the project area. First, the physical environment is described (climate, soils, topography, hydrography, vegetation and fauna) followed by the social characteristics (household size, age & occupation, housing & transportation, ethnicity & religion, village facilities, level of education, health and farming practices). Information included in this chapter is obtained from the Social and Environmental Impact Assessment by Tollenaar (2013) unless otherwise specified.

Below, a map is shown of the Tain II Forest Reserve and the area where the area managed by Form Ghana is depicted in green.

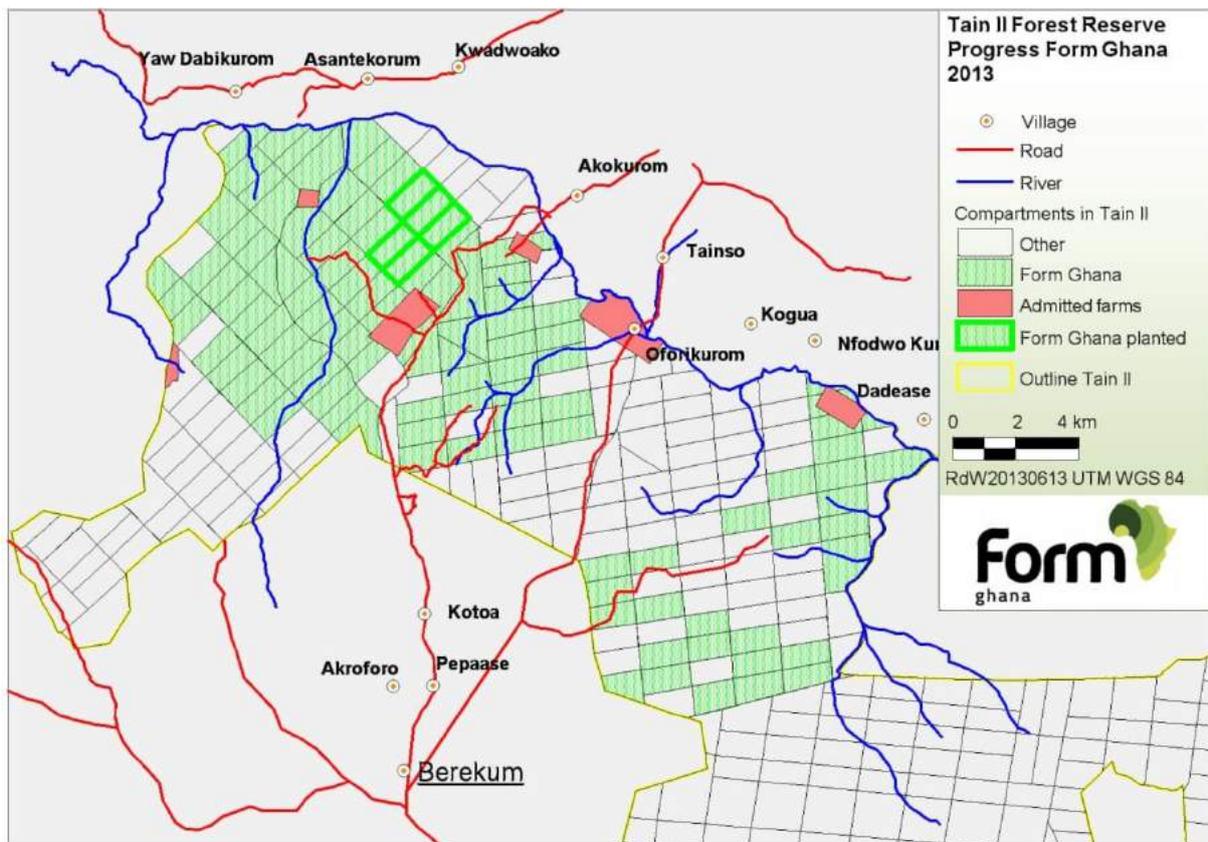


Figure 3.1. Map Tain II FR area managed by Form Ghana. The area surrounded with a green line has been planted in 2013.

3.1 Physical environment

3.1.1 Climate

Tain II Forest Reserve has a bi-modal rainfall pattern with a major and minor peak in June and October respectively. The main dry season is from November to March and there is a second dry spell in August. The mean annual rainfall is 1200 mm and the minimum and maximum annual temperature for 26 years were 23.6°C and 26°C (Orgle, 1994). Relative humidity in the dry season ranges from 100% at night to 30% near midday when the harmattan wind is strongest.

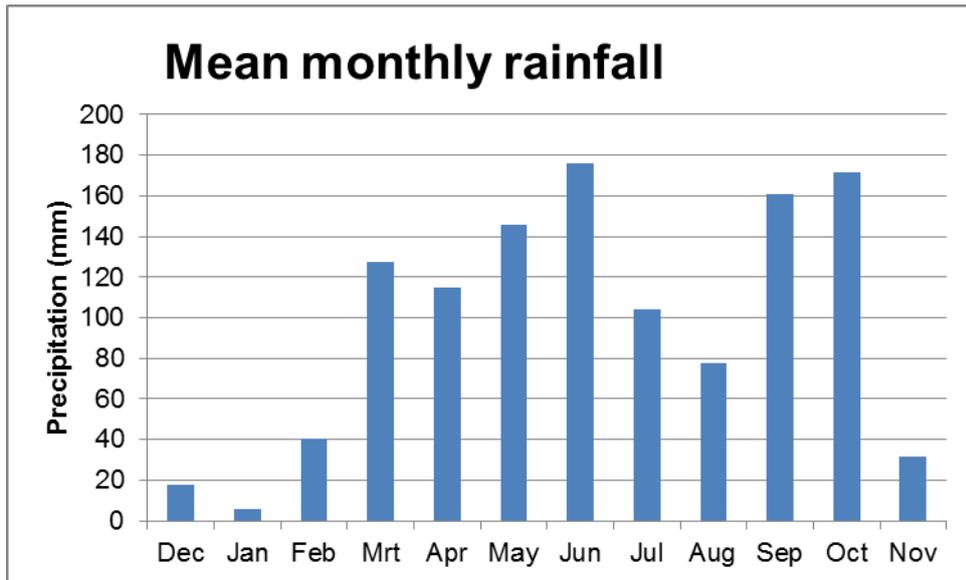


Figure 3.2. Mean monthly rainfall in Sunyani measured over thirty years. Source: reforestation plan, 2013.

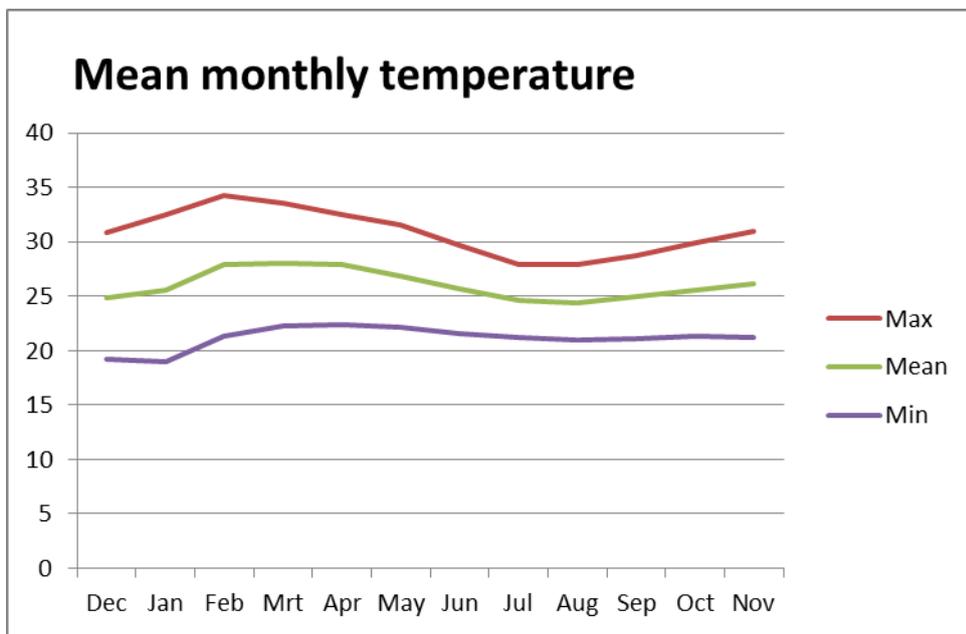


Figure 3.3. Mean monthly temperature in Sunyani measured over thirty years. Source: reforestation plan, 2013.

3.1.2 Soils

The soil survey by Scholten *et al.* (2013) exposed five different soil series present in the area: Bekwai, Nzima, Kokofu, Oda and Wenchi, three of which are suitable for teak cultivation, despite a relatively low nutrient content (table 3.1). The Wenchi soil series are unsuitable due to limitations in depth and presence of stones, gravels and iron pan. The Oda soil series are marginally suitable due to restrictions in drainage capacity (Scholten *et al.*, 2013).

Table 3.1. Soil series found in Tain II Forest Reserve. Source: Scholten *et al.*, 2012.

| Soil series | Suitability | Constraints | Favourable | Ha | Cover |
|----------------------|-------------|----------------------|--|-------|--------|
| Bekwai series | High | Low nutrient content | Drainage and soil depth | 718 | 4.93% |
| Nzima series | High | Low nutrient content | Drainage and soil depth | 1,883 | 12.92% |
| Kokofu series | Moderate | Internal drainage | Deep topsoil with humus up to 35 cm depth. | 9,639 | 66.12% |
| Oda series | Low | Drainage | Topsoil rich in humus | 2,203 | 15.11% |
| Wenchi series | Marginal | Shallow soil | Topsoil rich in humus | 135 | 0.93% |

The Bekwai and Nzima series, located on summits and upper to middle slope sites were found to be moderately deep to deep, well drained, stony and gravels brown to red in colour, well developed in-situ. They have well developed alluvial clay accumulated subsoil horizons. The soils were classified as Ferric Acrisols (WRB) and Typic Paleudult (USDA). The two soils were assessed as moderately suitable for rain fed agriculture (Scholten *et al.*, 2013).

The major upland soils encountered in the compartment namely Bekwai, Nzima and Kokofu series are considered suitable for cultivation of teak. Therefore, a total of 12,240 ha, or 84% of the total soil surface is suitable for planting teak. These soil series are soils with no physical restriction to the root movement. However, they are susceptible to erosion and therefore will require effective soil conservation and management practices. Scholten *et al.* (2013) strongly recommend to maintain or to improve the level of organic matter in the soils. Erosion should be prevented, and organic matter should be recycled as much as possible. Finally, burning should be avoided as valuable organic matter is destroyed by burning while carbon, nitrogen and sulphur are lost into the air as gases.

More detailed soil research will be carried out during the end of 2013.

3.1.3 Topography

The area is gently undulating with moderately steep slopes ranging between 5% and 12%. The summits are broad and nearly flat with slopes of 0 – 4%. Drainage conditions range from well drained in the summits and upper slope sites to moderately to imperfectly drained on middle to lower slopes and poorly drained in the valley bottoms. The soils are of medium to low plant fertility levels and are liable to mostly moderate sheet erosion.

3.1.4 Hydrography

Water bodies

The Tain II FR owes his name to the Tain River that forms the northern boundary of the western half of the FR and runs in easterly direction. There are streams and drainage grooves all over the area which drains northwards into the Tain River, like Kankama River, south of Dadease. There are no permanently running streams in the western part of the Forest Reserve.

Water quality

The analysis of the hydrological samples showed that water in Tain II Forest Reserve is not suitable for drinking. Although turbidity per se does not have to be a risk for people's health, it is an indicator for possible presence of contaminants that do threaten health. Also, it interferes with disinfection of water. For effective disinfection, turbidity should be lower than 1 NTU (nephelometric turbidity units), and definitely not exceed 5 NTU. Turbidity in these sam-

ples ranges from 11.77 to 54.47 NTU. No health-based guideline value is proposed for colour in drinking-water. But commonly values below 15 PtCo (Platinum-Cobalt scale) are acceptable to consumers. In the Tain II samples, apparent colour ranges from 82 PtCo to 388 PtCo.

Ph lies well within the range of 6.5 – 8.5 recommended by the WHO. Calcium, magnesium, nitrate and chloride do not exceed recommended maximum levels. Hardness, conductivity and alkalinity are also within acceptable range.

Copper and iron levels however are high. No health-based guideline value is proposed for iron by the WHO but it is recommended to maintain levels below 0.3 mg/l because iron promotes the growth of “iron bacteria”, which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures. Iron levels in these samples reach up to 5.5 mg/l. The health-based guideline for copper is set at 2 mg/l by the WHO. Overall high concentrations can interfere with the intended domestic uses of the water. Staining of sanitary ware and laundry may occur at copper concentrations above 1 mg/l. At levels above 5 mg/l, copper also imparts a colour and an undesirable bitter taste to water. This level is exceeded in one of the samples (2.4 mg/l), located in the Kankama River, south of Dadease. In the other samples levels are generally low (0-0.63mg/l).

3.1.5 Vegetation

Four main vegetation types were identified and classified as forest, teak plantation, farmlands and degraded areas (table 3.2).

Table 3.2. Main vegetation types surveyed

| Vegetation type | Characteristics |
|------------------------|---|
| Forest | Natural forest fragments riverine/ gallery forests, secondary forests |
| Teak plantation | Teak monocultures at various stages of development and management |
| Farmland | Actively cultivated areas (maize, cassava, vegetables, etc.) including fallowed areas |
| Degraded areas | Severely disturbed areas, grasslands, chromolaena stands, bare soil, etc. |

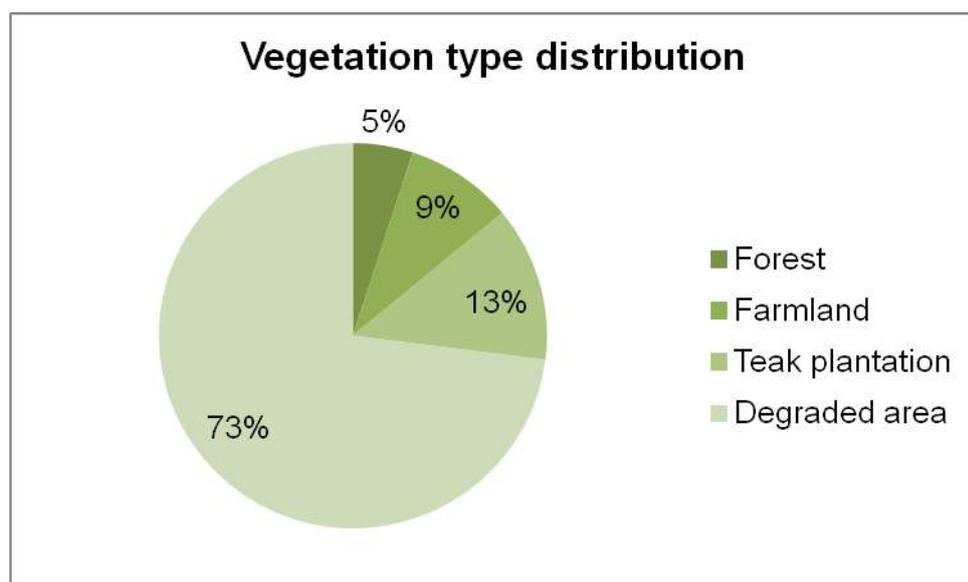


Figure 3.4. Vegetation types found on transects in the study area.

