Rehabilitation and sustainable use of degraded community forests in the Bale Mountains of Ethiopia

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1. GENERAL INTRODUCTION AND PROBLEM STATEMENT

1.1 GENERAL INTRODUCTION

Sustainable forest management has been the main focus of the worldwide forestry sector over the last few decades. It aims to ensure that the goods and services derived from the forest meet present day needs without compromising the ability of future generations to satisfy their own requirements. Moreover, sustainable forest management aims at balancing social, economic and environmental objectives. However, only about 6 % of the total forest area in developing countries is managed formally (FAO 2001a). This is in contrast to about 89 % of the total forest area in industrialized countries, which is subject to either a formal or an informal forest management plan. These figures indicate that much work has to be done to bring forests in developing countries under sustainable management.

The current trend in developing countries shows that governments are increasingly turning to community-based forest management approaches to protect and manage forests. The ongoing policy and legal reforms indicate that there is a willingness and strong commitment from the government side to support community forestry. ALDEN WILY (2003) reported that some 5,000 communities are involved in the management of about 3 million ha of forest in Africa.

Forests and woodlands are estimated to occupy 650 million ha or about 22 % of the total land area of Africa, which corresponds to about 17 % of the global forest cover (FAO 2001a). Firewood is the most important forest product and the main source of energy for most African households, accounting for 91 % of all wood consumption. According to the FAO (2001a), the forests of the East Africa region account for 21 % of the forest area of Africa. However, the annual rate of deforestation in the region has increased from 0.7 % during the period 1981-1990 (FAO 1993) to 1 % between 1990-2000 (FAO 2001a). Ethiopia is one of the countries in this region with annual deforestation rate of 0.8 % (FAO 2001a). The loss of forest cover in the country's highlands is not a recent phenomenon. Archeological and palynological studies conducted in the northern highlands indicate that there was already a major clearing of forests about 2,000 years ago (YIRDAW 1996). However, the extent and intensity of forest loss to occur over the last hundred years has been severe.

The main agents of deforestation include agricultural expansion, grazing, consumption of firewood and charcoal, and forest fire. Poverty and rapid population growth are the main causes of deforestation. Owing to the severe deforestation, the country is now left with an estimated forest cover of about 4 % (FAO 2001a). This process has a negative impact on the contribution of the forestry sector to the national income. Moreover, the degradation and depletion of the forest resource base has a major impact on other natural resource uses and sectors in the economy such as agriculture, and water resource, energy and biodiversity conservation.

Experiences made in Ethiopia have shown that participatory forest management approaches can play a key role in reversing the ongoing process of forest degradation by enhancing the involvement of local communities in the management of forest resources in their locality. Forest user groups in the Bale Mountains of South Ethiopia provide one important example, successfully managing part of the previously state-owned Adaba-Dodola forest priority area. KUBSA and TADESSE (2002) reported improvements in forest condition after the empowerment of user groups to manage the forests.

However, forests placed under the management of user groups tend to be highly degraded due to intensive illegal logging and overgrazing in the past. Moreover, the standing volume consists mainly of over-mature and over-sized trees, whereas the younger and medium-sized intermediate trees have already been extracted. Meanwhile, the user groups are demanding technical support to improve the productivity of their forests but little silvicultural know-how is available to help the user groups to rehabilitate and sustainably utilize their forests. The purpose of this study, therefore, is to provide simple and locally adapted silvicultural tools to transform the degraded forests into managed selection forests.

1.2 CONTRIBUTION OF FORESTS TO POVERTY ALLEVIATION

The international community is committed to reducing by half the number of people who are short of food and the proportion of people living in extreme poverty by the year 2015. With about 50 % of the population living below the poverty line, Ethiopia is one of the poorest countries in the world (THE WORLD FACT BOOK 2005).

The potential role of forests in poverty alleviation has been an issue much discussed in recent years. However, little information is available regarding the contribution of forests to poverty alleviation. It is estimated that the livelihoods of more than 1.6 billion people depend on the utilization of forest resources (FAO 2001b). It is mainly poor people in rural areas who rely on forest products for their subsistence economies. Forest resources contribute directly to peoples' livelihoods by providing subsistence goods (fuel, timber, food, medicine and fodder), goods for sale to generate additional income and other indirect social and ecological benefits. Moreover, forests create local employment through forest-based micro-enterprises such as carpentry, furniture production, pit-sawing and others (KAIMOWITZ 2003).

The FAO (2003a) classified the contribution of forests to poverty alleviation in two ways:

- poverty avoidance or mitigation, with forest resources serving as safety nets in otherwise slack seasons,
- poverty elimination, with forest resources helping to lift the poor households out of poverty by serving as a source of savings, asset building and as a permanent source of income.

However, the contribution of forests to poverty alleviation can only be sustainable if the forest resources are managed and used in a sustainable way (ANGELSEN and WUNDER 2003 and WARNER 2000). Poor forest dependent communities are more vulnerable to the effects of forest degradation than other members of society. Therefore, local communities should be the main stakeholders in management decisions where forests are the main source of livelihood. In this regard, people-centered forestry approaches play a key role in establishing strong local control and sustainable use. Moreover, increasing the value and the productivity of the forests is an important means of increasing the contribution forests can make.

The FAO (2003a) identified the following key strategies to improve the contribution of forests to the alleviation of poverty:

- promoting people-centered forestry,
- removing tenure and regulatory restrictions,
- improving marketing arrangements,
- working in partnership,
- improvement of transfer payments (such as payment to the local people for safeguarding biologically diverse forests) and
- integrating forestry into the rural development and poverty reduction strategies.

It is high time now to take actions to maximize the ways in which forestry can help to alleviate poverty. Specifically, action is required to promote people-centered forestry to enhance sustainable livelihoods.

1.3 GENERAL DESCRIPTION OF ETHIOPIA

1.3.1 Geography and socio-economic conditions

Ethiopia has an area of 1.1 million km^2 (Fig. 1.1). It has two plateaus, separated by the Great Rift Valley and surrounded on all sides by lowlands at altitudes of 200-500 m (FRIIS et al.1982). More than 40 % of the land area is highland with altitudes in excess of 1,500 m a.s.l.

Because of the favorable climate and the absence of tropical diseases 80 % of the human and two thirds of the livestock population is concentrated on the highlands. According to the current administrative division Ethiopia consists of nine ethnically based states and two self-governing administrations. Oromia is the largest regional state, with an area of about 376,000 km^2. The projected population estimate of the country for 2002 was 67 million, and growing at a rate of about 2.9 % per annum (CSA 1999). About 85 % of the population lives in the rural areas.

Figure 1.1: Map of Ethiopia (source: THE WORLD FACT BOOK 2005)

Agriculture is the main economic sector in the country. According to the Ethiopian Forestry Action Program (EFAP) 1994, agriculture accounts for 45 % of the total gross domestic product (GDP) and employs 85 % of the total workforce. Forestry accounts for 5.5% of the agricultural sector GDP and 2.5% of the total GDP. The current per person annual income is about US$ 110. The economic development strategy of the country is agricultural development led industrialization (ADLI). The goal of this strategy is to bring about rapid economic growth through improving the productivity of the agricultural sector and then building up an agriculture based industrial sector.

Biomass fuels, specifically firewood, charcoal, dung and crop residues, are the main source of energy in Ethiopia. Firewood accounts for 78 % of the total energy consumption followed by dung and crop residue at 9 % and 8 % respectively. Based on the last national energy study conducted by the Ethiopian National Energy Commission in 1986, the ‘Woody Biomass Inventory and Strategic Planning Project’ (WBISPP), the proportions of total energy consumption by sector are presented in the table below (Tab. 1.1).

Table 1.1: Energy consumption pattern by sector (acc. to WBISPP 2001)

ECONOMY SECTORS	ENERGY CONSUMPTION terra-calorie	PERCENTAGE %
Households	113,000	*89*
Industry	8,500	*7*
Transport	4,000	*3*
Agriculture	280	*0.2*
Public and commercial	140	*0.1*
Others	370	*0.3*
Total	**126,290**	***100***

Households dominate the energy consumption pattern. Within the households firewood provides 81 % of the energy consumed. There is no significant difference in firewood consumption between rural and urban households, which indicates that people are highly dependent on wood fuels even in the urban areas. The development of alternative commercial fuel sources such as hydro-electricity requires substantial capital investment, which the country cannot currently afford. Hence, for a vast majority of homes in the rural areas wood and its biomass substitutes will remain the only affordable and socially acceptable fuel for cooking and heating for several decades to come.

1.3.2 Forest resources

Owing to the diverse biophysical setting, Ethiopia has the fifth largest flora in tropical Africa. It is estimated to consist of 6,500-7,000 higher plant species, of which 12 % are endemic (TEKETAY 2002). The few remnant natural high forests bear witness to this fact, endowed as they are with a rich diversity of flora and fauna species. However, little information is available on the extent, standing volume and growth rates of the national forest resources. Forest resources of Ethiopia are estimated to cover 27.5 million ha (Tab.

1.2). They include natural high forests, woodlands, bush lands and plantations. About 70 % of the high forests are heavily disturbed while the rest are slightly disturbed.

Table 1.2: Forest resources of Ethiopia (EFAP 1994)

FOREST RESOURCE	AREA mill. ha	GROWING STOCK m^3/ha	ANNUAL INCREMENT m^3/ha/yr
Natural high forest	2.3		
-slightly disturbed	0.7	90-120	5-7
-highly disturbed	1.6	30-100	3-4
Woodlands	5.0	10-50	1.2
Bush lands	20.0	5-30	0.2
Plantations	0.2	----	10-14
Farm forests	not available	not available	not available
Total	**27.5**		

Plantations contribute little to the total forest area. The existing plantations comprise industrial plantations, peri-urban plantations, community woodlots, catchment and protection forests. Most of the industrial plantations are within the national and regional forest priority areas.

Large-scale peri-urban plantations were established around the country's large urban centers in the 1970s with the objective of supplying fuel and construction timber. These plantations were established in the densely populated highlands of the country where farmers utilize the land intensively. The state made efforts to appropriate land for the establishment of further such plantations without providing compensation, which failed due to tough resistance put up by the farmers (AMENTE 2002 and EFAP 1994). According to a report by the Ministry of Natural Resource Development and Environmental Protection in (1993), it will hardly be possible to establish large-scale block plantations in the highlands in the future without seriously affecting the farmers. The strategy now is to encourage farmers to grow trees on their farms for their own consumption and in the form of cash crops for the urban market (EFAP 1994).

The demand for wood greatly exceeds that the forest resources can sustainably supply (Tab. 1.3). Moreover, it is important to note that the deficit is predicted to rise because of declining capacity of the existing forest resources to meet the demands of the growing population. Firewood accounts for 95 % of the total wood demand, which implies the demand for industrial and construction wood is small at the moment. The FAO (2003 b) stated that the low level of demand for and supply of industrial wood in East African countries, including Ethiopia, would remain the same for the coming decade.