Teak plantation represented areas with monocultures of teak whilst farmlands were actively cultivated areas including fallowed areas used for the production of a variety of food crops including maize and cassava. Degraded areas represented highly disturbed forests and grasslands with thickets of *Chromolaena odorata* (acheampong) and isolated trees (basal area of less than 10 m²/ ha). These areas also serve as active Fulani cattle grasslands and are constantly razed by fires in the dry season (figure 3.5).



Figure 3.5. Cattle grazing in Tain II FR.

Generally, forest patches are prevalent along the main water bodies, especially along the Tain River and its tributaries. These forests generally existed as riverine forests and occur along the northern and western fringes of the reserve. There are also smaller forest fragments dotted within the central portions of the reserve. There seems to be no clear pattern in the distribution of degraded areas and teak plantation, but farmland was recorded mostly towards the fringes of the reserve. Although the percentage of actively farmed land for food crops varied across the study area, fallowed areas (farm bush) was more or less evenly distributed.

The main weeds are the species *Broussonetia papyrifera* (York), the shrub *Chromolaena odorata* (Akyeampong) and several grass species of which *Penisetum purpureum* (Elephant grass) is most abundant.

A number of scarlet star-rated species was found in both forest reserves (table 3.3). Most of these species are also planted by Form Ghana (see table 5.1 in chapter 5.3 of this document).

Table 3.3. Scarlet star-rated species found in Asubima and Afrensu Brohuma FR.

| Local Name/Common name | Scientific name | Star-rated |
|------------------------|------------------------------------|------------|
| Awiemfosamina | <i>Albizia ferruginea</i> | x |
| Edinam | <i>Entandrophragma angolense</i> | |
| Sapele/Efoborodidwo | <i>Entandrophragma cylindricum</i> | |
| Utile | <i>Entandrophragma utile</i> | |
| Krumben | <i>Khaya anthotheca</i> | x |
| Dubini | <i>Khaya ivorensis</i> | |
| Odum | <i>Milicia excelsa</i> | x |

| | | |
|----------|---------------------------------|---|
| Kusia | <i>Nauclea diderrichii</i> | |
| Kokrodua | <i>Pericopsis elata</i> | |
| Wawa | <i>Triplochiton scleroxylon</i> | x |

3.1.6 Fauna

Small mammals

In total, individuals of four species of terrestrial small mammals were captured (table 3.4). Due to the small numbers of captures, it was impossible to make realistic comparison between sites. Nevertheless, most rodent species (mice and rat species) seemed to favour forest vegetation.

Table 3.4. Small mammal signs per km recorded in the various vegetation types

| Common name | Scientific name | Forest | Teak plantation | Farmland | Degraded areas |
|--------------------------------|-----------------------------|-----------|-----------------|----------|----------------|
| Large headed shrew | <i>Crocidura grandiceps</i> | 1 | 0 | 0 | 1 |
| Tullberg's soft furred mouse | <i>Proamys tullbergi</i> | 4 | 0 | 2 | 0 |
| Natal multimammate mouse | <i>Mastomys natalensis</i> | 5 | 1 | 3 | 0 |
| Rusty-bellied brush-furred rat | <i>Lophuromys sikapusi</i> | 2 | 1 | 2 | 0 |
| Total specimens | | 12 | 2 | 7 | 1 |
| Total species | | 4 | 2 | 3 | 1 |

Both Tullberg's soft furred mouse (*Proamys tullbergi*) and the shrew *Crocidura gradiceps* are endemic to West Africa. The latter is ranked on the red list as Near Threatened (Hutterer, 2008).

Medium-sized to large mammals

Rodents were widespread in the study area with grass-cutters and brush-tailed porcupines representing the most abundant species whereas giant rats and ground squirrels were restricted in abundance and distribution. Common carnivores were mongooses, civets and genets. These species occurred in lower densities than rodents and were largely restricted to forest vegetation, with highest densities occurring in the riverine vegetation. Bushbucks were the most abundant ungulates followed by Maxwell's duikers, whilst red river hogs and royal antelopes were restricted to just a handful of sites. Apart from the forest cobra and green mamba, the activities of reptiles, including the Nile Monitor (a giant lizard species), were among the least recorded animal signs.

No direct recordings of primate activity were made throughout the study. Nevertheless, a few hunters interviewed confirmed the presence of Demidoff's galago and Bossman's potto in a few sites, particularly in some of the forested vegetation.

The majority of animal signs (62%), consisting mostly of ungulates (73%), carnivores (21%) and reptiles (6%), were spotted in forest vegetation type with high canopy cover and low understory density. Comparative analysis showed little overlap in species composition between forest and the other three vegetation types ((farmland, teak plantation and degraded land).

While forests provided the highest encounter rates for most species, the activities of cane rats (commonly called grass-cutters) were particularly recorded in farmlands and degraded areas.

Factors affecting mammal distribution

Mammal density was affected by the distance to water sources, number of hunting signs, length of forest and distance to roads in the study area. Length of forest is classified as the length of the transect that has been determined as 'forest vegetation type'. Mammal density decreased with increasing distance to water-bodies. Lowest numbers of mammals are found at maximum distance from water-bodies, where habitat condition may be unsuitable. Mammal density generally increased steadily with increasing length of forests. Highest numbers of fauna species were found at maximum intensities of forest vegetation. Proximity to roads emerged as the third most important variable influencing mammal density. Signs of hunting were relatively low in the study area surveyed and mostly consisted of rat hunting activities (50%).

Amphibians

Fourteen frog species (62 individuals) were found during the study in Tain II FR. Amphibians were generally difficult to encounter in the study area and individuals encountered represented a variety of habitats including savannah, forest and grassland vegetation types. It is expected that when the canopy in the teak plantation closes with time, a shift in species composition will occur. Closed canopy species will thrive as teak stands mature.

Avifauna

Sixty species, belonging to 23 families, were recorded on survey transects. More than 10% of the species recorded belongs to the weavers and malimbés family (Ploceidae). Other families included flycatchers (Muscicapidae), bulbuls, greenbulbs (Pycnonotidae), pigeons and doves (Columbidae). Most bird species were recorded in the forest vegetation (38), followed by degraded areas (33), teak plantations (21) and farmlands (19). The transect and mist net sampling protocols recorded a different species on each sampling day. This is a good indication that there is still a large biodiversity of birds in Tain II Forest Reserve.

Hotspots

Animal sightings were most abundant in the western part of Tain II Forest Reserve, west of the road leading northwards from Kotaa. This reflects the analysis shown previously about factors affecting wildlife distribution: it is a remote area, far from villages and roads where human presence is generally low. Carnivores, rodents and ungulates show a similar distribution pattern to the total animal sighting distribution but reptiles show a different pattern. Reptiles occur less often in the strip where mammals are most abundant, and more often in the centre part of the reserve, east of the road from Namasua to Seikwa.

3.2 Socio-economic environment

The socio-economic data were collected at 18 villages located near Tain II FR: Akrofoa, Ampenkrom, Arkokrom, Asantekrom, Dadease, Domeabra, Kojoakokrom, Kotoa, Kutre 1, Kutre 2, Meremano, Mpatapo, Mpatasie, Namasua, Nfodwokrom, Oforikrom, Pepaase and Tainso.

The information in these paragraphs was gathered from questionnaires filled out by household heads in the selected communities and from group discussions held with a number of focal people and village representatives in each community.

3.2.1 Household size, age and occupation

Household size

Average household size is 8 people, usually consisting of the household head, his wife and their children. On average, a household had 4 children living in the village.

Most households were reduced in size because part of their children had moved out of the village, either temporarily or permanently. There were often other relatives included in the household, such as parents of the household head, brother/sisters, uncles/aunts or family in law.

Age

The average age of the household members was 22, but the most frequently occurring age was 4. The distribution in age classes shows a peak for ages 10 and 25 and a rapid decline above the age of 25 and again above 50. It is remarkable that the youngest age classes are less abundant than the teenagers. This may be explained by a decline in population growth or by migration of children into the communities after primary school (age 10-15).

Occupation

Approximately 14% of the respondents were a child before school attendance, ca. one third was student. Over half of the respondents were working (52%) or unemployed (2%). Of the working respondents, the vast majority was farmer (76%). The next most frequently occurring occupations were trader (5%) and mason (3%). Other professions included tailor, taxi driver, hairdresser and teacher.



Figure 3.6. Tailor in her atelier.

3.2.2 Housing and transportation

Housing

Approximately half of the houses is built from clay, some of them plastered, some of them uncovered. The other half is built with either blocks or bricks. Bricks and blocks are building materials shaped in a rectangular wooden or metallic box, either manually or mechanically. Bricks are made purely from clay, similar to the bricks used in modern buildings whereas blocks are made from a mixture of sand and cement. Traditional clay buildings are made solely from clay, not moulded into rectangular shapes or dried before building. Most of the houses used corrugated steel for roofing but there was still 18% with thatched roofing, made from grass species found in the forest reserve: *Imperata cylindricum* and *Hyparrhenia spp.*

The interviewed households had 1 to 12 rooms at their disposal, with an average of 4 rooms, for an average of 8 residents.

Transportation

Approximately 78% of the households owned at least one bicycle, 15% owned a motorcycle. Main means of motorized transportation are taxis (close to Berekum) and market trucks.



Figure 3.7a. Proud biker.

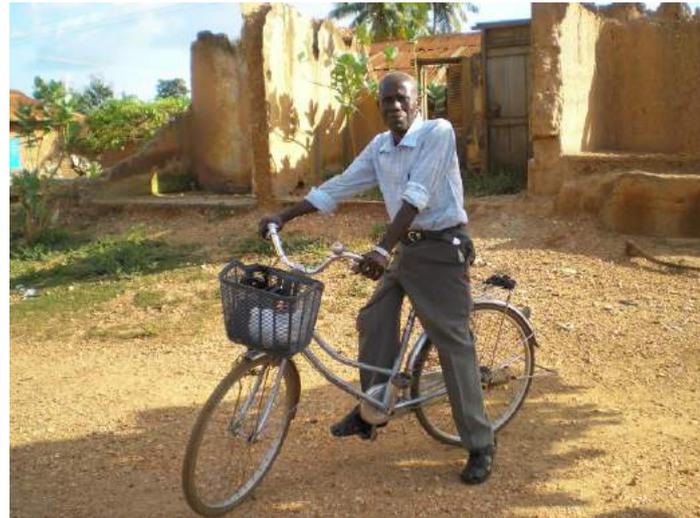


Figure 3.7b. Proud cyclist.

3.2.3 Ethnicity and religion

Ethnicity

Overall, most respondents were born in the village that they currently lived in (23%). Between the different villages, there was a large difference in the percentage of migrants. The highest migration rates were found in the communities bordering the forest reserve, where it is easier for settlers to find a piece of farmland. These villages are located at the most remote locations with the largest distance to facilities like markets, school or hospitals. The communities with the lowest number of migrants can be found closer to Berekum. Most of the migrants interviewed in this assessment migrated in the past decade. Migrants are defined as non-native to the village where they resided at the time of the interviews.

Most of the migrant respondents originated from another village within Brong Ahafo Region (35%). Most of the people from outside the Brong Ahafo Region came in from the Northern Region (29%), followed by Upper West (15%). In total, 11 different ethnicities were interviewed in this assessment. The largest ethnic group is the Bono (81%), the original inhabitants of Brong Ahafo Region. The largest ethnic minority are the Dagarti (12%).

Religion

Religion is mainly Christian, combined with traditional customs and worship. Only a small percentage indicated that they were Muslim.

3.2.4 Village facilities

The facilities present in the villages surrounding Tain II FR are described below.

Electricity

10 of the 18 villages are connected to the electricity network. The villages in the South are generally connected while those in the North are not.

Water

Most of the communities fringing Tain II Forest Reserve had access to a borehole. These have been established in the region since 1983. Water quality and quantity was generally perceived to be good. However, many of the boreholes were non-functional at the time of this assessment and have been left discarded for the past years. Mpatasie is the only village with

tap water from Berekum. In Meremano, a reservoir and pump system had been established with a network of pipes throughout the village. Asantekrum and Oforikrum still depended on the Tain River for their water, but people living in communities with boreholes often preferred the river water to the borehole water. Some people explained this water is more 'filling' than the water from the boreholes.



Figure 3.8. Women pumping water from borehole.

Communication

None of the villages had a computer and/ or internet connection. Telephone reception was generally low or absent, except in the villages close to the towns of Seikwa and Berekum. Despite of poor reception, most of the prominent village members owned a mobile phone that they used to make phone calls in nearby towns.

Churches

The villages around the forest reserve had between 0 and 10 church buildings, with an average of 4. The most common Christian churches were Roman – Catholic, Presbyterian, Methodist and Anglican. Only 3 villages had a mosque.

Roads

A paved road runs from Berekum to Mpatapo, Kutre 1 and Kutre 2 and to Mpatasie. After this, the roads are all unpaved and often in poor condition. Dadease, Arkokrom, Kojokrom and Asantekrom are especially inaccessible in the rainy season.

Hospital

The nearest hospital for most of the villages around Tain II Forest Reserve is the Berekum Holy Family Hospital. There are also small clinics in Akrofoa, Mpatasie and Namasua with 5, 5 and 2 nurses as permanent staff respectively.

Schools

All villages have a primary school within 3 miles radius and most also have at least one Junior High School (JHS), although some students have to travel up to 16 miles (Dadease). The only Senior High School in the area is located in Mpatasie (Star Business College). Other students travel to Berekum or even to Sunyani if they want to continue their education after JHS. They commonly stay with relatives in the town where they attend school and come back to their village in weekends or during holidays, depending on the distance.

Market

The main markets in the area are in Berekum and Seikwa, on Thursdays and Fridays respectively. Other markets are in Drobo and Goka. Market trucks come to all villages to pick up people and their products, but during the rainy season the condition of the roads is sometimes too poor to cross, making the remote villages (Dadease, Nfodwokrom) inaccessible. This is a problem for the inhabitants of those communities as they then cannot sell their farm produce.

Fire service

Bushfires occur frequently in Tain II Forest Reserve. In the winter of 2011-2012, 38 bushfires occurred in the period from December to March. This is a great pain for the farmers that risk losing their crops, but also poses a threat to the communities as they are often located close to the fire. Several villages have been struck by the fires in the past years, e.g. Kotoa and Pruso. In order to counteract these fires, the districts work together to locate hazards as quickly as possible and combat the hazards effectively. In addition to the banning of hazardous activities in and outside of the reserves, the district fire office developed systems to alarm communities and educates volunteers in fire extinguishing techniques.

3.2.5 Level of education

Illiteracy amongst the population >11 years of age at the national level is 26%, according to the 2010 Ghana national population and housing census report (Ghana Statistical Service, 2012). In Brong Ahafo Region this percentage is higher: 30%. The 20% illiteracy amongst the respondents of this assessment is hence below the national as well as the regional average, possibly because a large part of the respondents in this study lived in the vicinity of Berekum. Literacy in urban areas is commonly higher than in rural areas. This trend is visible in the national census report as well as in this study.

The communities located in Berekum district have the lowest level of people without education (13%). The highest level of people without education is in the communities in the east of Seikwa district (50%). Only 5% of the people in these communities went to JHS and 3% to SHS or higher level education. This coincides with the longest distance to the nearest JHS School for these communities: 12 and 16 miles for Nfodwokrom and Dadease respectively. The level of highly educated people (SHS and higher) is relatively low throughout Seikwa district, with 7% in Seikwa compared to 15-17% in the other three districts bordering Tain II FR.

The education level of people above the age of 25 is different from the people aged 25 or younger. The percentage of people without education is considerably higher amongst the older generation (28%) compared to the younger generation (8%), and more children attend primary school in this generation: 41% against 16%. However, the share of students that continue after primary school to do JHS or higher education is not that different, even a little bit higher for the older generation: 56% compared to 51%.

3.2.6 Health

Malaria is the most frequently occurring disease in the area. According to interviewed community members, over 30% of all hospital visits were for malaria treatment. This reflects the statistics of the Berekum Holy Family hospital, where malaria is the number one reason for admission (10% of all admissions). Other frequently encountered complaints in the interviewed communities are stomach ache, headache, injuries from accidents and skin rashes. The main cause of death in the Berekum Holy Family hospital is HIV/AIDS.

3.2.7 Farming

Main agricultural crops cultivated

Households commonly have some acres with their main bulk food crops (used for e.g. fufu and banku) and a small piece of land with vegetables. These crops are grown in a mixed cropping system, with an average size of 9 acres. Some households grow perennial crops like cocoa, cashew or palm nut. The main bulk crops cultivated in the area, calculated by the frequency of cultivation by the households included in the social assessment, are cassava, maize and plantain, followed by cocoyam and yam. Most frequently cultivated vegetables are pepper, okra and garden eggs, followed by tomatoes, onions and green beans. Some households grow fruits like pineapple and watermelon but this is a small minority. Cocoa was the most frequently grown perennial crop, followed by cashew and palmtree.

Farm location

Most farmers farm on their own land or in the Forest Reserve. Only a few farmers reported to pay rent to or share their benefits with the land-owner. Most of the households were farming outside the Forest Reserve (74%). Approximately half of the households with a farm inside the reserve also farmed on land outside the reserve. The households that farm inside the reserve were located in the communities closest to the Forest Reserve. The farms located inside the forest reserve were on average twice as big as the farms located outside of the reserve: 6.8 acres and 3.1 acres respectively.

Use of herbicides/ pesticides and fertilizers

A large share of farmers used artificial ways to stimulate growth of their crops. Herbicides were used by over 90% of the households, and pesticides by nearly 70%. Fertilizers were used less frequently (30% of the households). Many farmers indicated that they would prefer to use them but couldn't afford it.

Farm production

The average yield for maize is 18 bags per year. The production of maize per ha is much higher within the forest reserve than outside of the forest reserve: 2.8 bags/acre/year compared to 1.9 bags/acre/year. This can be explained by the conditions in the forest reserve or by the farmers that farm in the FR. It is likely that the soils within the reserve haven't been exhausted yet, and that abiotic conditions are more favourable to farming than outside the reserve. It can also be attributed to the efforts of the farmers farming inside the reserve. Farmers inside the reserve are mainly migrants from the northern parts of Ghana. They may be motivated to farm with a higher intensity compared to the native inhabitants.

4. FOREST MANAGEMENT

This chapter states the forest management objectives of Form Ghana, followed by the consequences on land-use.

4.1 Objectives

Introduction

The Forestry Commission has established Forest Reserves as an instrument to secure a sustainable forest estate throughout Ghana. Sustainable and controlled timber extraction is allowed in these Reserves.

The Tain II Forest Reserve has been qualified as degraded by the Forestry Commission, due to severe logging, extensive wildfires (especially in the 1980s some heavy episodes occurred) and illegal farming practices. The area was degraded before Form Ghana started its activities.

Since the nineties of the previous century, there is a presidential policy to actively restore the ecological, social and economic values of the degraded Forest Reserves in Ghana. In this framework, Form Ghana now establishes a commercial timber plantation in the north-western, north-mid and south-mid parts of the Tain II Forest Reserve.

Objectives

The general objective for the plantation is the establishment of a commercial forest plantation in the degraded Tain II Forest Reserve along with the conservation and restoration of natural, riparian forest in accordance with the requirements as laid down in the lease agreement and the relevant national legislation for the restoration of degraded Forest Reserves.

The specific management objectives are to:

1. establish and manage a commercial timber plantation in an ecologically sustainable manner with a maximum of 90% teak and at least 10% mixed local species with conservation of natural, riparian forest and improvement of environmental quality;
2. guarantee financial and economic sustainability through the generation of income from the produced round-wood and carbon sequestration;
3. create employment and provide social benefits by offering good economic conditions for employees and the surrounding smallholder community.

Phased approach

The above-mentioned specific objectives will be realised through a phased approach. This means that the timing of the implementation and achievements will largely depend on ecological, social and economic feasibility during implementation. If successful implementation can be reached, a next step can be taken to meet the management objectives. If more preparation and development is needed, implementation will take place at a later stage.

In the following paragraphs, Form Ghana's vision concerning the ecological, economic and social aspects of the abovementioned objectives is elaborated upon.

4.1.1 *Ecologically sustainable plantation management*

The environmental impact assessment of Tain II FR (Tollenaar, 2013) shows that little of the original semi-dry deciduous forest remains. The vegetation has been degraded so drastically that it is now a mosaic of savannah, agricultural land, unmanaged teak plantation and degraded forest. The forest occurs in patches throughout the reserve, mainly bordering the streams and rivers in the area. Some of the original forest fauna still remains, such as bush pigs and antelopes, but most of the animals encountered during the survey are birds, snakes and small mammals characteristic for savannah vegetation.

Restoration ecological values

Form Ghana will reforest part of the Tain II Forest Reserve and will restore some ecological values. Through the restoration of tree cover a forest climate will be created, carbon is stored above and below-ground, nutrient cycling as well as water quality improves and corridors of natural, riparian forest are established in the form of buffer zones alongside rivers and water bodies.

Buffer zones: biodiversity and fire breaks

Especially in the buffer zones (where some of the original vegetation still persists) plants and animals will benefit from the restored cover and will start spreading. It has often been proven (Chapman & Chapman, 1999; Chazdon, 2008; Montagnini, 2001) that this effect can start accelerating once a minimum threshold has been crossed. The increase in cover of fruiting plants attracts birds and mammals which carry seeds (in their digestive tract or in their fur) and in that way assists in seed dispersal. It is likely, therefore, that the buffer zones will be areas where biodiversity will increase over time (see Parotta, 1992). The continuous cover will provide the growing conditions for many fungi and other soil life. In time this will restore the soil with higher organic matter content and water retention capacity (Montagnini, 2001). In the commercial plantations similar effects take place, though they are more temporary in nature (due to the final felling after 20 years).

Besides their biodiversity function, the buffer zones also fulfil the function of fire prevention as green belts running through the timber plantation. Because of their proximity to rivers, riparian forests are moist and generally perform well as green belts (Pettit and Naiman, 2007).

Chosen formula: a mix of teak and indigenous tree species

Form Ghana intends to reforest degraded Forest Reserves using maximally 90% teak and minimally 10% mixed local tree species. The soil study by Dwomo and Bafo (2012) showed that around 84% of the soils are suitable for planting teak.

Form Ghana believes that the chosen formula (maximum 90% teak and at least 10% mixed local species) creates an environment which is beneficial for the restoration of ecological and economic values. Good plantation management practises will ensure the sustainability of these values. These practises are to be such that they can remain certified according to the standard of the Forest Stewardship Council (FSCTM) for which a certificate was obtained in 2010 for the plantation in Asubima FR. This certification guarantees the quality of forest management. In 2013, Form Ghana achieved verification and validation under the Verified Carbon Standard (VCS) for a specific reforested area demonstrating the positive carbon balance due to reforestation of degraded forest reserves in Ghana.

4.1.2 *Economically sustainable timber plantation management*

Currently, the economic values of Tain II Forest Reserve are agricultural (farmland and via intercropping in Modified Taungya System), cattle grazing, timber production (teak planta-

tion), hunting and water collection. Not much timber is extracted and used for commercial purposes though. Due to the fact that nearly all Forest Reserves are in a similar state, the wood working industry in Ghana is in severe trouble.

The planting of fast growing, high quality timber species will provide the market with logs in a foreseeable future. Considering the potential of the soils in Tain II FR, the first logs for the production of poles should become available around 2025. The uneven age character of the plantation (annual planting) will assure that periodically revenues will be generated through sales of poles. Form Ghana intends to guarantee the long-term production of high quality timber, which is assured through good financial returns from Teak (*Tectona grandis*) round-wood production.

The other tree species to be planted (e.g. *Terminalia* spp., *Khaya* spp) have rotations that can be equally short but may be longer for most species (20-40 years). This way, economic interest on the medium and long term is generated.

4.1.3 Social benefits for employees and surrounding communities

Employees

Form Ghana provides its employees with good economic and working conditions and uses a step-wise approach to increasingly improve conditions at the plantation and nursery in terms of facilities and social benefits. Social conditions for the personnel at Form Ghana will comply with national legislation and meet the standards of FSC. The First Aid Procedures & Emergency Evacuation Protocol (P8) provides guidelines for ensuring health and safety of all Form Ghana employees.

Surrounding smallholder communities

Form Ghana will develop and maintain good relations with the surrounding community. In the benefit sharing agreement, accompanying the land lease, it is officially laid down how the community benefits from Form Ghana's activities in Tain II FR.

Additionally to the benefit sharing agreement, Form Ghana has developed a social plan (see chapter 10) in which is described how it deals with employment, training of personnel and intercropping.

Upon plantation establishment in 2013 agricultural activity existed in Tain II FR on an illegal basis; officially no farming is allowed in Forest Reserves. Form Ghana has the objective to restore the Forest Reserve which means agriculture cannot be practiced as before. However, as part of its social plan, Form Ghana gives local farmers the opportunity to participate in intercropping agreements, which enables them to temporarily practice agriculture in a way that is compatible with the timber plantation and national legislation. Under these agreements local farmers can intercrop in the timber plantation for the first two years after planting, according to the rules set in the agreement.

4.2 Consequences on land-use

Form Ghana will establish a new forest estate in Tain II Forest Reserve that contributes to sustainable timber production, yields ecological and social benefits and is therefore in line with the national land use plans issued by the Forestry Commission of Ghana.

The fact that Tain II Forest Reserve will gradually be reforested means its availability for agriculture will be reduced. Fortunately, the number of farmers in the Forest Reserve is limited

and no major obstacles are foreseen since all farmers can be linked to the intercropping system if they wish. The way the management is envisaged is that after every final felling, land will become available for planting of agricultural crops together with the new trees. This enables a continued agricultural use which is compatible with the timber plantation.

5. ORGANISATION OF MANAGED AREAS

5.1 Localisation and limits

The Tain II Forest Reserve is situated in the dry semi-deciduous forest zone at about 10 km north of Sunyani and 6 km north-east of Berekum in the Brong Ahafo region (see Annex C). It falls under the authority of the Dormaa Ahenkrum Forest District. Total surface of Tain II FR is 50,906 ha. This comprises 49,262 ha of productive forest, 1,062 ha of admitted farms, 65 ha of roads and waterways and about 518 ha of grassland. Ownership is vested in the stools of Berekum, Odumasi and Nsoatre (Kosoe, 2012).

The selected site for plantation establishment comprises 3 blocks. Block A is the largest and consists of 81 compartments located in the north-western part of the Tain II FR, numbered: 30-32, 34-38, 42-52, 54-63, 65-74, 76-92, 99, 102-104, 108, 110-115, 118-126, 135, 136 and 138-140. Block B consists of 13 compartments located in the mid-northern part of Tain II FR, numbered: 193, 205, 207, 216-224 and 226. Block C consists of 16 compartments located in the mid-southern part and numbered 150-152, 155, 157, 158, 160, 162, 182, 183, 185-188, 212 and 213. Selection of this area was done on the basis of availability. In total, Form Ghana manages 14,596 ha of the Tain II Forest Reserve.

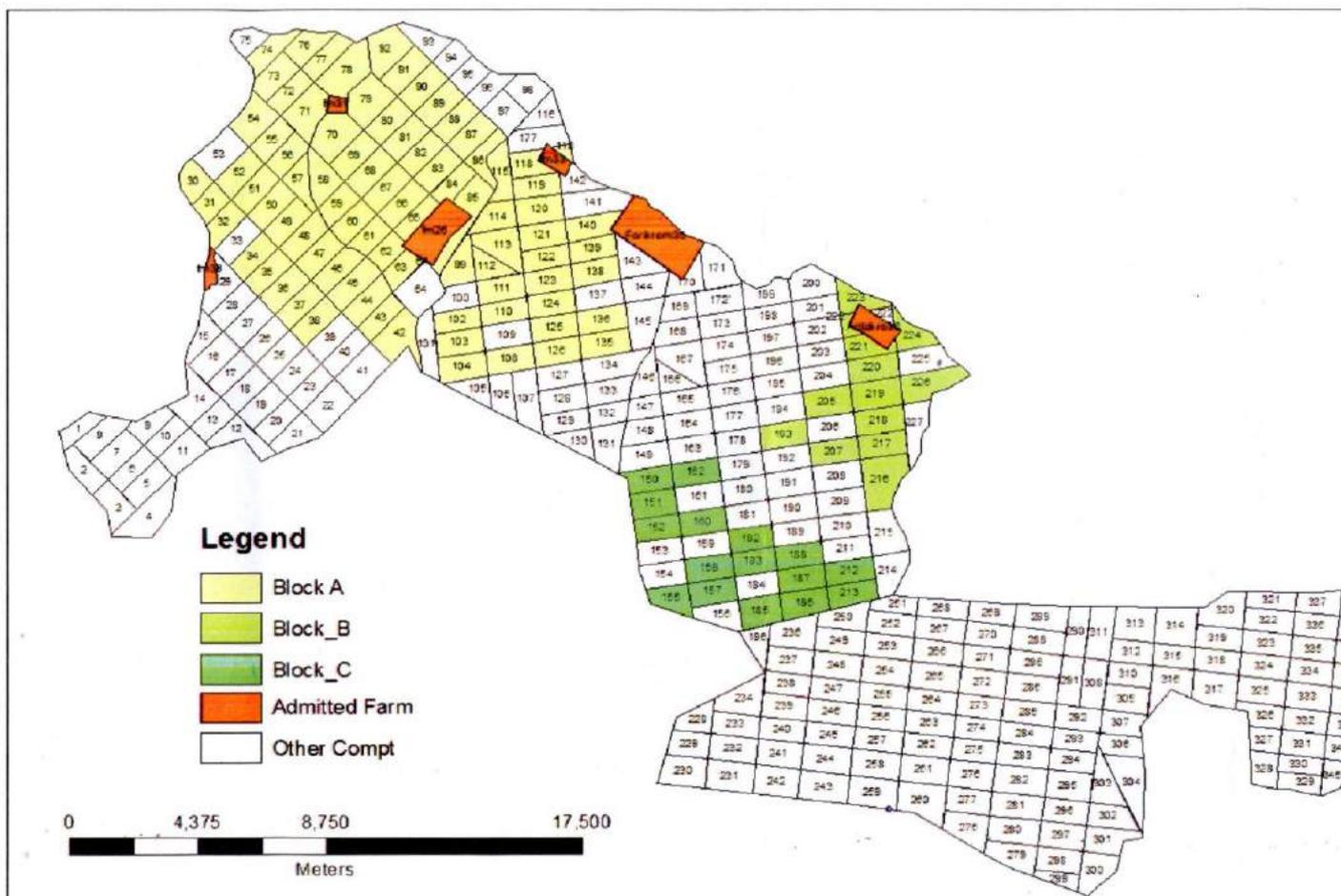


Figure 5.1. Map Tain II showing compartments included in PPP, managed by Form Ghana.