Table 1.3: Demand and supply of wood (acc. to EFAP 1994)

DESCRIPTION	INDUSTRIAL WOOD mill. m^3		FIREWOOD mill. m^3	
	1992	2014	1992	2014
Demand	48	95	45	89
Supply	14	11	13	---
Deficit	34	84	32	---

The huge gap between the demand and the supply is a potential cause of further depletion of the forest resource base leading to a reduction of the stock of woody biomass and of its increment. As supplies of wood from forests decline, trees growing outside of forests are becoming more important. The wood scarcity has already forced farmers to start growing trees on their own land. With the majority of the population living in scattered rural villages one possible approach geared towards meeting the forest product requirement might be through promoting tree planting by farmers.

1.3.3 Forest management

1.3.3.1 History of forest management

The history of modern forest management in Ethiopia dates back to the beginning of the 20th century, although there were some indigenous management efforts made by the ruling families before this time (CONN 1991). In general, the modern forest management history of the country can be categorized according to three periods.

The first attempt to legally regulate the conservation and utilization of forests in Ethiopia was made by Emperor Menelik II at the beginning of the 20th century. He established the first Ethiopian forest regulations, which can be interpreted as a modern development and recognition of the forests as the productive resources of the national economy (CONN 1991). At this time efforts were made to establish boundary definitions and to demarcate crown forestlands, such as Menagesha Forest, in order to organize the conservation and utilization of the forests. This can be taken as the first attempt at developing a forest management plan in Ethiopia. Afterwards, efforts were made by government and donor communities to put the forest resources of the country under management. Little was ever put into practice, however.

The second and more organized effort made to conserve the forest resources commenced at the beginning of the 1970s (MENGISTU 2003 and MOGES and HUNDE 2002). During this time, the first reconnaissance inventory was carried out to identify the existing natural forests. In 1977, based on the inventory results, the forestry and wildlife development authority of the time initiated a natural forest management program in five forest areas selected as pilot projects (MENGISTU 2003). The five pilot project areas were Munessa Shashemene, Tiro-Boter Becho, Menagesha Suba, Dindin and Megada state forests. The management activities included detailed inventories, road construction, improved logging techniques and the testing of various silvicultural operations and systems. In the 1980s the management concept applied in the pilot projects was scaled up to provide for a designation of national forest priority areas. Consequently, the most important high forest areas were selected and incorporated into 58 national forest priority areas with an estimated area of around 2.3 million hectares (EFAP 1994).

The objectives behind the establishment of the national forest priority areas were to protect and develop the remaining natural forests by introducing integrated forest management guided by management plans. However, management plans were prepared for only eight national forest priority areas, and these plans were only partially implemented in two of them due to the lack of any implementation capacity (MENGISTU 2003). According to EFAP (1994), it was proposed that 40 % of the forest area of the national forest priority areas be developed for production, while 60 % was dedicated to biodiversity conservation and watershed management.

The third and current forest management situation was created after the decentralization of power to the regional states. Following decentralization and the subsequent devolution of power, the national regional states and their executive organs were empowered to manage forest priority areas on their territories (MENGISTU 2003 and YEMISHAW 2002). In some regional states the management of certain forest priority areas was further decentralized to the district level executive bodies. In 1994 a forest conservation, development and utilization proclamation was issued to guide forest management in the country. However, all of the forest priority areas are under extreme pressure from settlement, land use conversion to farming and grazing, and excessive extraction despite the fact that all these activities are prohibited under the forest proclamation of 1994. In most cases, the management of the forests is taking place with little or no participation on the part of the local communities. This has contributed to an unhealthy relationship between the management of the forests and the local communities resulting in continued encroachment into the forests.

In general, the measures taken to conserve and manage the national forest resources so far have not brought about the expected results. This may be the reason why CONN (1991) described the situation by saying, "*Ethiopia has only been successful in the utilization of its forests that is if one is prepared to call devastation utilization*".

1.3.3.2 Silvicultural experience

Knowledge and experience of the silviculture of Ethiopia's natural forests is completely lacking (MOGES and HUNDE 2002, EFAP 1994). Silvicultural practices are mainly limited to the planting and cultivating of fast growing exotic species. There is little information on growth rates, silvicultural characteristics and management of the indigenous species.

To date, forest utilization is mostly conducted without planning or pre-harvest inventories. The valuable species with good quality are removed through selective cuttings. Only a small number of species like *Juniperus excelsa*, *Podocarpus falcatus* and *Hagenia abyssinica* are in high demand. The potential uses of many other species have not yet been investigated, the outcome being the depletion of these few species. Improvement operations after logging are not even considered, resulting in forests stocked with poor quality over-aged trees and very scarce natural regrowth. After logging, in most cases, there is the chance that forests are converted to agricultural and grazing lands.

So far, forestry research has not played a significant role in forest management in Ethiopia (EFAP 1994). The existing scant research findings rarely reach the users owing to the poor research and extension linkage (TEKETAY 2000). Consequently, under the current extension program little information about forest management is made available to the forest experts and farmers, with the exception of tree planting.

1.3.4 Deforestation

According to the findings of the WBISPP (2004), about 113,000 ha of forests is cleared per annum. If the current trend continues, it is estimated that this amount could reach 240,000 ha per annum in the next twenty years.

Most of the remaining natural forests and woodlands are suffering from the open access type of use. Attempts to protect forests from use by people are barely feasible. On the contrary, attempts to restrict access resulted in a situation whereby local communities were forced to utilize forests illegally and consequently felt no responsibility for the condition of the forests. As they were not sure whether they could get legal access to the forests in the future the population saw no need to control their use (MENGESHA 2004). Consequently, the degradation of the forest resources is continuing as the Forest Service lacks the capacity to safeguard them. It is difficult to conserve forest resources without the cooperation of those who depend on them for their livelihoods (ARNOLD 1998). According to DE GRAAF (1986) strategy of wise use is more effective for conservation than a purely defensive strategy.

The rapid degradation and depletion of the forest resource base is already finding its expression in the different sectors of the economy such as agriculture, water resources, energy and biodiversity. Agriculture is the sector most affected by the deteriorating natural resource base. With a decline in the availability of firewood, animal dung and crop residues are increasingly required for use as household fuel instead of serving as natural fertilizers for the soil, thereby further depressing agricultural yields. The rapid population growth coupled with accelerated land degradation has lead to an increasing demand for agricultural land. However, the horizontal expansion of the existing croplands into fertile forests to increase agricultural production is no longer an option as the few remaining forests are located in very inaccessible areas (LEMENIH 2004).

Moreover, the existing hydroelectric power plants and irrigation schemes are seriously affected by siltation, which is a direct consequence of watershed degradation. The resulting frequent power interruptions have had negative consequences for investment, industries and the economy as a whole. Furthermore, deforestation is widely recognized as one of the most important factors aggravating the existing drought conditions, which have in turn increased the vulnerability of the population to food shortages.

Therefore, in order for Ethiopia to achieve security of food supply for its citizens, the sustainable management of the natural resource base, particularly that of the forests, is the first important measure that must be taken.

1.4 COMMUNITY FORESTRY IN ETHIOPIA

1.4.1 Development of community forest management

Although the term community forestry covers a wide range of approaches, they all share the same concept of promoting fair partnership between the relevant stakeholders, especially people living in and around the forests and the Forest Service. The FAO (1978) defined community forestry as "*any situation that involves local people in forestry activity*". This definition includes most of the ways in which forestry and its goods and services directly affect the lives of the rural people.

The first attempt to implement a community forestry program in Ethiopia was started in the late 1970s with the objective to promote soil and water conservation by planting hilltops and hillsides (EFAP 1994). However, this program was state driven and carried out with little or no participation by local community. As a result, the communities viewed most of these types of community forests as state properties. There were no clear objectives and procedures with respect to the management and utilization of these forests (POSCHEN-EICHE 1987). Ultimately, most of these community forests were destroyed during the transition period of 1990/91.

The second attempt to establish community-based forest management was started in the 1990s, which incorporated participatory forest management initiatives after the state controlled management system proved to be an inefficient means of slowing down the depletion of the forest resource. Currently, there are considerable numbers of projects implementing community based forest management approaches in the country. In areas where it has been implemented the forest user groups have proved their capacity to assume responsibility for the conservation of forests. As an example, the impact assessment conducted in forest areas managed by forest dwellers' associations in the Adaba-Dodola forest priority area has shown an improvement in the forest condition and the livelihoods of the people (BEKELE *et al.* 2004).

However, most of the approaches are initiated with support from NGOs and donors. This implies the need for fine-tuning the approaches so that they will be implementable within the capacity of the government institutions. To this end, there is a need to develop general implementation guidelines which could be adapted to local realities based on the experiences gained and lessons learnt so far from the different cases to facilitate the scaling up of the best practices.

1.4.2 Existing legal and policy framework for community forestry

The success of community-based forest management depends on creating appropriate legal and policy framework conditions to secure community interest in forest management. To ensure the sustainable management of the remaining forests of Ethiopia it is important to make sure that appropriate policies taking into consideration the historical and legitimate rights of local communities are in place (EFAP 1994).

In Ethiopia's land tenure system land and natural resources are the common property of the state and the people, and shall not be subject to sale or other means of exchange. The forestry conservation, development and utilization proclamation of 1994 recognizes three major types of forest ownership that are state, regional and private forests. The private forest by definition includes a forest development by peasant associations or by an association organized by private individuals. According to this definition the forest dwellers association in Adaba-Dodola forest can be classified under the private type of forest ownership. Moreover, the same proclamation provides that the sustainable utilization of the country's forest resource should involve the participation of the people and benefit the communities concerned. Article 4(2) of the same proclamation also stipulates that the conservation, development and management of state and regional forests shall be conducted by concerned ministry or region in a manner that inhabitants within the forest do not obstruct or hinder forest development while facilitating conditions that ensure their well-being in such a way that the inhabitants would be beneficiaries from the development.

Empowering communities in the management of natural resources is fully in line with the rural development strategies and decentralization processes being undertaken in the country. Local control of the forest resource provides special opportunities in the fight against poverty and helps to enhance sustainable livelihoods. Moreover, grassroots initiatives aimed at improving local communities' utilization of and control over forest resources can contribute to improved local governance (AMENTE and TADESSE 2004, BROWN *et al.* 2001).

Besides improvements in forest condition and livelihoods, experiences gained from successful community based forest management approaches have contributed to the consideration of community forestry as a viable pathway for forest management in the country. The regional forest proclamation enacted in July 2003 in Oromia, the regional state in which the study area is located, bears witness to this fact. Article 4(3) of the forest proclamation no. 72/2003 of the Oromia regional state stipulates community-based forest management as a strategy for forest conservation in the region. In addition, article 4(6) of the same proclamation elaborates that the concerned regional executive office can conclude agreements with appropriate parties to strengthen forest protection, development and management.

Moreover, article 20(3) of the land use proclamation no. 56/2002 of the Oromia regional state indicates that the delineation, demarcation, development, protection, rehabilitation and management of protected areas shall be done with the participation of the local communities. The same proclamation also states that pockets of natural forestlands should be identified, demarcated, protected, managed and sustainably used by the local communities. All of these supportive legal framework conditions indicate the interest from the government side to promote community-based forest management in the country.