5.2 Plantation infrastructure

5.2.1 Roads

A paved road runs from Berekum to Mpatapo, Kutre 1 and Kutre 2 and to Mpatasie. After this, the roads are all unpaved and often in poor condition. Dadease, Arkokrom, Kojakokrom and Asantekrom are especially inaccessible in the rainy season.

There is one feeder road that connects the Form Ghana plantation in Tain II FR with the national road network. This road leads over 22 kilometres from the highway at Berekum to the boundary of the Forest Reserve. The road between the highway and the forest reserve is improved and maintained by Form Ghana.

A number of main roads that run through or along the edges of the plantation are planned and will be constructed. From the main roads into the plantation in-roads will be created by profiling old roads or following contour lines when new roads are constructed. Main roads and in-roads are built and maintained by Form Ghana. In total, roughly 280 km of road will be constructed.

5.2.2 Communication

Watchtowers will be placed at strategic locations, overseeing the entire plantation. Communication is organised via radio contact (Motorola) at a specific channel. Form Ghana management, foremen and fire squad have radios at their disposal.

5.3 Plantation organisation

The plantation is organised based on stands, compartments and blocks. Stands are homogeneous management areas, unique in forest type, plant year and location. Stands are subdivided in compartments. Compartments are the former logging coupes and measure 128 hectares, The compartments are subdivided in blocks of 64 hectares..

Stands are named according to the tree species planted and the plant year. For example: Teak 2001, Teak 2008, or Terminalia 2010. In principle, management regimes are defined per stand. In case tree growth is very heterogeneous within a stand, different areas within the stand will be managed according to different regimes.

Exceptions to this are the stands of natural forests or areas planted with indigenous trees. The stands of natural forest will not be harvested and the stands of indigenous species which fall within buffer zones along rivers will also be exempt from harvesting.

5.4 Field planting program

The soils in most of the area are suitable for planting teak (84%). The field planting program is structured on the basis of the compartments, which are the land units as received from the Forestry Commission, and the projected progress each year. In 2013, 640 hectares have been planted. Compartments 82, 83, 88 and 89 have been completely planted with teak stumps. Compartment 87 was planted with a combination of teak and indigenous species. From 2014, the aim is to plant 2,000 hectares per year including teak plantation, indigenous plantation and buffer zones.

As soon as the in-depth soil research has been carried out, a field planting program will be elaborated stipulating which compartment will be planted in what year with teak or indigenous tree species. The Management Plan will be updated subsequently.

Each year the planting of 1,500 hectares of teak will require 1,7 million plants for the initial planting and some 250,000 for the beating up after the first year. Next to this some 150,000 plants of native tree species will need to be cultivated for the restoration of river buffer zones and for planting on poorer land.

Table 5.1. Annual planning of the plantation activities.

| Activity/ Month | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|----|----|----|---|---|---|---|---|---|
| Staking out & final mapping of area to be planted | ■ | ■ | ■ | | | | | | | | | |
| Final layout of road network | ■ | ■ | ■ | | | | | | | | | |
| Road construction | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| Tilling of terrain suitable for plantation | | | | | ■ | ■ | ■ | | | | | |
| Pegging 3x3 meter planting grid | | | | | | | | ■ | ■ | | | |
| Pegging planting grid in buffer-zones | | | | | | | | ■ | ■ | | | |
| Road maintenance | | | | | | | | | | | | |
| Digging of holes at pegs | | | | | | | | | | ■ | ■ | ■ |
| Transport to planting site and planting | | | | | | | | | | ■ | ■ | ■ |

6. TREE SPECIES SELECTION

This chapter describes the tree species that will be planted by Form Ghana, the forest types they form and the way these forest types are going to be allocated.

Form will not make use of genetically modified (GMO) planting material of any kind and will not introduce species new to the area that have not been introduced before, in order to avoid introducing pests or invasive species.

6.1 Teak

Teak (*Tectona grandis*) is the principle species that will be planted in Tain II FR. A number of factors justify its application from a technical and economical perspective, the main ones are outlined here below.

High profitability

Because of the physical and aesthetic qualities of its wood, teak is a much desired timber species with a good commercial value. The price of teak is about € 300 / m³ for saw logs versus about € 50 / m³ for plantation saw logs of Wawa (*Triplochiton scleroxylon*) or Ofram (*Terminalia superba*). The growth speed of about 15 m³/yr/ha for teak is well known but growth rates are virtually unknown for many indigenous species. Teak is therefore currently the only commercially viable option.

In comparison with indigenous tree species and other exotic species, teak performs best economically (Maldonado and Louppe, 2000; Dupuy and Verhaegen, 1993; Keogh and Pentsil, 2001; Behaghel, 1999).

Solid technical basis for plantation establishment

Experience with the silviculture of teak plantations started in the 19th century (Behaghel, 1999) and this longstanding practise has resulted in sound management guidelines and good yield prognoses. Also in West Africa the production of teak has been successfully adopted. This provides a solid technical basis for plantation establishment.

Low disease risk

As an exotic tree species in Ghana, teak does not suffer much from diseases which reduces the risk of plantation failure. Disease risk can be reduced significantly through careful site selection. On suitable sites, tree health is good which prevents disease from overtaking the plantation (Keogh and Pentsil, 2001). More information on pests and diseases is provided in section 10.3.

Non-harmful to environment

The environmental impact of teak production is low, because it will be planted on deep, fertile and level soils which are relatively insensitive to erosion. Moreover, teak is not planted in the buffer zones and ecologically valuable areas. Due to the low susceptibility of teak to diseases, no chemical treatments are required for pest control. Also, the spread of teak outside the plantation can be controlled, since dispersal distance of teak seeds is limited. Being a high light demanding species, teak cannot invade areas with dense vegetation (e.g. high grass). It needs the help of man to be successfully established.

Furthermore, the presence of buffer strips and fire breaks around the plantation inhibits the spread of teak outside plantation boundaries. Most areas surrounding the plantation are in agricultural use for which teak poses no threat.

6.1.1 Climate and soil conditions

The optimal climate conditions for teak are a mean annual temperature between 22 and 27 °C, and an annual precipitation between 1200 and 2000 mm per year (Keogh and Pentsil, 2001). With temperatures between 23.6 and 26 degrees Celsius (Orgle, 1994) Tain II FR has the required temperatures for teak. The mean annual rainfall of 1200mm (Orgle, 1994) is the minimum of the recommended rainfall range. Actually, having rainfall a little less than the amount that is needed for maximum growth is good for the health of the trees and the quality of the timber.

6.1.2 Provenances

Form Ghana has acquired a lot of experience with teak planting through its reforestation activities in Asubima FR and Afrensu Brohuma FR. Anno 2012, 3,500 ha have been reforested of which 84% with teak. Systematic selection during plant production and before planting will assure the transfer of only the best material to the field.

The seeds for Tain II are proposed to be harvested from selected plus-trees in the 2001 pilot plantation in the Asubima FR, that originate from the SODEFOR plantations in Bouaké, Côte d'Ivoire, and that have proved a very suitable provenance for teak.

The genetic quality of the SODEFOR plantation is very good and the trees are adapted to the climate there as well as that of Asubima FR. Its origin goes back via selections from Trinidad and India to Tenasserim (Burma), the provenance of the best teak. The teak in the 64 hectares 2001 pilot plantation is estimated to be of growth class 2 and to produce a mean annual increment of 14 – 16 m³.

Other provenances with improved qualities will be explored in- or outside Ghana.

6.2 Other commercial tree species

Complementary to teak, a number of species native to Ghana will be planted in the buffer zones along rivers and in areas where the soil conditions are not favourable for teak. These indigenous species will be grown in mixed stands to resemble a natural forest. Indigenous species planted by Form Ghana in Asubima FR and Afrensu Brohuma FR are shown in table 6.1.

Table 6.1. Indigenous tree species planted by Form Ghana.

| Informal name | Scientific name |
|---------------|---------------------------------|
| Mansonia | <i>Mansonia altissima</i> |
| Wawa* | <i>Triplochiton scleroxylon</i> |
| Bombax | <i>Bombax buonopuense</i> |
| Potrodom | <i>Erythrophleum ivorense</i> |
| Ofram* | <i>Terminalia superba</i> |
| Emeri* | <i>Terminalia ivorense</i> |
| Kusia | <i>Nauclea diderrichii</i> |
| Watapuo | <i>Cola gigantea</i> |
| Awiemfosamina | <i>Albizia ferruginea</i> |
| Kokrodua | <i>Pericopsis elata</i> |

**Fast growing species*

The local species will be sourced in Ghana, in order to maintain the genetic integrity of the local forests. For the indigenous species this means that efforts should be concentrated on selecting trees in the region to function as seed trees. This procedure avoids genetic pollution. This is especially important as these species are to be used to restore buffer zones along rivers and on poorer soils. As far as possible the project employs certified seeds for these species obtained from FORIG in Ghana.

6.3 Buffer vegetation

Along-side rivers and water bodies buffer vegetation will be established with a width of 30 meters to each side of the water. This buffer vegetation will consist of a mix of native tree species and endangered tree species that are being reintroduced in the area (see table 6.1). This is achieved by natural regeneration and where tree stocking is low or absent indigenous trees will be planted to increase the speed with which the buffers will regenerate. This combination of natural regeneration and planting is called 'assisted natural regeneration'. The buffer zones will develop into natural forests.

6.4 Forest type allocation

Based on the differences in tree species and management objectives, three forest types are distinguished: 1) teak plantation, 2) buffer vegetation, and 3) other commercial plantation. Land allocation between these three forest types is as follows:

1. Buffer vegetation will be planted with a 30 meter width alongside rivers and water bodies.
2. Teak plantation will be established on the best quality sites.

Growing teak successfully requires the following conditions of the soil:

- Ph level shall be above 5;
- Rootability shall be deeper than 1.20 m (4 ft);
- Drainage shall be good to absorb and drain rainwater;
- The landscape shall be flat to slightly sloping to avoid erosion of the topsoil.

As these conditions are not found everywhere in the FR, a selection is done based on the results of the research by Scholten *et al.* (2013). The major upland soils encountered in the compartment namely Bekwai, Nzima and Kokofu series are considered suitable for cultivation of teak. This means that a total of 12,240 ha, or 84% of the total soil surface is suitable for planting teak. These soil series are soils with no physical restriction to the root movement. However, they are susceptible to erosion and therefore will require effective soil conservation and management practices. More detailed soil research will be carried out to determine more precisely which areas are most suitable for teak plantation establishment.

3. Other commercial plantation will be allocated to sites less suitable for teak and not allocated to buffer vegetation.

7. TREE NURSERY

The tree nursery is located in Akumadan, near the Asubima and Afrensu Brohuma Forest Reserves where Form Ghana has a land lease as well. The nursery comprises three greenhouses, shaded irrigation sheds for 500,000 to 600,000 plants per season and 6 hectares for stump production. It has an independent water supply system for irrigation and a thoroughly trained staff.



Figure 7.1. Irrigation sheds nursery Akumadan Form Ghana.

This chapter describes general aspects of tree nursery management. Detailed nursery management procedures are worked out in protocol P14.

At the entrance of the Tain II Forest Reserve Form Ghana has installed another nursery of about 6 hectares. This nursery will produce about 2 million plants annually.

7.1 Tree nursery practices

Planting material is selected to suit the local conditions and based on genetic and phenotypic quality. Systematic selection during production and before planting will assure the transfer of only the best material to the field. Planting stock is produced in the nursery through two methods: via seeds and stumps.

7.1.1 Seeds

Seeds are used in two ways: 1) direct seeding in the nursery to produce stumps and 2) sowing in beds for transferring to poly pots. Mostly the native tree species are grown from seed in poly pots. The nursery is equipped with a special area for treating seeds in order to break dormancy. As soon as germination starts between January and March each year, plantlets are pricked out and transferred to prepared poly pots where they can grow until May.

7.1.2 Stumps

For teak production the emphasis is on stumps. Seeding in the nursery takes place in the wet season in August. When the planting season starts in April the seedlings are uprooted and pruned, to form stumps. These stumps are then used for planting in the wet season end of April - June.



Figure 7.2. Stump.

7.2 Transport to planting site

The transport distance from Akumadan to Oforikrom (northern boundary of the Tain II FR) is 146 km or max. 3 hour drive. A truckload of stumps is estimated at 80,000 stumps which is enough to plant 70 hectares.

Form the nursery at the entrance of the forest reserve the transport distance is very short. This allows the planting to proceed without delays.

7.3 Annual planning

Table 7.1. Annual planning of the nursery activities.

| Activity/ Month | 9 | 10 | 11 | 12 | 01 | 02 | 03 | 04 | 05 |
|---|---|----|----|----|----|----|----|----|----|
| Seed procurement | | | | | | | | | |
| Sowing of native trees | | | | | | | | | |
| Sowing of teak | | | | | | | | | |
| Weeding and watering | | | | | | | | | |
| Hardening of the plants | | | | | | | | | |
| Cutting plants to stumps | | | | | | | | | |
| Transport to planting site and planting | | | | | | | | | |

8. SILVICULTURAL SYSTEM

The silvicultural system described in this chapter refers mainly to teak. Other commercial tree species are managed in a similar manner, but with different specifications, depending on the tree species under consideration. Buffer vegetation management is described in section 11.2.1.

8.1 Management strategy

The main tree species to be planted in Tain II FR is teak which will be managed according to the best practises and based on up-to-date information. Management is based on yield tables derived from teak plantations in Ivory Coast that will be updated with information from the plantation established by Form Ghana.

The aim is to produce high quality teak saw logs. This means that plantation management has to be intensive. The expected revenues for high quality teak justify the intensive management. The final harvest is expected to generate the largest revenues, as the timber volumes will be largest and timber quality will be highest during at this time.

Other commercial tree species are planted on sites which are less suitable for teak. This optimizes the utilisation of these sites and reduces the risks related to monocultures. These risks are further reduced by the buffer vegetation. By creating a continuous plantation with optimal forest cover also fire risk is reduced.

8.1.1 *Rotation overview*

The silvicultural system to be applied depends on the tree species under consideration, its performance and the desired product in the end of the rotation. For teak a rotation length of 20 years is chosen, based on economical and silvicultural considerations. For other tree species a suitable rotation length is determined per species which varies between 20 and 40 years.

8.1.2 *Yield tables teak*

Yield tables form the basis for the thinning regime of a timber plantation and they provide the best estimate of expected harvestable volumes and increments. They can be used as calculation and estimation tool for management, but management timing and intensity will depend on the field situation. The yield tables that are used for Tain II FR are derived from teak stands in Ivory Coast which have comparable soil and climate conditions.