Nevertheless, the existing proclamations lack detailed implementation guidelines for some of these provisions. One aspect that needs clarity is the use of prohibited tree species in the community forests. Both in federal and regional proclamations it is stated that tree species such as *Juniperus excelsa*, *Podocarpus falcatus* and *Hagenia abyssinica* are prohibited from use in regional and state forests. This means it is possible to sustainably utilize these species in private and community forests, which are also recognized in the proclamations. Despite of this fact there is a misunderstanding among the implementing institutions and foresters whether the ban on these species concerns only state and regional forests or all types of ownership. Therefore, there is a need to clarify these important issues by developing clear and detailed implementation guidelines. This will in turn enhance the scaling up of community-based forest management initiatives in the country.

Furthermore, due to frequent restructuring and limited institutional capacity the forest service lacks the capability to engage in sustainable forest resource management. It has not only financial and material constraints but also lack the expertise to work closely with the people. The successful implementation of community based forest management requires experts who play facilitation and advisory roles rather than controlling. In this regard there is a gap that should be bridged with training and capacity building.

1.5 THE PROBLEM STATEMENT

Forest areas placed under community-based management are mostly those that are degraded and less productive. Transforming these degraded forests into productive forests that meet the needs and demands of the community requires the careful planning of silvicultural activities. Until recently, community forestry research addressed mainly social, legal and institutional aspects. Little progress has been made in the development of new silvicultural techniques and practices, which would enable the natural forests to better meet the communities' many needs for different forest products and services (MIAGOSTOVICH 2001 and OJHA 1999). Consequently, foresters lack the range of tools and skills necessary to assist the communities in developing more productive forests.

Conventional forest management practices emphasize the management of forests for the production of timber or other industrial forest products. In community forestry, communities expect a wider range of products and services from their forests, which necessitates the development of management practices reflecting these needs. According to DONOVAN (1997), local knowledge may be the best starting point for learning more about the local ecology and management of community forests. The farmers' forest management school in Thailand is a good example of an innovative approach, which integrates local knowledge and modern science. The school is being developed by the regional community forestry training center to respond to the identified needs of the farmers and their interest in learning more about forest management practices, and to create opportunities for joint learning between forest experts and communities for the purposes of generating new silvicultural knowledge to better respond to local needs (MIAGOSTOVICH 2001).

Silvicultural research in community forests will have great potential to enhance the productivity of those forests and improve the livelihoods of the communities if the findings are put in a simple and locally understandable form facilitating easy application. Most of the existing research findings employ technical language that the community members cannot understand. Therefore, there is a need to develop simple and practical silvicultural management techniques that can be implemented using locally available facilities and capacities.

1.6 HYPOTHESES, OBJECTIVES AND STRUCTURE OF THE STUDY

1.6.1 Hypotheses

In order to analyze the potential of the forests, the underlying socio-economic factors and the management capacity of the user groups the following hypotheses were formulated.

The establishment of natural regrowth has been widely considered to be difficult due to grazing pressure. However, it is recognized that there are some young regrowth >2 m height which obviously managed to escape the danger of grazing. The first hypothesis was formulated as follows:

H_1: there are a sufficient number of naturally established young regrowth that could be tended as potential crop trees to rehabilitate the forest.

With the existing conifer dominated open forest conditions it seems likely that there is enough forage to support livestock grazing by the user groups without harming young regrowth. In addition, it is likely that silvicultural practices such as pruning increase grazing potential under tree crowns. Therefore, the second hypothesis is:

H_2: it is possible to combine grazing with forest management.

It is accepted that the user groups are interested in and motivated to improve their forests. However, silvicultural management requires labor, time, tools and equipment, skills and knowledge. The third hypothesis is:

H_3: the user groups have the capacity required to implement the proposed silvicultural treatments.

1.6.2 Objectives of the study

The overall objective of this study is to contribute to the rehabilitation and sustainable management of degraded community forests in Ethiopia by providing locally adapted silvicultural tools and recommendations. To achieve this objective detailed information about the prevailing socio-economic conditions is required. Moreover, information about the forest structure and composition is very important. This information includes the abundance and distribution of young regrowth, their sizes and species distribution. Equally important is knowledge of the abundance and distribution of mature trees in the forests in order to guide future utilization. The local communities rely on the forest for multiple functions of which wood utilization and forest grazing are the major ones. The integration of the two production systems requires investigation of the actual forest use patterns of the user groups.

Therefore, the specific objectives of the study are to

- understand the legal and socio-economic preconditions for silvicultural management,
- estimate the crown development of the dominant timber species,
- investigate the abundance and distribution of young regrowth and mature trees,
- provide silvicultural tools to transform the existing degraded forests to managed selection forests,
- propose a silvicultural management system that integrates wood production and grazing.

1.6.3 Conceptual framework

According to LAMPRECHT (1989) forestry and silviculture cannot be investigated in isolation. The main task of silviculture is to meet the ever-changing needs of society with regards to the optimal silvicultural management of forest resources. This depends not only on the forest conditions but also on the extra forest-surrounding field which include legal, institutional and socio-economic conditions. Therefore, a thorough assessment of the entire situation is necessary.

The conceptual framework (Fig. 1.2) shows that the outside (legal and socio-economic) conditions and the inside (ecological) forest conditions influence the type of a silvicultural system and management regime we are going to use. Conversely, the success or failures of the management practices we apply to the forest have influence on the functions of the forest, livelihood of the people depending on the forest and the decisions of the policy makers on forest management.

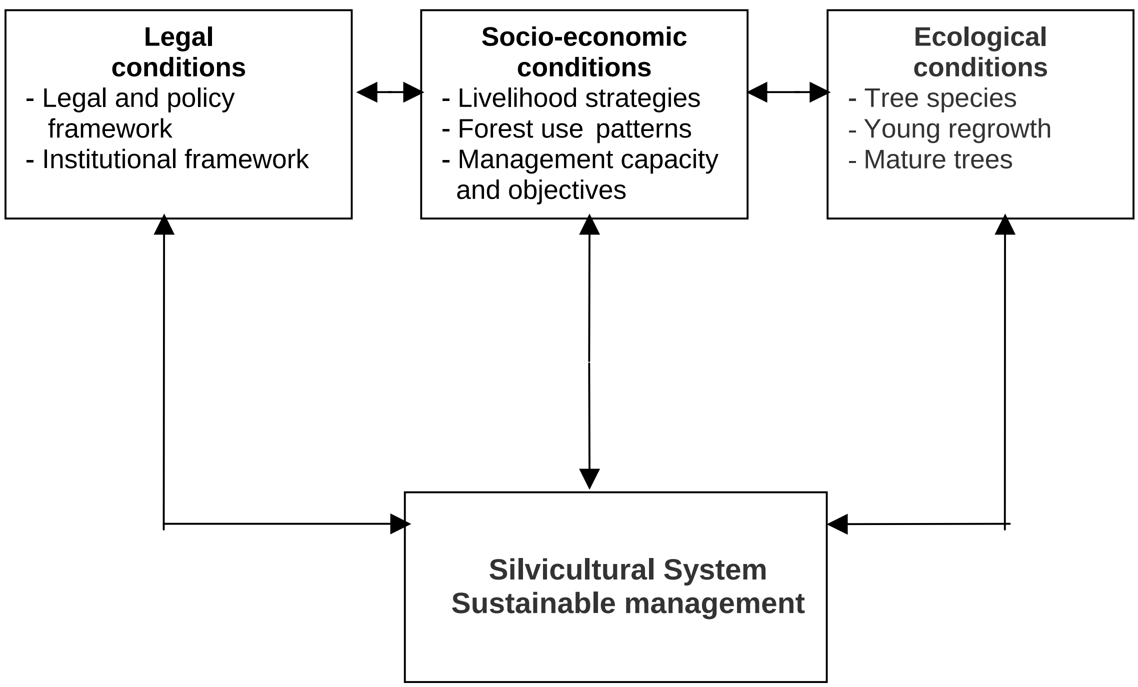

Figure 1.2: Conceptual framework of the study

1.6.4 Structure of the study

The study is presented in six chapters. The Introduction (chapter 1) provided general socio-economic and forestry related information for Ethiopia, as well as the main and specific objectives of the study.

In chapter 2 the natural and socio-economic conditions of the study site are described. Moreover, the participatory forest management approach implemented in the area, the forest user groups and the study approach are described.

Chapter 3 presents the study conducted to estimate the crown development of the dominant timber species occurring in the study area. The optimum number of crop trees that can be maintained considering the grazing needs of the user groups is indicated.

In chapter 4 the silvicultural potential of the user group forests is characterized. The abundance and distribution of potential crop trees and mature trees are investigated. The spatial distribution of the potential crop trees in terms of species and in relation to prominent physical features is described.

A management system that encompasses the multiple functions of the forest is described in chapter 5. Moreover, the level of improvement and harvest cuttings necessary to guide the sustainable utilization of the forests are described.

In chapter 6 the overall results of the study are summarized. The opportunities and constraints for sustainable management of the user group forests are discussed. The implementation capacity of the user groups and the need for further research are also discussed.

2 DESCRIPTIONS OF THE STUDY AREA AND STUDY APPROACH

2.1 STUDY SITE

2.1.1 Location

The Adaba-Dodola forest priority area is located in the northern slopes of the Bale Mountains, ca. 320 km southeast of Addis Ababa. It is one of the 38 forest priority areas in Oromia, and serves as a buffer zone for the Bale Mountains National Park. The study site is situated between latitude 6^0 50’ and 7^0 00’ N and longitude 39^0 07’ and 39^0 22’ E.

2.1.2 Climatic conditions

The rainfall depends on the prevailing winds, which are governed by the seasonal fluctuation of the intertropical convergence zone, but modified by local relief. Rainfall is bimodal, with the main rainy season occurring between July and September. The dry season lasts from November to February, followed by the short rainy season during the months of March and April. From the weather records of 1994-2002, the average rainfall of the study area is 733 mm (AMEHA 2004). The temperature ranges from 7-24 ^{0}C.

2.1.3 Topography and soils

The topographic landscapes of the study site are divided into two categories (ASRAT *et al.* 1997):

- The northern part with an average elevation of 2,400 m a.s.l. is devoid of tree vegetation and intensively cultivated with barley and wheat, whereas
- the southern half is mountainous with a maximum elevation of 3,750 m a.s.l. It is this part of the landscape that is covered by degraded forests. Most of the slightly disturbed forest patches are located in inaccessible areas such as valley bottoms, and along riverbanks and ridges.

The whole area is a source of important perennial rivers, which flow northwards to the River Wabe Shebele and to the Genale-Dawa drainage basin to the south.

The soils of the study site are of volcanic origin. They generally constitute well-structured silt or clay of more than 1 m depth on gentle slopes and valleys, but are shallow on steep slopes and the tops of ridges (ASRAT *et al.* 1997).

2.1.4 Vegetation

FRIIS (1992) classified the vegetation as undifferentiated afro-montane forests, which are also called mixed upland evergreen forests (FRIIS and TADESSE 1990), upland dry evergreen forests (FRIIS *et al.* 1982) and coniferous and mixed forests (RUSS 1979). They are either dominated by *Juniperus* and *Podocarpus* or predominantly *Podocarpus* forests, both with an element of broadleaf species. The forest formation changes along the altitudinal gradient (Tab. 2.1)

Table 2.1: Forest formations along altitudinal gradient (STIPL 1998 and FRIIS 1992)

FOREST FORMATIONS	ALTITUDE m. a.s.l.
Juniperus excelsa and *Podocarpus falcatus* dominate the forest canopy	up to 2,850
Juniperus excelsa is associated with broadleaf species	2,850-3,000
Hagenia abyssinica, Hypericum lanceolatum and *Erica arborea* dominate the forest canopy	3,000-3,400
Erica shrub	>3,400

The forest formation reveals the strong dominance of conifers up to 2,850 m a.s.l. where *Juniperus excelsa* rules over all other species, followed by *Podocarpus falcatus*. At the middle altitude between 2,850-3,000 m a.s.l., *Juniperus excelsa* is still dominant in association with other broadleaf hardwood species. *Podocarpus falcatus* no longer occurs at this altitude as a canopy species although some trees may appear in the understorey. At the lower and middle altitudes *Mytenus species* and *Rapanea melanphloeos* are the most frequent understorey species (TADESSE 1999). At the upper zone between 3,000-3,400 m a.s.l., *Hagenia abyssinica, Hypericum lanceolatum* and *Erica arborea* dominate the forest formation, sometimes mixed with *Juniperus excelsa*. *Erica arborea* occurs as a shrub at its uppermost distribution range.

According to TRAINER (1996), the three timber species dominating the species composition of the forests account for 73 % of the total number of trees (Tab. 2.2).

Table 2.2: Species proportion based on basal area (TRAINER 1996)

SPECIES	PROPORTION %
Juniperus excelsa	*56*
Hagenia abyssinica	*13*
Podocarpus falcatus	*4*
Hypericum lanceolatum	*10*
Erica arborea	*6*
Other species	*11*
Total	***100***

Other indigenous tree species found in the forests include *Olea europea ssb subsidata, Alophylus abyssinicus, Nuxia congesta, Ekebergia capensis, Scheffleria abyssinica, Buddleya polystachia, Mytenus species* and *Pittosporum viridiflorum.*
There are also enrichment plantings of *Eucalptus* species and *Cupressus lusitanica* in the peripheral areas and on former logging sites.

Before the establishment of community-based forest management the forests were seriously affected by the uncontrolled use for wood extraction and grazing. The remaining forest area is estimated to cover 73,600 ha (Tab. 2.3). According to the report produced by the 'Woody Biomass Inventory and Strategic Planning Project' (WBISPP), 10 % of the forest area is situated on a slope in excess of 30 %.

Table 2.3: Land cover types in the Adaba-Dodola forest area (acc. to WBISPP 2001)

LAND COVER	AREA ha	PROPORTION %
Forest	54,000	*73*
-closed forest	10,800	
-disturbed forest	43,200	
Afro-alpine vegetation	18,000	*25*
Grassland	1,400	*2*
Farmland	200	---
Total	**73,600**	***100***

The Adaba-Dodola forest area is very fragmented due to scattered settlements within the forests consisting of about 4,000 households. Wood extraction and grazing is beyond a sustainable level. Studies conducted in the area have shown that pole sized and intermediate trees are entirely missing due to past selective cuttings (HOLWEG 1998 and TRAINER 1996). Subsequently, the forests are deprived of their valuable trees and the annual increment is accumulating on over-mature and poor quality trees. The average standing volume of the forest is about 140 m^3/ha, of which 114 m^3/ha is mainly from the three valuable timber species (TRAINER 1996). The average annual increment is extremely low, just 1 m^3/ha/yr. The average annual increments estimated for slightly and heavily disturbed natural high forests by the EFAP (1994) were 5-7 and 3-4 m^3/ha/yr respectively.

2.2 THE PARTICIPATORY FOREST MANAGEMENT APPROACH

The failure of conventional forest management approaches to safeguard the Adaba-Dodola forests led to an attempt to involve the people living in and around the forests. Broad discussions have been conducted with the stakeholders concerned to try and come up with a feasible and participatory forest conservation approach as an alternative.
The discussions resulted in shared objectives and strategies to conserve the forests. It was through such discussions that a new participatory forest management model called the WAJIB approach developed. WAJIB stands for forest dwellers' associations in the local language; hereafter referred to as "user groups". The process of developing the new approach was facilitated by the Integrated Forest Management Project Adaba-Dodola (IFMP). The project is a technical cooperation project between the governments of Ethiopia and Germany, implemented by German Technical Cooperation (GTZ) and the Oromia Bureau of Agriculture and Rural Development. The central concept of the new approach is to grant exclusive user rights to organized user groups (KUBSA and TADESSE 2002). This approach empowers the forest dwellers to get organized and systematically access the forest resource with clearly defined rights and responsibilities.

To establish user groups a forest in a given village is subdivided into forest blocks with areas of 300-500 ha. During the implementation, discussions and negotiations with the adjacent communities and villages are held frequently in order to reach consensus on the issues requiring common agreement such as border demarcation. Such processes involve important persons from the community groups, villages, forest service and district administration. Based on the forest carrying capacity of 12 ha per household (UNCOVSKY 1998), each forest block is managed by a user group of not more than 30 households.

Each user group signs a forest block allocation contract with the forest service, which gives them legal entitlement to use and manage the forest. The contract document clearly defines the rights and duties of the user groups and the Forest Service:

- the rights of the user groups include settlement in the block, grazing, maintaining the already existing farm plots, and use of forest products both for consumption and sale,
- the duties are to restrict further settlement and agricultural expansion, maintain the initial forest cover and pay forest rent in exchange for the use rights they have been granted,
- the Forest Service is obliged to provide organizational and technical support, carry out annual and periodic forest cover assessments and settlement censuses. Moreover, the Forest Service is expected to respect the rights of the user groups on the one hand and safeguard against free riders on the other.

There are sanctioning mechanisms in place in case of non-compliance with the terms of the contract.

To date, 40 forest user groups have been established and taken responsibility for management with organizational and technical support from the Forest Service. In those areas where user groups were empowered forest management burdens have been lifted off government shoulders. Meanwhile, the right of the people to use the forest resource is also respected. As a result, the forest service is currently striving for the establishment of more user groups.

From the observations so far it has been learnt that the user groups have the capacity to take over the responsibility for the conservation of the forests provided that their rights and responsibilities are clearly defined and respected.

The change in the role of the Forest Service from the usual command and control to advisory is another lesson learnt from this approach. Moreover, the positive outcomes of this approach have influenced the regional forest policy issued in 2003, which recognizes community forestry as a viable forest management strategy (AMENTE and TADESSE 2004). Owing to this fact, practical steps are already being taken to scale up experiences gained from this approach to other forest priority areas.

2.3 SOCIO-ECONOMIC CHARACTERIZATION OF THE USER GROUPS

Understanding the socio-economic attributes of the user groups is an important pre-condition for the development of a silvicultural system. This is because silviculture is simply a tool to achieve the expectations and objectives of the user groups based on the natural capacity of the forests. Hence, the socio-economic information about the user groups was reviewed to disclose the social and organizational structure, forest utilization patterns and management capacity of the user groups. A household level socio-economic study conducted in 3 user groups, namely Jaldo, Changiti and Gede by SCHMITT (2003) provided most of this information. Moreover, reports and studies conducted by the Integrated Forest Management Project Adaba-Dodola were also reviewed.

2.3.1 Social structure

The average family size in the study area is five persons. The report from the Oromia bureau of planning and program (2000) shows that there is a high proportion of both youngsters and adults in the population (Tab. 2.4). On one hand, this implies the availability of a productive labor force. On the other hand, it indicates the need to accommodate the youngsters within the user groups beyond the current carrying capacity unless other means of livelihood can be created for them.

Table 2.4: Population structure

POPULATION STRUCTURE	**PROPORTION %**
Young	*51*
Adult	*46*
Old	*3*
Total	***100***

Polygamy is a common practice in the area. In the case of forest dwellers, it varies from 1-3 wives per adult male. The great majority of the user group members belong to the Oromo ethnic group, who are predominantly Muslim.

The society as a whole is very traditional and male-dominated. Hence, the male partners decide most of the family issues. There is a very clear division of labor in the investigated households. Normally, it is the duty of the children to care for the livestock unless they are at school. In the absence of children the wives cover this duty. Household activities such as preparing food, caring for children, fetching water and firewood collection are shouldered by the women. When it comes to forestry activities, the men are most involved in patrolling, wood processing and tending activities. In some user groups women also participate in patrolling the forest during the daytime.

Access to agricultural land and the number of livestock determine a person’s status in the society. The number of livestock, in particular, is regarded as a symbol of wealth. Most members of the user groups are those with the lowest standard of living. Based on the local wealth classification, 59 % of the male and 82 % of the female run households are classified as poor (SCHMITT 2003).

Owing to the remoteness and inaccessibility of the forests in which they have been sheltered, the user groups have poor access to basic social services and infrastructure. For such economically marginalized people forests serve as the last-resort livelihood alternatives (FAO 2003a).

The user groups have well-established social ties with non-member village communities. In case of major social events such as weddings and funerals they allow them to collect firewood for free. Moreover, 40 % of the forest rent paid by the user groups goes to the village administration to support village development activities from which non-members also benefit (KUBSA and TADESSE 2002). Despite this homogeneity of the internal social structure and the smooth relationships with adjacent communities, conflicts are inevitable. The type of the conflicts may include within group, between groups and between the user groups and non-member village communities. The existence of conflicts is not a problem in itself provided that they are tackled properly and in a timely manner. The mediation of these conflicts at grassroots level using the in-built traditional and formal mechanisms is creating tolerance and understanding among the people. Consequently, the occurrence of these conflicts was reported to be on the decline after the establishment of the user groups (TOLESSA 2002). Sometimes conflicts exist between adjacent user groups and occasionally also between the members of a single user group.

2.3.2 Organizational structure

Although the user groups are members of the village administration, they have their own organizational structure when it comes to forest management (Fig. 2.1).

One user group can have a general assembly, an executive committee with five members and four other committees elected democratically by the members. The function of the executive committee members and the other committees is clearly defined in the bylaws of the user groups. To ensure the representation of women in the decision-making process the executive committees of all user groups have at least one female member.

All members and both sexes have equal rights in all aspects. They have their own regular meetings where they openly discuss and agree on pertinent issues (Fig. 2.2). Decisions are made by all members after intense discussion and consensus has been reached. Forest protection, development, utilization and all other administrative aspects are governed by their bylaws.