The yield tables from Ivory Coast (see Annex D) provide us with growth data over a period of 20 years which is based on a specific management regime, including thinning and final felling. These yield tables form the basis of four yield classes, each having a specific total production potential and mean annual increment (see table 8.1). The four yield classes are based on the dominant height (H_{dom}) which varies between 18.7m (yield class 4) and 28m (yield class 1). A good categorization of the tree stands in Tain II FR within these yield classes is of essential importance for management decisions to be based upon. Categorization is done by measuring growth performance in Permanent Sample Plots (PSPs), as described in section 12.1.1.

Table 8.1. Yield classes from Ivory Coast with main characteristics.

| Yield class | H _{dom} (m after 20 years) | Total production (m ³ after 20 years) | Mean annual increment (m ³ /ha/y) |
|-------------|-------------------------------------|--|--|
| 1 | 28.0 | 350.3 | 17.5 |
| 2 | 24.9 | 283.9 | 14.2 |
| 3 | 21.8 | 201.0 | 10.1 |
| 4 | 18.7 | 153.8 | 7.7 |

Yield classes are based on an initial planting density of 1111 plants/ ha, a 20 year rotation and 2-4 thinnings before final felling.

Through careful selection of sites for teak, based on the soil survey, it is expected that on average yield class 2 will apply for Tain II FR. The accuracy of this assumption will be monitored in PSPs. The distribution of the four yield classes over the plantation can then be observed on the basis of field data.

8.1.3 Expected teak yield from Tain II FR

The expected teak yields are calculated based on area surfaces, the expected yield class (on average class 2) and the corresponding yield table. The thinning regime for yield class 2 consists of three thinnings (after 4, 8 and 12 years) and a final harvest (after 20 years). Harvesting first commences in 2021 with the first commercial thinning and will continue until circa 2043 with the final felling for the first rotation.

The last two thinnings and the final harvest are expected to give a commercial return. Harvestable volumes are calculated with values from the yield table of yield class 2 (see annex D) where commercial thinning volumes are 25 m³/ha, final harvest volume is 229.9 m³/ha. Assumed in this table is that 90% of the plantation area will be planted with teak.

As soon as the field planting program will be concrete (after detailed soil research is done), calculations of expected harvestable volumes will be made and these will be included in the Management Plan.

8.2 Silvicultural treatments

Silvicultural treatments are executed from the plantation establishment till the final harvest. In this paragraph all planned treatments are described for one teak rotation.

This paragraph describes general aspects of technical plantation management practises. Detailed technical plantation management procedures are worked out in protocol P15.

8.2.1 Ground preparation

Before planting, the ground has to be prepared to facilitate planting and create optimal conditions for the seedlings. The main purpose is to remove weeds. First, the area to be planted is cleared. This is mainly done by ploughing and/ or harrowing, depending on what vegetation is present. Where necessary, herbicides (Roundup) are sprayed to control weeds.

The Forestry Commission will do initial demarcation and assist with subsequent surveys and demarcation. Form Ghana will pillar outside boundaries and establish roads on boundaries as far as practically possible.

Ground preparation takes place between January and April.

8.2.2 *Plantation establishment*

Planting

Planting is done using a spacing of 3m x 3m which results in an initial planting density of 1,111 trees/ha.

Planting takes place from April till June. Planting is commenced in the second half of April when the rainy season has really set in, to avoid the risk of drought stress by too early planting.

Beating up

A few months after planting a balance can be made of the mortality rate of the planted material. When more than 10% of all planted seedlings has died or not developed, the 'gaps' need to be filled in. This is done in the short rainy season after initial planting, in September.

8.2.3 *Weeding and singling*

Weeding

During the first 2-3 years, before canopy closure, weeding is very important to prevent weeds from restraining the performance of the seedlings. Weeding is carried out at least three times per year until canopy closure (3rd – 4th year). The method applied is cutting of grass completed with strip or circle weeding. Circle weeding takes place around a planted tree, strip weeding along the planting lines.

In addition to mechanical weeding, the herbicide Roundup is used twice a year to control regrowth of weeds.

Singling

Some stumps grow more than one stem. About six months after planting, between October and December, individuals with multiple stems are reduced to just one stem. Singling might be needed in later stages as well, when forked or multiple stems are formed and this cannot be corrected for by thinning. Singling is done along with weeding by Form Ghana staff (intercroppers do weeding, but not singling)

8.2.4 *Climber cutting*

Climber cutting has to be undertaken to prevent the planted stock from being smothered by climbers. Forest stands are checked every year to determine whether climber cutting is necessary.

8.2.5 *Thinning*

To direct the productivity of the stand, thinning has to be applied. Wood distribution between stem and branches can be influenced by thinning and pruning. By timely thinning and pruning the trees can be directed to have optimal height growth and well-formed crowns, with little biomass going into the branches in early life stages.

The moment and the intensity of thinning are dependent on the growth performance of a stand, which is determined in PSPs (see 12.1.1). The right timing is checked by comparing measured basal area (G) with the yield tables (see annex D).

A comprehensive management model is provided by standard thinning regimes per yield class (see Annex D). Depending on the yield class, two to four thinnings have to be executed at estimated stand ages. The real age at which the targeted G for a thinning is reached depends on the stand's growth.

Each stand starts with 1,111 stems/ ha. Throughout the rotation the number of stems per ha will gradually be reduced to 165 (for yield class 1), 300 (for yield classes 2 & 3) or 450 (for yield class 4).

Table 8.2 shows the estimated number of stems that has to be removed in a thinning. The real number of stems to be removed in a thinning is determined in a standard methodology which makes use of crown and tree diameters. This methodology is worked out in the management procedure on thinning, P15.

Table 8.2. Thinning regime based on the yield classes from Ivory Coast.

| Yield class | G (m ² / ha) at moment of thinning | Estimated stand age (years) | Thinning intensity (N/ ha) | Thinning intensity (%)* |
|-------------|---|-----------------------------|----------------------------|-------------------------|
| 1 | >12 | 3 | 361 (1,111 to 750) | 20.4 |
| | >15 | 6 | 350 (750 to 400) | 32.1 |
| | >18 | 10 | 150 (400 to 250) | 23.8 |
| | >20 | 15 | 85 (250 to 165) | 21.7 |
| 2 | >12 | 4 | 700 (1,111 to 750) | 18.3 |
| | >15 | 8 | 300 (750 to 450) | 26.5 |
| | >18 | 12 | 150 (450 to 300) | 20.4 |
| 3 | >12 | 5 | 700 (1,111 to 750) | 18.3 |
| | >15 | 10 | 300 (750 to 450) | 27.1 |
| | >18 | 16 | 150 (450 to 300) | 21.1 |
| 4 | >12 | 6 | 700 (1,111 to 750) | 20.7 |
| | >15 | 13 | 300 (750 to 450) | 26.7 |

Timing of thinning is determined by actual G as measured in PSPs. The age at which the targeted basal area (G) for a thinning is reached depends on the stand's growth, so given thinning ages are estimates.

* based on G

Stumps of thinned trees are cut off low to the ground and covered with soil and leaves so that it experiences lack of light. This will prevent the stump from coppicing which is not desired because of root competition.

8.2.6 Pruning

Pruning is undertaken to clean part of the stem from branches. This leads to higher timber quality and better machineability.

As a rule one year after each thinning the stand is prune, but in practise it may be required more often to keep the stems clean.

8.2.7 Final harvesting

With the final harvesting after 20 years, all remaining trees are harvested. This may change depending on market development. Stumps are treated with round-up to kill them, because establishment of the new plantation is done by planting new seedlings/ stumps, not through coppicing.

8.2.8 *Maintaining the positive effects of plantation establishment throughout the project cycle (several rotations)*

To safeguard against the potential significant reversal of the accrued environmental and climate change benefits from forest restoration, the following activities are important:

- i) minimizing fire risks;
- ii) no harvesting of trees in the restored buffer zones;
- iii) avoiding erosion and pollution during harvesting
- iv) ensuring a timely replanting after the final harvest
- v) A mosaic of buffer-zones and indigenous plantation will ensure that key parts of the forest land scape remain in place.

8.3 Seed stand management

Form Ghana retrieves high quality seeds from the pilot plantation (established in 2001) located in Asubima Forest Reserve. This is an Ivory Coast provenance. Systematic selection during production and before planting will assure the planting of only the best material in the field. In the future, other good sites for seed harvest will be selected and managed as seed stands.

9. RISK MANAGEMENT

9.1 Prevention of illegal activities

Exploring the boundaries of Form Ghana's area is the first step to prevent illegal activities such as intrusions, hunting, trapping, felling, burning, planting food crops without Form Ghana's consent, etcetera. Also awareness raising of the local population is important. Information supply will provide local people with insight into Form Ghana's activities, so that they hopefully will be willing to cooperate in preventing illegal activities.

Continuously boundary surveillances will be undertaken by the security guards of Form Ghana against poaching, unauthorised felling and other illegal activities within Form Ghana's plantations. Any illegal activities encountered are reported to the Technical Offer of Ghana's Forestry Commission. During the stakeholder meetings, which will take place at least twice a year, reported illegal activities will be discussed.

Prevention activities that are undertaken are further elaborated in protocol P02.

9.2 Fire management

Fire is the greatest risk to the success of the plantation. Although teak can withstand some fire at a later age, growth will be influenced considerably by fire damage and young plants will be killed by fire. Most native forest species cannot stand fire at all.

Fire management is employed to reduce fire risk and will focus on four main axes: fuel load reduction, fire breaks, establishment and training of a fire squad and awareness raising on the risks of fire for local people.

9.2.1 *Fuel load reduction*

Plantation management (in cooperation with farmers through the intercropping system) assures regular weeding of the plantation and the removal of combustible biomass during the dry season. After canopy closure, the shade of the trees will repress undergrowth. In this way, the fuel load will not be allowed to build up and the risk of fire spreading throughout the plantation is greatly diminished.

9.2.2 *Fire breaks*

Fire breaks will be installed around every planted compartment as well as within compartments to make sure that eventual fires can be contained. Fire breaks will be sufficiently wide (at least 10 m) to prevent the fire from leaping over them and they will be kept bare. Outside the dry season, these firebreaks may be planted with food crops as part of the intercropping agreement with local farmers.

9.2.3 *Fire squad*

Although physically the risk of fire occurrence can be reduced, we will have to keep watch during the risky dry seasons. For this purpose, a fire squad will be trained in fire prevention and combat. This team will patrol the plantation throughout the dry seasons. The fire squad

uses watchtowers positioned in strategic locations, overseeing most of the plantation. Also, they will have radio communication and transport at their disposition. These towers are manned 24/7 during the dry season.

In case of fire, the fire squad will warn all people in the vicinity and organise the workers to extinguish the fire with knapsack spray guns, swatter flaps, rakes and shovels. A pickup equipped with a water tank, motor pump and water hoses (bakkie-sakkie - South African invention) is standby during dry seasons.



Figure 9.1. Pick-ups carrying water in bakkie-sakkie.

9.2.4 Awareness raising

Traditionally, people have used fire as a means of clearing land and for hunting. Though a fire may boast soil fertility for a short period, the reduction of organic matter to ashes has profound negative effects on soil organic matter, soil flora and fauna and through this on soil water holding capacity and soil fertility.

As laid out in the PPP, the Forestry Commission will fulfil the task of awareness raising or sensitization of surrounding communities regarding fire use and risks. The principles fire management will be explained to the people in the surrounding villages in cooperation with agricultural extension agencies. Aim is that people will see how they can profit from developing agricultural systems which focus on soil organic matter, fire prevention and improved fallow. If successful, the overall risk of fire will be greatly reduced. Cooperation will also be sought with the district fire office in the sensitization of the local communities.

The farmers in the surrounding villages will be advised to inform Form Ghana beforehand in case they decide to set fire to their farms, so that the fire squads can control the fire and protect hearth and home of the farmers.

9.3 Control of pests and diseases

Pests can cause considerable damage to monocultures. Form Ghana has several strategies to avoid the occurrence of pests. The most important strategy is to plant trees that naturally suffer little from pests.

Teak

The most important species planted by Form Ghana is teak (*Tectona grandis*), for which not many problems with diseases have been recorded (Gibson, 1975). In Ghana, occasionally stem rot occurs (Keogh and Pentsil, 2001); a number of fungi that cause white and brown rot in West Africa were listed by Gibson (1975). The risks of stem and root rot and also other diseases can be controlled by planting teak only on appropriate sites, by keeping a good nutrient balance and preventing damage from fire, pruning and harvesting (Keogh and Pentsil, 2001). Form Ghana will only plant teak on suitable soils. The previous section has described the measures taken to prevent and control fire to keep fire damage to a minimum. Pruning, thinning and harvesting is only carried out by trained staff to prevent damage to the teak stands.

Native trees

Various insects attack native trees (Wagner *et al.*, 1991). Therefore, good management from the start of the plantation will be crucial in avoiding the outbreak of pests. Avoiding monocultures of trees such as Odum (*Milicia excelsa*) and members of the Meliaceae family (Mahogany) will avoid the risk of pest attacks (Evans, 1992). Native trees have some pathogens which can be managed by mixing species and by good hygiene. Form Ghana only plants native trees in mixed stands. In some cases, pesticides may be needed to protect the tree. This will only be used as a last resort as pesticides are costly and may damage the environment. Termites can be a problem for some of the tree species. However, since termites are important in keeping the soil open and fertile no action will be taken against them.

In the nursery, good hygiene is the most important measure to avoid negative fungal and bacterial infections (damping off) and termites.

Monitoring of plantation health is a continuous activity. In case any pest or disease is identified, action will be decided upon in cooperation with FORIG.

10. SOCIAL PLAN

The purpose of the social plan is to share the benefits of the plantation company with stakeholders and to safeguard their rights.

10.1 Oversight body

An oversight body consisting of two individuals from Form Ghana Ltd and two individuals from FSD/FC will meet quarterly during 2013 to discuss and advise upon progress of the PPP project. After the initial implementation year, the meeting frequency may be reduced.

10.2 Stakeholders' committee

A stakeholders' committee will be created consisting of traditional landowners, farmers, environmental NGO, the government's Forestry Commission and Form Ghana. This stakeholders' committee holds regular meetings (three times per year) during which wishes, demands and complaints of the stakeholders will be recorded and treated.

The stakeholders' committee is in charge of the following:

1. Inform the population on the management plan of Form Ghana
2. Facilitate the exchange and distribution of information between nearby villages
3. Identify and formulate projects for the region for which funds are available
4. Arbitrate conflicts in cooperation with the plantation management
5. Plan diverse activities and evaluate them

After every meeting, minutes are prepared and sent to the Forestry Commission and the District Assembly. Minutes can be consulted at Form Ghana.

In the conflict management procedure is stated how Form Ghana deals with complaints and grievances.

10.3 Benefit sharing

The benefits accruing from the commercial thinning and harvesting of timber and other benefits, after deduction of project costs, will be shared among the different PPP partners according to the following key:

The Forestry Commission shall receive 12% of the Standing Tree Value (STV) of commercial thinnings and of the final harvest obtained from the Project, and shall receive the same percentage of other Benefits less the costs of Form Ghana Ltd. that would accrue from the project. Form Ghana Ltd. shall receive 80%, the Landowner shall receive 6% and the Local Community shall receive 2%.