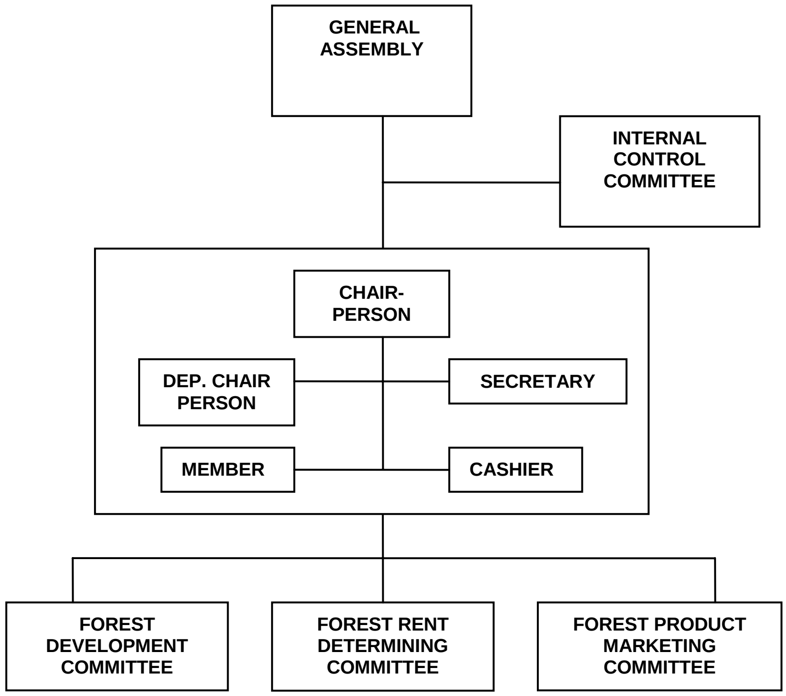

Figure 2.1: Organizational structure (TADESSE and GEBREKIDAN 2004)

Figure 2.2: Regular meeting at Sokora user groups

Recently, the user groups established an umbrella organization at the village and sub-village level in an attempt to improve coordination and communication. This umbrella organization is called "*Golbicha*" in the local language. The umbrella organization plays the counseling and coordination role. Since its establishment it has proved its effectiveness in mediating conflicts within and between user groups that are beyond the capacity of the individual user groups to resolve. The organization also coordinates the marketing of forest products in such a way that members of the user groups receive fair prices for their products. Furthermore, the umbrella organization facilitates the sharing of experiences between the user groups by organizing forums in the forest. Representatives of adjacent villages, the Forest Service and district level offices are invited to attend such forums so that they can observe and witness the improvements in the forest condition. In order to better access the markets and have strong bargaining power, the user groups are now organizing themselves into forest cooperatives.

2.3.3 Livelihood strategies

Mixed farming is a widely practiced strategy in the area, serving as a means to diversify livelihoods. Subsistence agriculture, livestock production and forest utilization are the three main livelihood sources of the user groups (TSEGAYE *et al.* 2004 and SCHMITT 2003). These three strategies are interlinked and depend on one another. According to WIERSUM (1997) forest management is not specialized activity for local communities as is mostly the case in professional forestry. Rather it forms a part of the local livelihood strategy.

Agriculture is more important at the lower altitudes, its importance declining with increasing altitude, where the role of animal husbandry increases. According to the terms of the contract governing forest block allocation, the forest user groups have the right to maintain their existing farm plots in the forests. Agricultural land in the forest blocks accounts for only 1.5 % of the total area (SCHMITT 2003). However, 21 % of the forest dwellers have been reported to have agricultural plots on the plains outside of the forests, yet the majority of the forest dwellers have either no land or not enough to meet their subsistence demands. This implies the reliance on livestock and forest production as a strategy to make up the deficit.

The user groups believe that the forests play a significant role in improving the local climate resulting in a stable rain distribution benefiting agriculture. Had it not been for the presence of ample firewood from the forest, the user groups might have been forced to utilize the agricultural residues and dung for energy, which under normal circumstances are used to fertilize the soil. The forests also provide shade and fodder for the livestock. The livestock alternately, particularly horses and donkeys, are the main means of transportation of forest products.

2.3.4 Forest utilization pattern

2.3.4.1 Wood utilization

The user groups depend entirely on their forests for any wood-related needs. SCHMITT (2003) identified four major types of wood products produced from the natural forest for consumption and sale by the user groups. These include fuel wood, smoothened juniper splits or poles (locally called *Kanchi*), rough juniper splits (locally called *Xarbi*) and lumber. Juniper poles and splits are products used locally for the construction of houses and fences. Pit sawing is the traditional method of wood processing widely used by forest dwellers. Using this method the trees are felled, debranched, cross cut and converted into different products inside the forest to be transported out of the forest by humans or animals. Axes and two-man saws are the most commonly used tools for processing. The recovery rate employing this method is reported to be 30 % (DEMESA 2002).

An average household needs about 6 m^3 of wood for consumption annually (Tab. 2.5). The most favoured species for the aforementioned uses are *Juniperus excelsa, Podocarpus falcatus* and *Hagenia abyssinica* (REGASSA 2003, SCHMITT 2003 and SHIFERAW 2003). *Juniperus excelsa* is particularly valued by the user groups for all sorts of construction wood, furniture and firewood.

Table 2.5: Annual household wood consumption (SCHMITT 2003)

WOOD PRODUCT	CONSUMPTION m^3
Firewood	3.4
Juniper splits	1.7
Smoothened juniper poles	0.4
Lumber	0.2
Total	**5.7**

Wood is the major source of energy for cooking and heating in all of the forest dweller households. There is no scarcity of firewood, which can be collected close to the settlement areas. There is greater flexibility in terms of the species that can be used for firewood. The annual consumption of firewood per person in the study area is 0.5 m^3 (WBISSP 2001). This means a household with an average family of five needs 2.5 m^3 of fuel wood per annum. An average forest dweller household utilizes 3.4 m^3 of firewood, however, which is above the average for the area. This is quite reasonable as they rely much more on wood for fuel than other biomass fuels such as dung and crop residues.

In addition to the household consumption, firewood is also the main source of additional income. SHIFERAW (2003) reported that 50 % of the forest dweller households sell two donkey loads of firewood every week. The same report indicates that the remaining 50 % of the households located at higher altitudes do not sell firewood because the local markets are too far away.

The processing of lumber of the three preferred timber species revealed the highest gross margins in terms of the achievable daily income in the area (SCHMITT 2003 and AMEHA and TADESSE 2000). The processing of juniper poles also has a positive gross margin. Although firewood collection and marketing showed negative gross margins, the women still do it as they have little other alternative sources of income. The positive gross margins associated with the processing of most wood products indicate the economic potential of the forests.

Market surveys conducted from 1999-2004 showed increasing trends in the prices paid for wood products stemming from natural forests (AMEHA 2004). The same surveys also revealed a decrease in the market supply of 7 % for wood products from natural forests and a corresponding increase in wood supply from plantations. The reason for this is the regulated access to the natural forests and the promotion of tree planting outside the natural forests.

2.3.4.2 Forest grazing

Grazing in the forest is the only means for the user groups to maintain their livestock. They consider the forests as a source of fodder and shade for their livestock. The grazing pattern changes seasonally. There is a traditional shifting of animals from one land use to the other. Open pasture areas, forestlands and farmlands are some of the areas in which the traditional grazing regime is exercised. During the rainy season the livestock is kept at the lower altitudes on open grazing grounds. Forest grazing is particularly important during the dry season when the availability of fodder on the open pasture is exhausted. After the crops have been harvested the livestock is also allowed to roam the fields. This traditional shifting of animals can be used as a basis for the introduction of rotational grazing.

Studies conducted in the study area from August 1998 to July 2000 investigated the fodder production capacity of different pasture types in the Adaba-Dodola forest (Tab. 2.6).

Table 2.6: Fodder production (BAPTIST *et al.* 2001)

PASTURE TYPES	PROPORTION %	FODDER PRODUCTION tones/ha/year
Wooded pasture	*50*	2
Rain-fed pasture	*45*	3.5
Swampy pasture	*5*	7

The major types of livestock are cattle, sheep, horses, donkeys and goats (Tab. 2.7). A total of 97 % of the user group members possess some kind of livestock (SCHMITT 2003). The average holding is 14 head of livestock per household. Almost all of the livestock types are local breeds, which are less productive but well adapted to the environment.

The impact of grazing on the forest vegetation varies with the livestock type and the tree species. Goats cause the greatest amount of damage to young plants. Realizing this, most of the user groups have already banned the entrance of goats to natural regeneration areas in their bylaws.

Table 2.7: Livestock types in the selected user groups (acc. to SCHMITT 2003)

LIVESTOCK TYPE	USER GROUPS			AVERAGE
	JALDO	CHANGITI	GEDE	
Cattle	5	6	8	6
Sheep	3	4	5	4
Horses	2	2	2	2
Goats	1	2	1	1
Donkeys	1	0.4	0.2	0.5
Average	**12**	**14**	**16**	**14**

Studies conducted in the area reported that the two indigenous conifer species, *Juniperus excelsa* and *Podocarpus falcatus,* are less sensitive to browsing (REGASSA 2003 and TESFAYE *et al.* 2002). The studies also revealed that grazing reduced mainly the young regrowth of broadleaf species. *Hagenia abyssinica*, in particular, is very palatable by all types of livestock. The implication of this is that it is necessary to regulate grazing in the broadleaf dominated parts of the forests.

There is strong interest and commitment from the user groups to establish grazing systems that allow the forests to regenerate. Some user groups have already started to set aside some portion of their forests for natural regeneration by barring their animals from entering such areas. Therefore, there is a great demand for a management system that supports the integration of the two production systems.

2.3.4.3 Ecotourism

Ecotourism in the area was initiated and promoted by the Integrated Forest Management Project Adaba-Dodola. The objective is to reduce pressure on the natural forests by creating alternative sources of income and local employment. The diverse forest formations along the altitudinal gradient are one of the main tourist attractions. The practice of sustainable forest management by the user groups is believed to be fundamental to the success of the ecotourism sector.

The community-organized tourism offers guided tours on horseback or by foot through the beautiful Bale Mountains of Ethiopia. The total income for the local communities from the ecotourism services has reached about US$ 10,000 annually, with about 1,000 tourists visiting the area each year. The direct beneficiaries of this income include six guides, five hut keepers, more than one hundred horse providers, and another hundred horse handlers. For them and their extended families, ecotourism is a significant additional source of income.

The increasing trend in the number of tourists is providing hope that the number of beneficiaries will grow in the near future. At the moment the user groups closest to the trekking line are benefiting most from the service. SCHMITT (2003) reported that 41 % of the members in one user group situated at the trek's starting point are already considering ecotourism as their third source of income.

Apart from the benefits to individuals, 20 % of the overnight payments also go to the village administration to support community development activities. Some villages use this share to cover the running costs of their public primary schools, which benefits the community at large (AMENTE 2004). This phenomenon has placed increased value on the notion of forest conservation and raised the awareness of the user groups and the general public of the importance of the forest resource.

2.3.4.4 Other non-wood forest products

According to a study conducted by SHIFERAW (2003), the forests provide the user groups with a wide range of non-wood forest products. In addition to providing wood products, grazing and ecotourism service they also provide medicines, food (edible fruits, leaves, roots, mushrooms), detergents, honey, bamboo, spices and dyes. Although forest dwellers have considerable know-how in utilizing these non-wood products, they are by no means utilizing the production potential of the forests. The reasons for this may be poor market information and communication. If the full range of these non-wood forest products were to be extracted and marketed, the forests could provide much greater economic benefits than when they are used exclusively for timber.

2.3.5 Traditional knowledge in forest management

Traditional knowledge is in essence knowledge acquired by local communities through the accumulation of formal and informal experiences, and through an intimate understanding of the environment in a given cultural context (BECKER and GHIMIRE 2003). Local communities often have a deep understanding of their environment from their lifelong relationship. Although the role traditional knowledge alone can play in sustainable forest management is still debatable, its combination with scientific knowledge can result in the maintenance of both ecosystem services and biodiversity (BECKER and GHIMIRE 2003).

Farmers in the study area have extensive knowledge and long traditions of managing and tending trees on farms and in home gardens. Forest dwellers have a good knowledge of the species diversity of their forests, their formations along the altitudinal gradients and respective uses. They also know the biology of the species, such as flowering and seed production periods. However, the silvicultural knowledge necessary to manage forests in such a way as to achieve certain objectives was seen to be lacking (SCHMITT 2003). This can be verified by the absence of any planned silvicultural interventions applied by the user groups.

2.3.6 Forest management capacity

Forest management requires a long-term commitment by the user groups to undertake forest improvement work and to regulate use. To transform the existing degraded forests into productive forests that generate tangible benefits on a sustainable basis, the user groups have to commit different resources to forestry activities. These resources include human resources, tools and skills, as well as financial resources. All these resources should be put together and used properly to bring about improvement in both forest condition and livelihoods.

2.3.6.1 Human resources

Human resources refer to the available labor force and the existing knowledge and skills. In general, the availability of labor is not a constraint as the user groups are committed to providing manpower for forest management activities. The availability of workers may vary seasonally, however. Households in possession of sufficient land for agriculture can provide labor for forestry for only 2-4 months after the harvesting of crops, whereas 35 % of the households who do not have any agricultural land can provide labor at any time of the year provided that they earn something in return (SCHMITT 2003). As indicated in section 2.3.5, the user groups possess certain traditional knowledge that may be used as a foundation upon which to build silvicultural knowledge. Moreover, the user groups' interest in and motivation to learn more about silvicultural practices is a good starting point for the development of user driven silvicultural capacity in the future.

2.3.6.2 Tools and skills for tending, harvesting and processing

The user groups possess only a few traditional tools for forestry activities and the processing of forest products. The available tools are mainly axes, two-man saws, slashers, wedges and hammers (SHIFERAW 2003 and SCHMITT 2003). These tools are generally of poor quality and unsuited for processing the over-sized and old trees that remain standing in the forests. The user groups have little skills with respect to tending activities such as pruning and thinning, and low impact harvesting techniques are not well practiced by the user groups. However, considerable numbers of forest dwellers have the traditional skills of wood processing using the pit sawing technique.

2.3.6.3 Financial resources

The very limited financial capacity of the user groups and lack of access to credit schemes has been identified as a factor limiting investment in forest management (SCHMITT 2003). However, the user groups have high livestock figures that can easily be converted into financial capital provided that conditions conducive to making an investment in forestry profitable are created. The existing lack of financial capital means that forest rehabilitation necessitates a reliance on minimum input into the natural processes.

2.4 THE STUDY APPROACH

Silvicultural management of previously unmanaged forests is an iterative process that can be refined through repeated experimentation, monitoring, and readjustments. A single approach by a researcher will not lead immediately to a satisfactory silvicultural system (DE GRAAF 1986). The function of the researcher is to provide technical expertise and help the concerned stakeholders in the identification of their problems, the analysis of information, facilitation and monitoring of changes. To this end, a participatory action research approach was employed in this study to ensure the active participation of the concerned stakeholders in the research process.

According to SELENER (1997), participatory action research is a process through which members of a group or community identify a problem, collect and analyze information, and subsequently act upon the problem in order to find solutions to bring about the required changes. Its foundation is a cycle of iterative learning: reflection, planning, action, observation and feedback. There are four types of participatory action research, namely participatory action research in community development, in organizations, in education and farmers' participatory research (SELENER 1997). In this study farmer participatory research or participatory technology development is used. This approach encourages farmers to participate in the development, testing, and evaluation of a technology in order to increase production. A greater understanding of and interest in applying the research findings depends on the active involvement of locals during the research process.

According to KARTASUBRATA and WIERSUM (1995) silvicultural research in the context of community forestry should be carried out in cooperation with local people rather than by forest researchers in isolation. The participatory development of silvicultural practices helps the forest users to become active managers of their forests (MIAGOSTOVICH 2001). It enables them to engage in continuous observation of the impacts of the implemented practices and to learn from the experience in order to adapt future management interventions.

In Ethiopia, research results are poorly disseminated because of weak linkage between research and extension (TEKETAY 2000). Participatory action research bridges such gaps by involving the concerned stakeholders in the research process. Unlike the classical research approaches, in participatory action research, the implementation of the research findings and related changes are the integral part of the research process. It also helps in strengthening the process of collaboration, information exchange, and communication among stakeholders seeking out opportunities to collectively learn about the impact of their actions (JUM *et al.* 2003).

Accordingly, the user groups and forest experts from the district forest service and Integrated Forest Management Project Adaba-Dodola were actively involved throughout this research process. The major activities conducted with them include:

- identification and formulation of the problem,
- collection and analysis of data,
- focus group discussions,
- on site demonstrations and discussions about the proposed silvicultural treatments.

Moreover, after external expert analysis of the collected information the preliminary findings of the study were presented and discussed with concerned stakeholders. Demonstration and experimental plots were also established so that the user groups and local experts can continuously observe and monitor the impacts of their intervention.

3. CROWN DEVELOPMENT OF THE DOMINANT TIMBER SPECIES

3.1 INTRODUCTION

In developing silvicultural prescriptions for a given forest, it is fundamentally important to be able to determine stand density (DANIEL *et al*. 1979). Measures of stand density help to determine the relationship between trees in the stand and the growing space they could potentially utilise (KRAJICEK *et al.* 1961). Stand density can be expressed in terms of the number of trees or basal area per unit area. Knowing the crown area occupied by trees in a stand contributes to an understanding of the growing space utilised by different species, and trees of the same species with different diameter classes. To this end, the relationships between tree diameter and crown parameters were investigated for the dominant species within the forest. As a result, models were established between tree diameter and crown parameters. The developed models facilitate the prediction of crown parameters based on tree diameter, an easily measurable parameter. The benefit of this is a reduction of both the costs and the time consumed in the course of ground-based forest monitoring.

The optimum number of trees/ha that could be tended as final crop trees was also determined, based on projected crown area and prevailing species mixtures in the studied forests, and taking into account the grazing needs of the user groups.

3.2 MATERIALS AND METHODS

3.2.1 Sampling and measurement procedures

The data for this study were obtained from Adaba-Dodola forest. The measurements were conducted on the three dominant timber species of the forest, namely *Juniperus excelsa*, *Podocarpus falcatus* and *Hagenia abyssinica*.

Owing to the history of selective logging in the studied forests it was very difficult to find the required number of sample trees per diameter class in a fixed sample plot. Trees in the intermediate diameter classes were particularly rare in the forest. Therefore, sample trees were selected along transects following altitudinal gradients, as the occurrence of the 3 timber species varies with altitude. This increased the likelihood of encountering the required sample trees compared to the fixed sample plot approach. At the same time it involved greater expense of time and effort. For this reason, 15 sample trees were measured per diameter class for each species, which is a minimum figure for such studies.

It was assumed that the crop trees of the three timber species reach harvestable size at a diameter of > 40 cm. In addition, young trees > 2 m in height were regarded as potential crop trees in the context of the study area as they are above the browsing zone. Further details concerning the definition of the potential crop trees are provided in chapter 4. Employing these underlying assumptions, tree diameter at breast height, crown radius, crown length and the tree height of the three indicated species were measured for trees > 2 m height and < 50 cm diameter. Five diameter classes of 10 cm intervals were employed (1-10, 10-20, 20-30, 30-40, 40-50 cm). The 40–50 cm diameter class was added to represent trees at maturity.

To maintain uniformity in the selection and measurement of the sample trees the following procedures were employed:

- Healthy and undamaged trees with relatively circular crowns were selected.
- Sample trees were evenly distributed within the diameter class as far as was possible.
- The crown edge of the sample trees was projected to the ground using a Clinometer at a 90^0 angle.
- For every sample tree the crown radii were measured in eight directions, as opposed to the more commonly used four measurements, as the crowns of stand grown trees are not as regular as open grown trees. Measurements were taken along the compass bearings.
- Crown diameter was obtained by adding the eight crown radii measurements and dividing it by four.
- Height and crown length measurements were taken using a Spiegel (mirror) relascope.

3.2.2 Establishing relationships between tree diameter and crown dimensions

A linear regression was performed using the MS Excel programme to determine whether there was a significant relationship between tree diameter, crown diameter and crown length. During the analysis, diameter at breast height was considered an independent variable. The model representing the relationship between tree and crown diameters is known as the crown ratio model. The relationship between tree diameter and height was also analysed. The linear regression model was chosen, as the coefficient of determination of the models is sufficiently high with reasonable standard errors of the estimate, and for its simplicity of application.

3.2.3 Determination of crown area

The crown area of the three dominant species was calculated using the crown diameter, and based on the assumption that tree crowns tend to be circular. The formula used was:

$$A = \frac{\pi * cd^2}{4},$$

where, A = crown area and cd = crown diameter.

For the other tree species occurring in the forest, which are mainly broadleaf species, the relationship between crown area and diameter was regarded as being equivalent to that of *Hagenia abyssinica*, as it is difficult to measure crowns of all the tree species at one time.

3.2.4 Determination of optimum number of crop trees/ha

According to ABETZ (1995) the optimum number of crop trees/ha in uneven-aged forest is almost twice the number in even-aged forests. Following this concept, the optimum number of crop trees/ha in even-aged mixed stands was first computed based on the diameter class at maturity of the final stand, which was 40-50 cm in the case of this study. In fully stocked even-aged stands trees occupy a maximum of 80 % of the total growing space. Hence, only 80 % of the available growing space/ha was allocated to the indicated diameter class. The growing space allocated to the final diameter class was subdivided according to tree species, based on the percentage of their occurrence in the forests. The prevailing species mixture in the three most common forest formations (compare Tab. 2.1) was analysed using GIS (geographic information systems), based on the inventory of young regrowth conducted in three selected forest areas (compare chapter 4).

The midpoint of the final diameter class was used to calculate the projected crown area of the trees in that class. The corresponding crown diameter for the midpoint was obtained using the crown ratio models established in section 3.2.2. The respective crown area was then calculated using the formula outlined in section 3.2.3. Then the growing space allocated to each species was divided by the corresponding projected crown area of the respective diameter class in order to obtain the optimum number of crop trees of that species. Adding the number of crop trees for all the species gave the optimum number of crop trees/ha in even-aged mixed stands. The number of crop trees/ha in uneven-aged mixed stands was subsequently obtained by multiplying the number of crop trees/ha in even-aged mixed stands by two for plenter-like uneven-aged forests (ABETZ 1995). Ultimately, the number of crop trees/ha was calculated taking into consideration grazing needs.

At the moment there is no information in relation to how much growing space should be left to provide an optimum quantity of fodder on the forest floor. Therefore, at this initial stage it was assumed that reserving 50 % of the growing space for grazing is enough to meet the grazing demands of the user groups. This figure should be adapted in the coming decades by monitoring the relationship between tree density, crown openness and fodder production.

3.2.5 Estimation of green crown percent

Crown length is the length along the main axis from the tree tip to the base of the crown. The green crown percent was estimated from crown length and tree height, and expressed as a percentage. It was computed as follows:

$$\text{Green crown percent (\%)} = \frac{cl}{ht} \times 100,$$

where, cl = crown length and ht = tree height.