10.4 Intercropping

During the first two years after tree planting, intercropping with food crops is possible. After 2 years, the trees provide too much shade for food crops to properly establish. Intercropping

agreements are signed with local farmers that after signature obtain the right to plant their food crops in between the planted trees. Only crops approved by Form Ghana's management will be allowed and minimum distances between the crops and the planted trees are to be respected. Intercropping agreements have a validity of one year. Every year, new intercropping agreements are signed between Form Ghana and the farmers.

10.5 Employment and training

Employment

For the employment of skilled and unskilled workers priority is given to inhabitants of the area surrounding the FR. For casual employment, intercroppers are given priority to ensure their livelihood throughout the year. The workers are employed under the national labour standards for the agricultural sector and the International Labour Organisation (ILO) standards.

Safety

Safety is of the utmost importance to Form Ghana. To ensure that everybody works in a safe manner in a safe environment three approaches are used:

- the workplace is periodically monitored to assess its safety
- personnel is trained in the safe use of equipment and in safe working techniques
- personnel uses individual protective gear

The use of protective equipment is based on the ILO Health and Safety in Forestry work standard, although this can be modified to fit local conditions.

First aid

Form Ghana has a medical team on site with a qualified nurses on duty.

Every year, training in first aid is given to all first aiders. A more intensive training is given to plantation manager, plantation supervisor, nursery supervisor and chief mechanic. First aid kits are always available at working sites or at least in the vicinity. There are enough kits in order to provide optimal help in case of an emergency.

In order to be able to rapidly evacuate any injured or gravely ill person a vehicle will always be available either in the plantation or at the nursery. Serious accidents are called using the radio to alert the nurse.

Training

Professional training in nursery and plantation techniques is given to promising workers. For this purpose subjects are selected and short courses given both in the plantation and at the nursery.

Training also covers the elements of the FSC certification scheme which are important to workers and to the local population. The objective of this training is to inform the workers on the implications of FSC for the people.

Up to three young forestry graduates will be engaged as management trainees in on-the-job learning (advanced nursery and plantation techniques). Some of these management trainees will later be employed by Form Ghana.

11. ENVIRONMENTAL MANAGEMENT

The Social and Environmental Impact Assessment (Tollenaar, 2013) foresees many positive effects on biodiversity, soils, hydrology, local climate and carbon balance to result from reforestation. Positive effects can be understood in the light of the degraded state of the forest reserve with only little natural forest left at the start of the reforestation activities by Form Ghana. The plantation is expected to restore many ecosystem functions that are presently degraded or absent whereas negative effects on biodiversity, soil and water are expected to be low.

Sound environmental management will ascertain that positive impacts are optimised and negative impacts avoided or mitigated. The focus of environmental management is on managing water and soil, biodiversity and High Conservation Value Forests.

11.1 Soil and water

To maintain and improve the soil and water quality, Form Ghana takes various measures concerning water quality management, soil management and use of chemicals.

11.1.1 *Water quality management*

Hydrological analysis showed high levels of turbidity in the streams and rivers of Tain II FR. Water courses and bodies have to be protected to restore water quality, regular water flow and aquatic ecology. By establishing buffer vegetation strips of 30 m along-side water courses and bodies Form Ghana intends to improve water quality, restore aquatic ecology and minimise negative impacts of plantation establishment and management.

Moreover, Fulani cattle will no longer be allowed in the area managed by Form Ghana, so they will no longer be bathing and defecating in rivers and streams. This is expected to severely reduce water turbidity and increase water quality.

As water from streams and rivers is used for drinking and other household purposes by a large share of nearby villages (see 3.2.4), the improved water quality will also benefit people's health.

11.1.2 *Soil management*

Care has to be taken with plantation establishment and management to prevent erosion, soil acidification, soil fertility loss and pollution with agro-chemicals. Form Ghana assures impact mitigation by following best practise guidelines (assuring compatibility with the FSC standard) for plantation establishment, forest management, road construction, soil fertility management and pollution control (see next section on use of chemicals). The construction of culverts in roads is an important measure to prevent soil erosion. Others include regular thinning (light allows soil vegetation to grow) and filling up gullies (with branches etc.). To maintain and enhance soil fertility dead wood, yearly shedding of leaves and crown biomass resulting from thinning and felling are left in the plantation for decomposition.

11.1.3 Policy for use of chemicals

As part of Form Ghana's sustainability policy, chemical use in the plantation is reduced to a minimum. Mechanical weeding is policy, but before the canopy is closed this method is very costly and not effective enough by itself. Therefore, herbicides (Roundup) are used during land preparation and to complement mechanical weeding during the first 3 years after plantation establishment to eradicate remaining stumps of teak and to control regrowth of weeds. Roundup (glyphosate) is a permitted herbicide by FSC and not highly hazardous.

Personnel that will apply herbicides will receive proper training and equipment to minimise health and environmental risks.

One type of insecticide and one type of fungicide are used in the nursery when necessary. Both are FSC approved. Form has specific internal protocols (P05) for the use and storage of these chemicals.

11.2 Biodiversity

Concerning biodiversity, the reforestation activities of Form Ghana will mainly have an impact on the buffer zone vegetation, wildlife and on harvesting of non-timber forest products by surrounding communities.

11.2.1 Buffer vegetation management

Although little of the natural forest remains in the area, some is still present, mainly next to rivers and streams and in the remote areas of the Forest Reserve. This vegetation will be actively restored and protected to serve as buffer vegetation.

Buffer vegetation areas break the teak monoculture stands and are specifically designed for biodiversity conservation. The buffer vegetation will develop into a network of mixed native vegetation, providing corridors and refugia of suitable habitat for native flora and fauna. Restoration of buffer zones is done by assisted natural regeneration which means that natural regeneration is supported in areas with low tree stocking by planting a mix of native tree species.

Native tree seedlings are grown in the nurseries of Form Ghana and then transplanted into the buffer zones. Where necessary, aggressive weeds will be removed to facilitate establishment of the planted seedlings and rapid restoration of the natural vegetation. As no intercropping will be allowed, weeding will be done several times during the first years in order to allow the trees to become well established.

11.2.2 Wildlife

The SEIA reported that forest wildlife in Tain II FR has been severely impacted by habitat loss caused by wildfires and over-exploitation by humans (Tollenaar, 2013). Form Ghana intends to maintain and enhance forest wildlife populations where possible. This is done in two ways: providing suitable habitat to house species native to the area and protect these species against hunting and poaching.

The buffer vegetation provides suitable habitat with various ecological niches, as well as shelter and food sources. As vegetation develops over time, the buffer zones will become

richer and more attractive for forest wildlife. The contiguous network of buffer zone vegetation acts as a wildlife corridor that alternates with open fields where young teak stands and savannah species grow. This heterogeneous landscape is the natural habitat for rodents, duiker, bushbuck and other wildlife species. Over time, the area will change from a savannah dominated ecosystem into a forest dominated ecosystem of various ages. This will gradually change wildlife composition favouring forest wildlife over species typical of savannah vegetation.

Poaching is strictly forbidden in the areas managed by Form Ghana. This is controlled by the security guards of Form Ghana.

11.2.3 *Harvesting non-timber forest products*

People living in the fringing communities of Tain II FR will need permission from the FC and Form Ghana to collect non-timber forest products within Form Ghana plantation grounds.

11.3 High Conservation Value Forests

According to the principles of the FSC standard for sustainable forest management, a forest (plantation) company should ensure 'maintenance of high conservation value forests – to maintain or enhance the attributes which define such forests.' Six High Conservation Value Forests (HCVFs) can be distinguished, see the box below.

FSC™ definition of HCVF

High Conservation Value Forests possess one or more of the following attributes:

1. Forests containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia);
2. Forests containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance;
3. Forests that are in or contain rare, threatened or endangered ecosystems;
4. Forests that provide basic services of nature in critical situations (e.g. watershed protection, erosion control);
5. Forests fundamental to meeting basic needs of local communities (e.g. subsistence, health);
6. Forests critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

Source: adapted from FSC-STD-01-001 (version 4-0) EN

Westerlaan & Tollenaar (2013) have analyzed whether one or more of these High Conservation Value Forests (HCVFs) are present in the project area. This section presents the conclusion and management implications of the HCVF analysis.

11.3.1 *Conclusion*

At the time of the study, the forest vegetation in Tain II Forest Reserve is highly degraded. The only forest that remains is distributed in small patches in riparian areas. Because of the

current conditions, no High Conservation Value Forest has been identified in Tain II Forest Reserve area managed by Form Ghana.

11.3.2 *Management implications*

Form Ghana already has a set of measures to conserve and enhance the biodiversity values in the forest area under their management. Wildlife will be protected by prohibiting poaching and hunting which is controlled by the security team that patrols the area. Connecting the various patches of forest can significantly increase the ecological value of the forest reserve, providing suitable habitat for local flora and fauna, refugia for wildlife and a buffer for soil erosion. Management of these buffer zones is geared towards protection and restoration using indigenous species of local provenances (cf. recommendation 6.4.4 in Rayden *et al.*, 2006). The current state of the vegetation makes it obvious that the watercourses are not sufficiently protected. Form Ghana is therefore actively engaged in the restoration of the buffer zones along water ways and in monitoring water quality to determine the effect of the activities. Seeds of the endangered Kokrodua tree have been used to produce seedlings that will be planted in the buffer zones scattered over the area to boost the current Kokrodua population, an endangered species, and conserve the species for the future.

11.3.3 *Future*

With reforestation of the degraded land it is expected that certain ecosystem services will be restored, e.g. water quality and climate regulation. The active reintroduction of endangered species (e.g. Kokrodua) and protection of wildlife can potentially make the area managed by Form Ghana an important habitat for flora and fauna. Future analyses will show whether the forests will gain more HCVs.

12. MONITORING AND EVALUATION

Monitoring and evaluation of forest conditions and management performance are necessary to assure set objectives for forest plantation management are met. Form Ghana has established a monitoring system to be able to evaluate its performance and adapt its management when necessary. The monitoring system consists of several activities aimed at collecting different types of information. The method of monitoring used depends on what is best suited per type of information.

The table below shows how monitoring by Form Ghana is performed. For each of the three management objectives, at least one criterion is formulated. Every criterion is verified using indicators that each have a means of verification.

Table 12.1. Monitoring by Form Ghana.

| Management objectives | Criterion | Indicator | Verifier |
|--|---|---|-------------------------------|
| 1. Establish and manage the timber plantation in an ecologically sustainable manner with a maximum of 90% teak and at least 10% of mixed local species with conservation of natural, riparian forest | 1.1 Forest growth and condition | 1.1.1 Area planted with teak | Map |
| | | 1.1.2 Area managed as natural forest (plantation) / buffer zone | Map |
| | | 1.1.3 Changes in planted area | Map |
| | | 1.1.4 Check of the growth rate of the plantation | PSP |
| | 1.2 Biological diversity | 1.2.1 Extent of area protected | Map |
| | | 1.2.2 Protected areas connected by biological corridors or stepping stones | Map |
| | | 1.2.3. Existence and implementation of procedures to identify/ protect endangered, rare and threatened species | Procedures |
| | 1.3 Rainfall, soil and water protection | 1.3.1 Mean monthly and annual rainfall | Measurements and calculation |
| | | 1.3.2 Procedures to protect soil productivity and avoid erosion | Procedures |
| | | 1.3.2 Effectiveness of activities undertaken to avoid soil erosion | PSP |
| | | 1.3.4 Procedures to avoid impact from work in the forest | Procedures |
| | | 1.3.5 Procedures to protect forest and vegetation along water courses | Procedures |
| | | 1.3.6 Checking of water quality | Sample analysis |
| 2. Guarantee financial and economic sustainability through the generation of income from the produced round-wood and carbon sequestration | 2.1 Forest production | 2.1.1 Harvest of round wood | Tables |
| | | 2.1.2 Comparison of yield with yield tables | Tables |
| | | 2.1.3 Calculation of carbon that is currently stored in the plantation | Calculation |
| | 2.2. Economic aspects | 2.2.1 Cost benefit of plantation | Table |
| | 2.2.2 Value of timber sales | Sales data | |
| 3. Provide social benefits by offering good economic conditions for employees and the surrounding small-holder community | 3.1 Social benefits | 3.1.1 Number of people (partially) depending on the plantation for their livelihood (employees and intercroppers) | Table |
| | | 3.1.2 Training and capacity building for employees and intercroppers | Table |
| | | 3.1.3 Information to the public | Website, stakeholder meetings |
| | | 3.1.4 Worker health / accidents on work floor | Statistics |
| | 3.1.5 Benefit sharing | | |

This chapter describes how monitoring for each of the criteria is carried out.

12.1 Plantation monitoring

The objective set for the plantation is to establish and manage a timber plantation in an ecologically sustainable manner with a maximum of 90% teak and at least 10% of mixed local species with conservation of natural, riparian forest.

To verify whether this objective is met, monitoring is undertaken in the plantation and covers forest growth and condition, biological diversity, soil and water protection. The monitoring activities undertaken for each of these subjects are described in this paragraph.

12.1.1 Forest growth and condition

To monitor the extent and the condition of the reforested areas, a map will be created and updated annually.

Analyses of forest growth are based on measurements taken in the plantation. These measurements are taken in permanent sample plots (PSP), which are established in every planted compartment. Every year after planting, additional plots will be laid out randomly in the newly planted compartments. The number of plots will therefore increase yearly. They will attain a cumulative surface of at least 0.1% of the plantation.

The basic shape of a PSP is a circular plot with a pole in the centre. GPS coordinates of the pole determine the site location. Each sample plot has to contain at least 20 trees. After each thinning the tree spacing changes, therefore the plot size is variable. A plot will have a size of 200, 250, 400 or 500 m². These sizes are chosen for calculation purposes because they are easy to convert to a hectare.

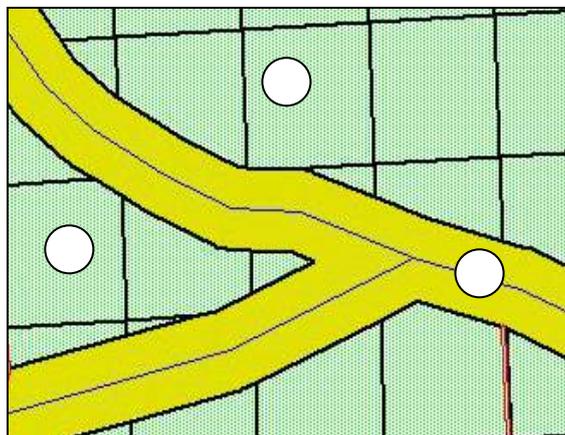


Figure 12.1. PSPs (white circles) are randomly spread over the plantation (green area), and in the buffer vegetation.

The measurements taken in these plots are:

- Date of measurement
- Tree girth: the circumference of each tree is measured at breast height with measurement tape
- Height: the height of all trees is measured as accurately as possible with a clinometer or a measurement pole
- Tree health: of measured trees is recorded whether they are healthy or affected by disease or pests
- Soil erosion: any visual sign of erosion will be noted (rills, gullies, splash erosion, crusting)
- Undergrowth: a note is written on the amount and the type of undergrowth

These growth data provide the information to classify a forest stand into a yield class (1-4).

For other commercial species similar activities will be conducted, but the density of the plots will depend on the total surface planted per species.

Monitoring the development of the teak provenances will be done in close cooperation with FORIG.