3.3 RESULTS

3.3.1 Crown ratio models

The linear model established representing the relationship between tree and crown diameter was found to be very strong and positive for the three investigated species (Fig. 3.1). Tree diameter explained 90 %, 81 % and 93 % of the variation in crown diameter of *Juniperus excelsa*, *Podocarpus falcatus* and *Hagenia abyssinica* respectively. The linear models were statistically significant ($p < 0.05$) for the three species. The standard errors of estimate for the models were small, indicating low variability of the observations around the regression line. This implies that the models were robust and the predictions good.

3.3.2 Relationship between tree diameter and crown length

The linear model fitted between tree diameter and crown length also showed a strong and positive relationship between the two parameters. Tree diameter explained 84 %, 65 % and 78 % of the variation observed in the crown length of *Juniperus excelsa, Podocarpus falcatus* and *Hagenia abyssinica* respectively (Fig. 3.2). The models were statistically significant ($p < 0.05$) for the three species.

However, the standard errors of estimate for the models were high compared to the crown ratio models. Of the three species, the model fitted for *Podocarpus* had the highest standard error of estimate, indicating the greater variability of the observations around the regression line. This is also reflected by the low coefficient of determination for this species.

3.3.3 Relationship between tree diameter and height

The relationship between tree diameter and height of the three species was found to be very strong and positive (fig. 3.3). Tree diameter explained 92 %, 84 % and 93 % of the variation in height of *Juniperus excelsa*, *Podocarpus falcatus* and *Hagenia abyssinica* respectively. The models established were statistically significant ($p < 0.05$) for the three species. The standard errors of estimate taking into account the range of values of the dependent parameter (height) were not high.