12.1.2 *Biological diversity*

Biological diversity monitoring will cover some standard issues, while at times it is possible to include extra subjects to evaluate these for the suitability for monitoring (tested so far are frogs and butterflies in Asubima FR and Afrensu Brohuma FR). Every five years biodiversity monitoring is carried out.

The standard subjects for biodiversity monitoring are the following:

- Plant diversity in the buffer zone vegetation
- Small and medium sized mammal diversity in the plantation and buffer zone
- Bird diversity in the plantation and buffer zone

Plant diversity in buffer zones

Plant diversity in the buffer zones is measured in circular plots just like those used for measuring the growth of planted trees. The middle of the plot corresponds with randomly chosen GPS coordinates. In these plots (200m²) all trees over 10 cm DBH are measured and in 5 nested subplots (1m²) undergrowth and regeneration are measured. For plant biodiversity in buffer zones the same measurements are taken as for forest growth (see 12.1.2). Within the 5 subplots measurements include biodiversity in shrubs, herbs, grasses and juvenile trees.

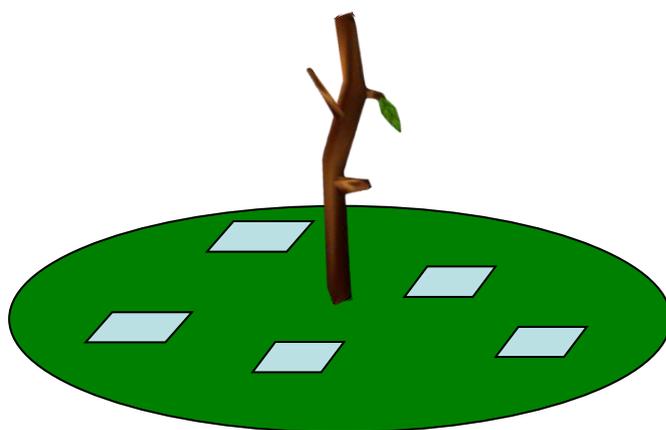


Figure 12.2. Circular plots used for plant biodiversity monitoring.

Small and medium sized mammal diversity in plantation

Small mammal species are defined as mammal species which weigh less than 1kg. Terrestrial small mammals (shrews and small rodents) are sampled mainly with Sherman live traps, and bats with visual analysis. Two sizes of Sherman live traps, Large Folding and Small Folding Aluminium, are used by baiting them with peanut butter and fishmeal. A prebaiting period of one week precedes actual trapping. At the evening of the last prebaiting day, traps are set and are checked twice daily, in the morning and evenings. Trapping lasts for 5 or 6 nights. The bat species will be checked at their abode.

Medium sized mammal diversity is surveyed by walking 1 km transects through sections of the reserves. Existing tracks, quadrant lines and dirt roads are used in some inaccessible areas as much as possible. When necessary, vegetation is cut to generate a path. Mammal species are recorded using direct observation and indirect observation through identification of tracks, dung, feeding sites and calls of animals to determine their presence. For sighted animals, species and geographic location are recorded. Perpendicular distance from the transect line to the sign of the animal is recorded for determining estimated densities of medium-sized mammals. Old shotgun shells are recorded to assess local hunting pressure.

Bird diversity in plantation

Bird diversity is determined by spotting, identifying and counting all birds encountered along transects of 400 metres walked through the plantation, the so called “recce” surveys. During a recce survey the observer(s) follow(s) pre-existing trails whenever possible and when necessary cut a path of least resistance through forest vegetation. It is best to census birds early in the morning or in the late afternoon. If animals can only be censused once a year, it is important to always execute the monitoring in the same season (White and Edwards 2000).

12.1.3 Rainfall, soil and water protection

Rainfall

Mean monthly and annual precipitation in the area is calculated from measurements that will be taken at the fire towers, the nursery and the offices.

Soil

The soil types of the concession are susceptible to erosion and therefore require effective soil conservation and management practices (Scholten *et al.*, 2013). For this reason we pay special attention to erosions on our roads and in the plantation.

In the permanent sample plots erosion is checked every time the plot is measured. Also, soil erosion is monitored on roads during road maintenance and when driving over it. If soil quality monitoring in the PSPs demonstrates soil quality to decline, corresponding fertility management will follow.

Water

An effort is made to restore the riparian forest. As this forest is now degraded the filtering and protection function of this forest is no longer optimal. According to our plan water will be analysed every 5 years to be compared with the original data. Measurements are carried out by a specialist.

Water quality parameters that are measured are:

- pH
- Turbidity (NTU)
- Dissolved Oxygen/(m/l)
- Conductivity ($\mu\text{s/cm}$)
- Nitrate (m/l)

Besides restoring riparian forests, other measures undertaken to maintain water quality are the upgrading of the old log bridges by replacing them with permanent concrete structures and the change of the road drainage to stop the runoff from going into the streams.

12.2 Economic aspects

12.2.1 *Timber*

The annual harvest is determined by the yield models that have been developed for Form Ghana. To monitor whether thinning and harvesting go according to plan, every year a comparison is made between the planned volumes for thinning and final felling and the realised volumes. Data for all species and quantities are gathered and analysed.

Analysis of timber sales will be done once commercial thinning starts. The yield from the first thinning (year 4) is regarded as 'thinning to waste', so revenue calculations include the 8-year and 12-year thinning and the final harvest (after 20 years). Once extracted, the volume and quality of the timber will be analysed.

According to the benefit sharing agreement, 20% of standing tree value will be paid to the Forestry Commission after commercial thinning and final harvest.

12.2.2 *Carbon credits*

As soon as the established timber plantations reach the age of three years (from 2016 onwards), Form Ghana will seek to have this area verified and validated under the Verified Carbon Standard (VCS) and include it in the Grouped project Reforestation of Degraded Forest Reserves in Ghana.

12.3 Social aspects

In various ways, information on social wellbeing and benefits is gathered. The plantation manager pays regular visits to surrounding communities to exchange on issues at play. There is a 'suggestion box' for employees to anonymously bring their ideas and suggestions to the table. The representatives of the workers' union are in direct contact with Form Ghana's management.

During the monthly management meeting, the social issues at play are an item on the agenda. The monitoring of social benefits will be based on the information presented during these monthly management meetings. The following information is gathered and analysed every year:

- The number of people in permanent employment
- The number of people finding casual employment
- Number of times medical treatment has been provided to workers
- Number of injuries that were sustained while working
- Frequency and types of diseases encountered by Form Ghana staff
- Number and types of trainings provided and number of participants
- Number of people that have signed an intercropping agreement
- Amount of land rent paid and benefit sharing paid
- Number of stakeholder meetings held
- Other relevant information

12.4 Utilization of study findings

The data of the various monitoring activities are used to evaluate the overall functioning and effectiveness of the management. If necessary, the content of the management plan can be adapted in view of the monitoring results. Especially the data on forest growth and condition will be used to make decisions on the moment and intensity of the thinning. The results from monitoring in the buffer zones will mainly be used as indicators on the effectiveness of the environmental management of Form Ghana. The monitoring survey returns information to review Form Ghana's off-site impacts and contributions to social welfare.

A monitoring report will be produced annually for publication on the Form Ghana website: www.formghana.com. The report will also be submitted to the parties concerned, i.e. the Plantations department of the Forest Services Division of the Forestry Commission.

13. OPERATIONAL MANAGEMENT PLAN

Operational management is organised based on homogeneous forest areas, or stands. A stand is unique in forest type, plant year and location. Specific management regimes (e.g. timing of thinning) are defined per stand. In case tree growth is very heterogeneous within a stand, different areas within one stand are managed with different regimes.

The operational management plan follows the general guidelines of the silvicultural system and/ or management for buffer vegetation, see chapter 8 and 12 respectively. In addition, for each stand a stand sheet is drawn up at the end of the planting year. This stand sheet gives a clear overview of the general stand characteristics, management information and history, expected management regime and a map of the stand. A standard stand sheet has been developed, see annex A for an example.

All stand sheets are kept together for the management planning to be based upon.

13.1 Annual planning

The stand sheets provide the information to make a detailed annual planning of activities and use of machines and personnel.

The annual planning is made in September/ October for the next calendar year.

14. REFERENCES

- Behaghel, 1999, Etats des plantations de teck (*Tectona grandis*) dans le monde. Deuxième partie, la filière du teck. Bois et Forêt des Tropiques, No 262 (4).
- Chapman, C.A. and L.J. Chapman, 1999, Forest Restoration in Abandoned Agricultural Land: A Case Study from East Africa, Conservation Biology, Vol. 13, No. 6 (Dec., 1999), pp. 1301-1311.
- Chazdon, R.L., 2008, Beyond Deforestation: Restoring Forests and Ecosystem Services on Degraded Lands, Science 13 June 2008: Vol. 320. no. 5882, pp. 1458 – 1460.
- Dupuy, B., 1990, Etudes sur la croissance et la productivité du teck (*Tectona grandis*) en Côte d'Ivoire – Tables de production. Centre Technique Forestier Tropical, Abidjan, Côte d'Ivoire.
- Dupuy, B. and D. Verhaegen, 1993, Le Teck de plantation *Tectona grandis* en Côte-d'Ivoire. Bois et Forêts des Tropiques, No 235.
- Evans, J., (1992), "Plantation forestry in the tropics – tree planting for industrial, social, environmental and agroforestry purposes", second edition, Oxford press.
- Ghana Statistical Service, 2012, 2010 population & housing census; summary report of final results, May 2012.
- Gibson, I.A.S., 1975, Diseases of forest trees widely planted as exotics in the tropics and southern hemisphere. Part 1. Important members of the Myrtaceae, Leguminosae, Verbenaceae and Meliaceae. Commonwealth Mycological Institute, Kew.
- Hutterer, R. 2008. *Crocidura grandiceps*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>. Downloaded on **19 March 2013**.
- Keogh, R.M. and M.Y. Pentsil, 2001, Teak in Ghana – A best practice field guide. Forest Plantation Development Centre.
- Kosoe, E. A., 2012, Assessment of community fire management around Tain II Forest Reserve, KNUST, college of engineering dept. material engineering, Kumasi-Ghana, April 2012.
- Maldonado, G. and D. Louppe, 2000, Challenges of teak in Côte d'Ivoire. Unasyva, No. 201.
- Montagnini, F., 2001, Strategies for the recovery of degraded ecosystems: experiences from Latin America. INCI. [online]. Oct. 2001, vol.26, no.10, p.498-503.
- Pettit, N.E. and R.J. Naiman, 2007, Fire in the Riparian Zone: Characteristics and Ecological Consequences. Ecosystems 10: 673–687
- Rayden, T., I. Doodoo, A. Lindhe and A. Baffoe, 2006, An Interpretation of Global HCVF Toolkit for use in Ghana. <http://hcvnetwork.org/resources/national-hcv-interpretations>
- Scholten, H., Dwomo, O. and Bofo, A., 2012, "Soil survey of selected compartments in Tain II Forest Reserve, near Berekum", November 2012, pp. 24.
- Tollenaar, M. 2013, Social and Environmental Impact Assessment Tain II Forest Reserve, Ghana.
- Wagner, M., J.R. Cobbinah and P. Bosu, 1991, Forest Entomology in West Tropical Africa: Forest Insects of Ghana. Springer Netherlands: <http://www.springerlink.com/content/n204849684772708/>.
- Westerlaan, P. and Tollenaar, M., 2013, High Conservation Value Forest Analysis Tain II Forest Reserve, Ghana.

ANNEX A. LIST OF PROTOCOLS

Legislation and document management

- **P 01 Follow-up of legislation and conventions**
This document describes how Form Ghana follows up on new legal texts that appear in Ghana and new conventions that are signed internationally. It also describes how texts are evaluated for applicability to Form Ghana.
- **P 02 Prevention of illegal activities**
This document describes how Form Ghana avoid illegal activities on the lands it manages.
- **P 03 Periodical review of documentation**
This document describes the system of annual evaluation of all management documents to include new information and assure continued relevance and actuality.

Waste management and environmental protection

- **P 04 Waste management**
This document describes how Form Ghana deals with waste produced on its various sites.
- **P 05 Responsible use of pesticides**
This document prescribes how pesticides need to be handled. It also describes the necessary safety measures.
- **P 16 Storage of fuel, lubricants and toxins**
This document prescribes how hazardous substances must be handled and stored.
- **P 18 Machine maintenance**
This document prescribes maintenance of machines to assure their continued functioning.

Stakeholder engagement

- **P 06 Information policy personnel and local population**
This document describes how personnel and the local population are informed on Form Ghana activities, and how stakeholders can engage with Form Ghana
- **P 07 Conflict management**
This documents describes how grievances are dealt with and how grievances are re-dressed.
- **Stakeholder engagement plan**
This plan identifies the stakeholders of Form Ghana and describes how stakeholders are engaged.
- **Resettlement Action Plan**
This document describes the resettlement activities that Form Ghana undertakes for people that need as a consequence of Form Ghana activities.
- **Community Development Plan**
This plan describes the community development activities that Form Ghana undertakes

Health and safety management

- **P 08 First Aid Procedures & Emergency Evacuation**
This document prescribes how to deal in cases of emergency.
- **P 09 Transport of personnel**
This documents prescribes how personnel can be transported.
- **P 10 Personal protection**
This documents assesses the risks related to the various work places and prescribes the safety gear people need for various jobs.

- **P 23 Envenomation by snakes and insects**
This documents describes the possible snakes and insects that may harm people and how to act in case of bites and stings.
- **P 27 information on contagious diseases**
This documents serves as a basis for sensitization on contagious diseases.

Personnel management and training

- **P 11 Training of personnel**
This document presents the general recurrent planning for training
- **P 17 Management Requirements Responsibilities Senior Staff**
This documents describes the capacities need for senior functions
- **P 20 Meeting schedule**
This document describes the management meetings
- **Training register**
This document is an up to date list of training provided to all workers

Certification management

- **P 12 Internal audits**
This document prescribes internal audits to be conducted at Form Ghana to assure the continued high level of performance at the company.
- **P 22 Chain of Custody procedures**
This documents describes the system of tracking and tracing of logs and timber at the company.
- **P 19 FSC logo usage**
This documents prescribes how the FSC logo can be used by the company.

Technical work prescriptions

- **P 14 Technical performance in the nursery**
This document describes all the activities in the nursery and presents quality standards
- **P 15 Technical performance in the plantation**
This document describes all the activities in the plantation and presents quality standards
- **P 21 Fire prevention and fire-fighting**
This document describes how fires will be prevented and when needed combatted.
- **P 24 Road construction and maintenance**
This document prescribes how roads are to be constructed and maintained.
- **P 25 Log extraction**
This document describes the system for extracting and preparing logs during forest harvesting.

Monitoring

- **P 13 Monitoring**
This protocol describes the various monitoring activities
- **Monitoring plan**
This document describes the planning of the various monitoring activities

ANNEX B. STAND SHEETS

1. Teak 2013

General information

| | |
|-----------------------|---|
| Stand name: Teak 2013 | Forest type: Plantation |
| Coordinates: | Tree species: Teak |
| Surface: 640 ha | Plant year: 2013 |
| Special remarks: | Plant spacing: 1111/ha |
| | Seed provenance: Seed from pilot plantation |
| | Asubima (Bouaké CI) |

Management information

Forest management and silvicultural treatments are performed as described in the management plan and management procedures.

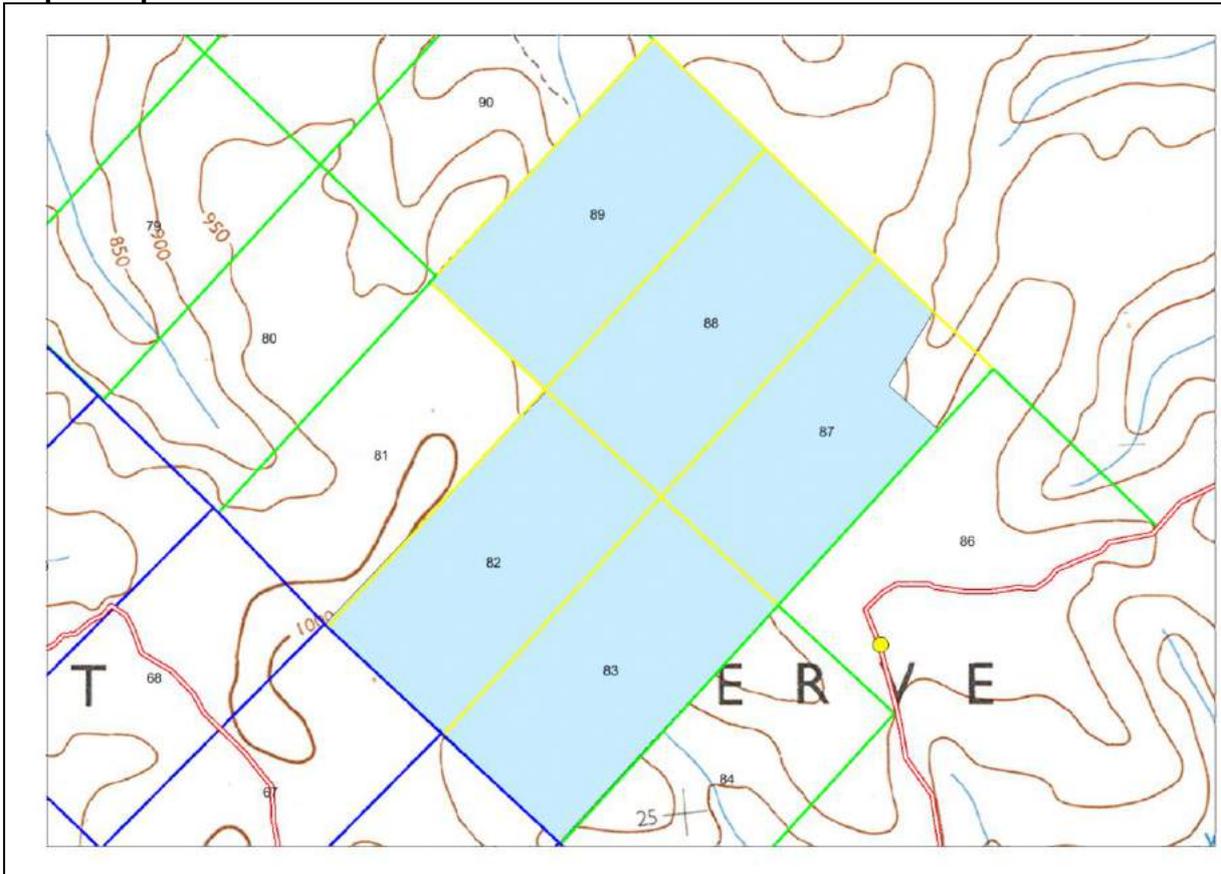
Expected rotation: 20 years
Expected yield class: 2

Management history
2013: Planting

Expected management regime

| Year | Beating up; singling | Weeding | Climber cutting | Pruning | Thinning | Harvest |
|------|-------------------------|---------|--------------------|---------|----------|---------|
| 2013 | | x | x | | | |
| 2014 | | x | x | | | |
| 2015 | | x | x | | | |
| 2016 | | x | x | x | | |
| 2017 | | | x | x | x | |
| 2021 | | | x | x | x | |
| 2025 | | | | | x | |
| 2033 | | | | | | x |

Map area planted with Teak in 2013



ANNEX C. OVERVIEW MAP OF TAIN II



ANNEX D. YIELD TABLES IVORY COAST

Yield tables for teak in Ivory Coast at initial stock density of 1,111 trees per ha and final felling after 20 years for 4 yield classes (adapted from Dupuy, 1990)

Legend

N: number of trees per ha

H dom: dominant height of forest stand

D before: mean diameter before thinning

D after: mean diameter after thinning

G before: basal area before thinning

G after: basal area after thinning

Table 1. Yield table for class 1: thinning at 3, 6, 10 and 15 years.

| Yield class 1 | | | | | | | | | |
|---|------------|-------------|---------------|--------------|--------------------------------|-------------------------------|-------------|------------------------------|---------------------------------------|
| Age (years) | N | H dom (m) | D before (cm) | D after (cm) | G before (m ² / ha) | G after (m ² / ha) | % thinning* | Volume (m ³ / ha) | Volume thinning (m ³ / ha) |
| 1 | 1,111 | 3.4 | 3.5 | | 0 | | | 0 | |
| 2 | 1,111 | 6.8 | 7.0 | | 4.3 | | | 10.2 | |
| 3 | 750 | 10.2 | 10.5 | 11.4 | 9.6 | 7.7 | 20.4 | 34.6 | 4.6 |
| 4 | 750 | 12.2 | 12.8 | | 9.6 | | | 41.0 | |
| 5 | 750 | 14.1 | 15.0 | | 13.3 | | | 65.8 | |
| 6 | 400 | 15.7 | 16.4 | 18.5 | 15.8 | 10.8 | 32.1 | 100.3 | 29.3 |
| 7 | 400 | 16.9 | 18.3 | | 10.5 | | | 71.5 | |
| 8 | 400 | 18.0 | 20.2 | | 12.8 | | | 93.0 | |
| 9 | 400 | 19.2 | 22.1 | | 15.3 | | | 118.5 | |
| 10 | 250 | 20.3 | 24.0 | 26.5 | 18.1 | 13.8 | 23.8 | 150.1 | 33.1 |
| 11 | 250 | 21.2 | 25.7 | | 12.9 | | | 111.9 | |
| 12 | 250 | 22.0 | 27.4 | | 14.7 | | | 132.2 | |
| 13 | 250 | 22.9 | 29.0 | | 16.6 | | | 154.8 | |
| 14 | 250 | 23.7 | 30.7 | | 18.5 | | | 179.7 | |
| 15 | 165 | 24.6 | 32.4 | 35.3 | 20.6 | 16.1 | 21.7 | 205.3 | 40.3 |
| 16 | 165 | 25.3 | 34.0 | | 15.0 | | | 153.7 | |
| 17 | 165 | 26.0 | 35.7 | | 16.5 | | | 173.4 | |
| 18 | 165 | 26.6 | 37.3 | | 18.0 | | | 194.7 | |
| 19 | 165 | 27.3 | 39.0 | | 19.7 | | | 217.6 | |
| 20 | 165 | 28.0 | 40.6 | 0 | 21.4 | 0 | 100 | 243.1 | 243.1 |
| Total production (m³/ ha) | | | | | | | | | 350.3 |
| Mean annual increment (m ³ / ha/ year) | | | | | | | | | 17.5 |

* based on G

Table 2. Yield table for class 2: thinning at 4, 8 and 12 years.

| Yield class 2 | | | | | | | | | |
|---|------------|-------------|---------------|--------------|--------------------------------|-------------------------------|-------------|------------------------------|---------------------------------------|
| Age (years) | N | H dom (m) | D before (cm) | D after (cm) | G before (m ² / ha) | G after (m ² / ha) | % thinning* | Volume (m ³ / ha) | Volume thinning (m ³ / ha) |
| 1 | 1,111 | 2.8 | 2.8 | | 0 | | | 0 | |
| 2 | 1,111 | 5.5 | 5.5 | | 2.6 | | | 5.2 | |
| 3 | 1,111 | 8.3 | 7.3 | | 4.7 | | | 13.8 | |
| 4 | 750 | 11.0 | 11.0 | 12.1 | 10.6 | 8.6 | 18.3 | 41.5 | 3.5 |
| 5 | 750 | 12.6 | 13.6 | | 10.9 | | | 49.0 | |
| 6 | 750 | 13.8 | 14.7 | | 12.7 | | | 62.7 | |
| 7 | 750 | 15.0 | 15.8 | | 14.7 | | | 78.8 | |
| 8 | 450 | 16.2 | 16.9 | 18.7 | 16.8 | 12.4 | 26.5 | 109.0 | 25.0 |
| 9 | 450 | 17.2 | 18.9 | | 12.6 | | | 86.6 | |
| 10 | 450 | 18.1 | 20.9 | | 15.4 | | | 111.8 | |
| 11 | 450 | 18.9 | 21.8 | | 16.8 | | | 127.0 | |
| 12 | 300 | 19.7 | 22.7 | 24.8 | 18.2 | 14.5 | 20.4 | 143.5 | 25.5 |
| 13 | 300 | 20.4 | 24.3 | | 14.0 | | | 114.0 | |
| 14 | 300 | 21.2 | 26.0 | | 15.9 | | | 134.5 | |
| 15 | 300 | 21.9 | 27.6 | | 17.9 | | | 157.2 | |
| 16 | 300 | 22.5 | 28.4 | | 18.9 | | | 170.4 | |
| 17 | 300 | 23.1 | 29.1 | | 20.0 | | | 184.4 | |
| 18 | 300 | 23.7 | 29.9 | | 21.0 | | | 199.0 | |
| 19 | 300 | 24.3 | 30.6 | | 22.1 | | | 214.4 | |
| 20 | 300 | 24.9 | 31.3 | 0 | 23.1 | 0 | 100 | 229.9 | 229.9 |
| Total production (m³/ ha) | | | | | | | | | 283.9 |
| Mean annual increment (m ³ / ha/ year) | | | | | | | | | 14.2 |

* based on G

Table 3. Yield table for class 3: thinning at 5, 10 and 16 years.

| Yield class 3 | | | | | | | | | |
|---|------------|-------------|---------------|--------------|--------------------------------|-------------------------------|-------------|------------------------------|---------------------------------------|
| Age (years) | N | H dom (m) | D before (cm) | D after (cm) | G before (m ² / ha) | G after (m ² / ha) | % thinning* | Volume (m ³ / ha) | Volume thinning (m ³ / ha) |
| 1 | 1,111 | 2,2 | 2.2 | | 0 | | | 0 | |
| 2 | 1,111 | 4,4 | 4.4 | | 1.7 | | | 2.7 | |
| 3 | 1,111 | 6,6 | 6.6 | | 3.8 | | | 9.1 | |
| 4 | 1,111 | 8,8 | 8.8 | | 6.8 | | | 21.6 | |
| 5 | 750 | 11,0 | 11.0 | 12.1 | 10.6 | 8.6 | 18.3 | 42.2 | 4.2 |
| 6 | 750 | 12,0 | 12.2 | | 8.8 | | | 38.3 | |
| 7 | 750 | 13,0 | 13.4 | | 10.6 | | | 50.0 | |
| 8 | 750 | 14,0 | 14.6 | | 12.6 | | | 63.9 | |
| 9 | 750 | 15,0 | 15.8 | | 14.7 | | | 80.2 | |
| 10 | 450 | 15,8 | 16.6 | 18.3 | 16.2 | 11.8 | 27.1 | 103.4 | 13.4 |
| 11 | 450 | 16,5 | 17.7 | | 11.0 | | | 73.3 | |
| 12 | 450 | 17,1 | 18.8 | | 12.4 | | | 85.9 | |
| 13 | 450 | 17,8 | 19.8 | | 13.9 | | | 99.7 | |
| 14 | 450 | 18,4 | 20.9 | | 15.5 | | | 115.0 | |
| 15 | 450 | 19,1 | 22.0 | | 17.1 | | | 131.7 | |
| 16 | 300 | 19,7 | 22.7 | 24.7 | 18.2 | 14.4 | 21.1 | 145.3 | 27.3 |
| 17 | 300 | 20,2 | 23.9 | | 13.4 | | | 110.0 | |
| 18 | 300 | 20,8 | 25.1 | | 14.8 | | | 124.2 | |
| 19 | 300 | 21,3 | 26.2 | | 16.2 | | | 139.6 | |
| 20 | 300 | 21,8 | 27.4 | 0 | 17.7 | 0 | 100 | 156.1 | 156.1 |
| Total production (m³/ ha) | | | | | | | | | 201.0 |
| Mean annual increment (m ³ / ha/ year) | | | | | | | | | 10.1 |

* based on G

Table 4. Yield table for class 4: thinning at 6 and 13 years.

| Yield class 4 | | | | | | | | | |
|---|------------|-------------|---------------|--------------|--------------------------------|-------------------------------|-------------|------------------------------|---------------------------------------|
| Age (years) | N | H dom (m) | D before (cm) | D after (cm) | G before (m ² / ha) | G after (m ² / ha) | % thinning* | Volume (m ³ / ha) | Volume thinning (m ³ / ha) |
| 1 | 1,111 | 1.7 | 1.8 | | 0 | | | 0 | |
| 2 | 1,111 | 3.5 | 3.6 | | 1.1 | | | 1.4 | |
| 3 | 1,111 | 5.2 | 5.4 | | 2.5 | | | 4.6 | |
| 4 | 1,111 | 6.9 | 7.1 | | 4.4 | | | 11.0 | |
| 5 | 1,111 | 9.1 | 9.4 | | 7.7 | | | 24.9 | |
| 6 | 750 | 10.4 | 10.7 | 11.6 | 10.0 | 7.9 | 20.7 | 37.1 | 5.1 |
| 7 | 750 | 11.2 | 11.7 | | 8.0 | | | 32.0 | |
| 8 | 750 | 12.0 | 12.6 | | 9.4 | | | 40.1 | |
| 9 | 750 | 12.8 | 13.6 | | 10.8 | | | 49.4 | |
| 10 | 750 | 13.6 | 14.5 | | 12.4 | | | 60.2 | |
| 11 | 750 | 14.2 | 15.0 | | 13.3 | | | 67.5 | |
| 12 | 750 | 14.8 | 15.6 | | 14.3 | | | 75.4 | |
| 13 | 450 | 15.4 | 16.1 | 17.8 | 15.3 | 11.2 | 26.7 | 96.0 | 24.0 |
| 14 | 450 | 15.9 | 17.6 | | 10.9 | | | 70.6 | |
| 15 | 450 | 16.4 | 19.0 | | 12.8 | | | 85.4 | |
| 16 | 450 | 16.9 | 19.5 | | 13.4 | | | 92.5 | |
| 17 | 450 | 17.3 | 20.0 | | 14.1 | | | 99.9 | |
| 18 | 450 | 17.8 | 20.5 | | 14.9 | | | 107.8 | |
| 19 | 450 | 18.2 | 21.0 | | 15.6 | | | 116.0 | |
| 20 | 450 | 18.7 | 21.5 | 0 | 16.3 | 0 | 100 | 124.7 | 124.7 |
| Total production (m³/ ha) | | | | | | | | | 153.8 |
| Mean annual increment (m ³ / ha/ year) | | | | | | | | | 7.7 |

* based on G