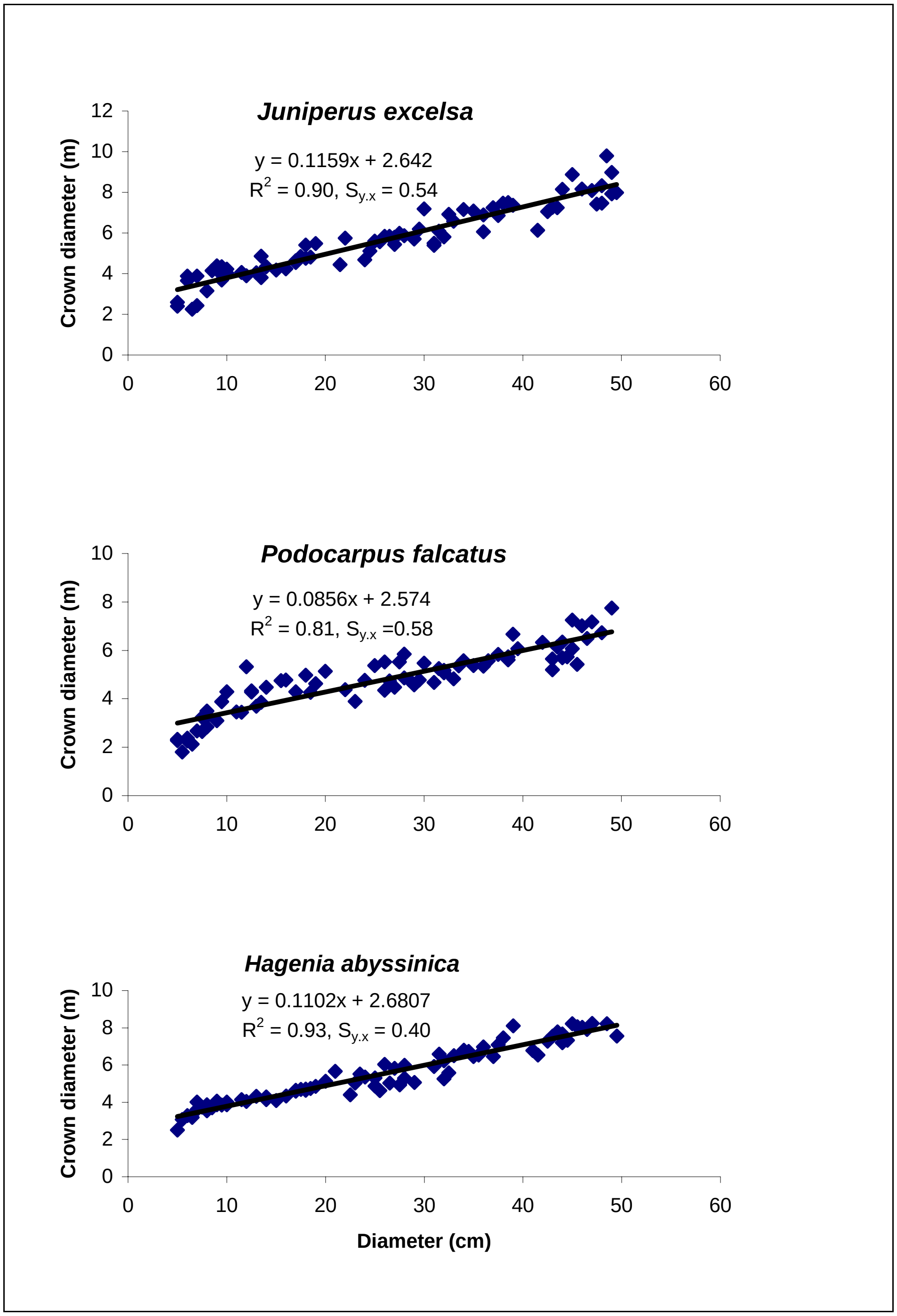

Figure 3.1: The relationship between tree diameter and crown diameter

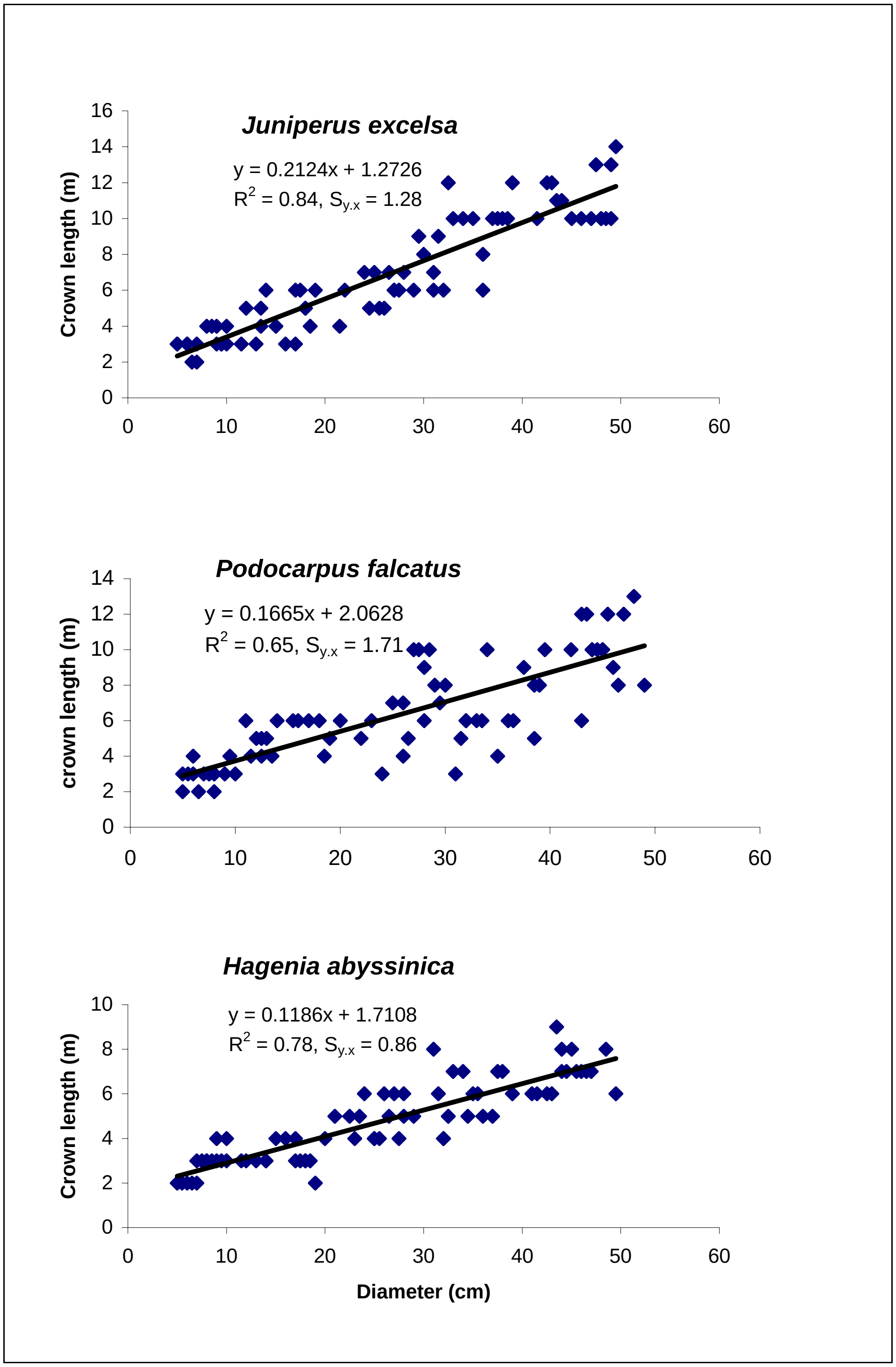

Figure 3.2: The relationship between tree diameter and crown length

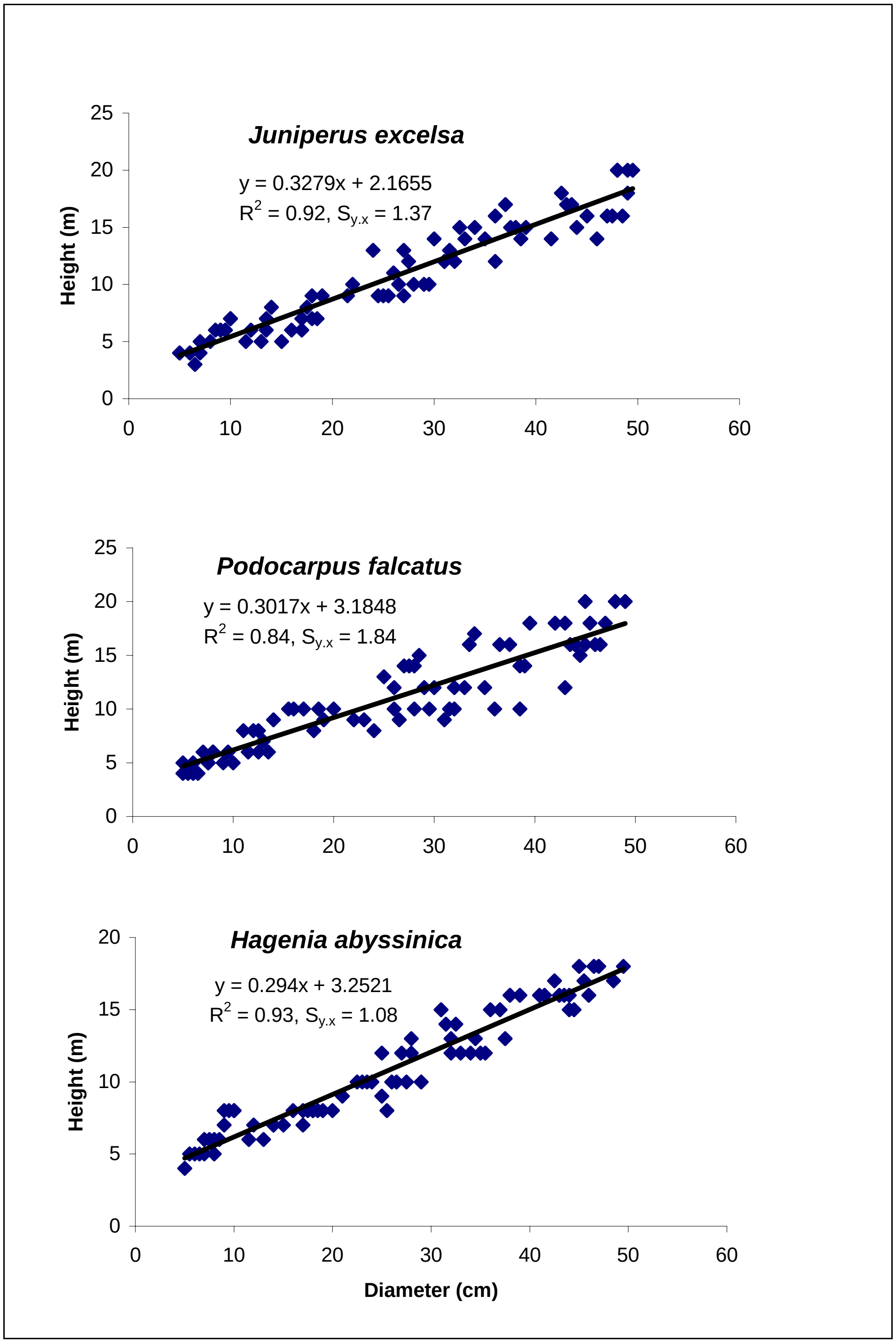

Figure 3.3: The relationship between tree diameter and height

3.3.4 Crown area of the dominant timber species

Stand grown trees of *Juniperus excelsa* and *Hagenia abyssinica* were found to occupy almost the same crown area, with *Podocarpus falcatus* trees occupying the least area (Tab. 3.1).

Table 3.1: Crown area of the three timber species at maturity

TREE SPECIES	DIAMETER CLASS cm	CROWN AREA m^2
Juniperus	40-50	48
Podocarpus	40-50	32
Hagenia	40-50	46

3.3.5 Optimum number of crop trees/ha with and without grazing

The results of the study revealed that 170-210 crop trees/ha could be accommodated in uneven-aged selection forests taking into consideration the grazing needs of the user groups (Tab. 3.2).

Table 3.2: Possible number of crop trees/ha

FOREST FORMATION	ALTITUDE m.a.s.l.	NO. OF CROP TREES/HA		
		Even-aged	Uneven-aged without grazing	Uneven-aged with grazing
Podocarpus-Juniperus	2600-2840	210	420	210
Juniperus + others	2841-3000	185	370	185
Juniperus + *Hagenia* + others	3001-3400	170	340	170

3.3.6 Green crown percent

The three investigated species were found to have different proportions of green crown, with *Juniperus excelsa* having the highest (Tab. 3.3). The figure could be higher for open grown *Juniperus* trees as it forms a short clear bole in the open (Fig. 3.4).

Table 3.3: Crown percent of the three timber species

Species	*Crown percent* %
Juniperus	*65*
Podocarpus	*60*
Hagenia	*45*

Figure 3.4: Young open grown *Juniperus excelsa* tree

3.4 DISCUSSION

3.4.1 The robustness of the developed models for prediction

The crown ratio models were robust, demonstrating a high coefficient of determination and low standard errors of estimate. The strong linear relationship established between tree and crown diameter indicated that tree diameter is a good predictor of crown diameter. For most tree species crown ratio models were generally described by the simple linear models (BECHTOLD 2004, MCELHINNY 1999, KOOP 1989, MINCKLER and GINGRICH 1970 and KRAJICEK *et al*. 1961). It has also been reported that the relationship between tree and crown diameter in well stocked uneven-aged stands was found to be similar to those of open grown trees and was independent of site, crown class and species (MINCKLER and GINGRICH 1970).

The relationship between tree diameter and crown length was also strong even though it was not as robust as the crown ratio models. The standard errors of estimate of the models were relatively high, implying variability of the data points around the regression line. In contrast, very strong and positive relationships were observed between tree diameter and height as revealed by the coefficients of determination of the models. These models were as robust as the crown ratio models. This implies that tree height can be readily estimated from tree diameter within the data set used to establish the models.

In all three different model types, those fitted for *Juniperus excelsa* and *Hagenia abyssinica*, two light-demanding species, were found to be stronger than for the shade-tolerant *Podocarpus falcatus*.

In general, tree diameter explained sufficiently the variation in crown diameter, crown length and height with the linear model. The fact that the coefficient of determination value was greater than 0.50 for all the linear models established between the parameters demonstrates that there were strong linear relationships between the parameters investigated. This reveals that it is possible to predict these parameters from tree diameter, which is easily measured in the forest. This in turn saves greatly in terms of the costs and the time invested in ground-based forest monitoring.

However, it should be noted that the models were developed for trees between 2-50 cm diameter. This implies on the one hand that the shape and type of the models used may not necessarily be the same when biologically attainable growth is considered. On the other hand, there is a need to adapt the models if they are to be used for extrapolation purposes such as in existing old growth forests, which consist of trees with larger diameter than the data set used to establish the models.

3.4.2 Crown area of the dominant timber species

The two light demanding species, *Juniperus excelsa* and *Hagenia abyssinica*, occupied similar crown areas. POORTER and WERGER (1999) also found that the saplings of light demanding species had similar crown areas and deeper crowns when compared to shade tolerant species. Moreover, *Juniperus excelsa* and *Hagenia abyssinica* trees have a higher crown area than the shade tolerant *Podocarpus falcatus*. This contradicts previous studies, which reported that shade tolerant species have deeper and wider crowns than light demanding species (VERWEIJ 2004). This can be explained by the history of selective logging, which left the investigated stands relatively open so that competition for light was not as intensive as in closed forests, except in few inaccessible areas. The prevailing tree cover in the investigated stands was estimated to be 50 %. The openness of the forest canopy might have prompted the light demanding species to invest more biomass in lateral crown expansion to maximise light interception than in height growth.

3.4.3 Optimum number of crop trees taking into account forest grazing

3.4.3.1 Method of determination

The determination of the optimum number of crop trees in an uneven-aged mixed stand is not a simple task, particularly in a situation where relevant information about the respective species is lacking. The approach used in this study does not provide information about the number of trees in the different age classes, rather it gives only the number of crop trees at a final stand in an uneven-aged situation. An alternative to this approach is the method of allocating growing space to age classes based on diameter class transition time and projected crown area (MCELHINNY 1999). Transition time is the time required for stems to grow through a particular diameter class. The transition time method allows for the allocation of each diameter class with an optimum area while the projected crown area helps to determine the optimum number of trees that could be accommodated within the area allocated to each diameter class. As information pertaining to the growth rates of the species studied is lacking, the transition time required by trees to grow through each diameter classes was unknown. Therefore, it was not possible to apply this alternative method in this study although information about the crown area of the species was available.

3.4.3.2 Optimum number of crop trees

The results of the study indicated that about 170-210 crop trees/ha could be maintained in the Adaba-Dodola forest considering the grazing service of the forests. It is assumed that this number of trees/ha will ensure the maintenance of a relatively open forest canopy with adequate pasture on the forest floor.

BAPTIST *et al*. (2001) reported dry matter fodder production of 2 t/ha/year in wooded pasture in the study area. However, the tree density of wooded pastures was not recorded. As the quantity and quality of undergrowth depends on the density of the forest stand and the canopy openness associated with the tree species, the influence of the recommended number of trees/ha on the undergrowth should be monitored and adapted from field observations.

3.4.4 The need for pruning

The green crown percent is a good index to guide pruning and thinning interventions (SMITH *et al*. 1997 and DANIEL *et al*. 1979). It is also an index of tree vigour (OLIVER and LARSON 1996), and indicates the extent of branch-free bole. The study results revealed that the two indigenous conifers, *Juniperus excelsa* and *Podocarpus falcatus*, retain a higher green crown percent than *Hagenia abyssinica*. This is in line with the findings of YIRDAW (2002) who reported that *Juniperus excelsa* plantations tend to form dense crowns and short clear bole lengths. In addition to maintaining a long crown, *Juniperus excelsa* is also reported to have a low degree of crown openness (YIRDAW and LUUKKANEN 2001), casting heavy shade and restricting undergrowth. This implies a need for pruning starting in the early stages for both *Juniperus excelsa* and *Podocarpus falcatus*. However, it should be borne in mind that reducing the crown percent to less than 30 % would cause substantial losses in terms of diameter growth (SMITH *et al.* 1997).

Moreover, the relatively open forest condition arising from integration of grazing will enable crop trees to develop larger and deeper crowns, as the lower branches stay alive longer. In such a situation pruning becomes compulsory activity to:

1. produce high quality timber,

2. increase grazing space by removing lower branches,
3. mark the crop trees permanently.

3.5 CONCLUSION

The developed models are promising in terms of predicting crown dimensions and tree height on the basis of the readily measurable tree diameter. With some adaptation the models can be used to evaluate the condition of the existing old growth forests.

Moreover, it is understood that maintaining 170-210 crop trees/ha can be considered as optimum figure taking into account the grazing needs of the user groups. However, the interaction between the proposed tree density and the undergrowth should be closely monitored and adapted if necessary based on field observation and research inputs.

Furthermore, the need for pruning in such open forest condition in order to improve the wood quality of the crop trees and regulate the growing space allocated for grazing was highlighted.

4 DISTRIBUTION OF YOUNG REGROWTH AND MATURE TREES

4.1 INTRODUCTION

Improving the production capacity of degraded forests is of great importance for the user groups whose livelihood is closely linked to the utilisation of these resources. However, the recovery potential of such forests depends on the intensity of past extraction and the availability of young regrowth in the forests. According to ITTO (2002), advanced regeneration of current and potential commercial species is the most crucial target for silvicultural intervention in degraded natural forests. This is because tending the already established regrowth is easier than inducing new natural regrowth or planting seedlings.

To this end, it was necessary to conduct diagnostic inventories to investigate the abundance and distribution of established young regrowth with the potential and quality to form the final stand in the long term. These young trees will be referred to as 'potential crop trees' from this point on. According to LAMPRECHT (1989) potential crop trees are trees of the desirable species that are most vigorous and the best qualitative predisposition.

In the inventories special emphasis was given to the dominant timber species, all of which are greatly threatened as a result of past over-exploitation. Focusing on the management and monitoring of these species is a good indicator for the evaluation of the success or failure of the rehabilitation processes and the sustainable management of the forests later on. The inventory results provide basic information about the abundance and distribution of the potential crop trees and the mature trees, and the need for silvicultural interventions

4.2 MATERIALS AND METHODS

4.2.1 Selection of the sample user group forests

During the time in which this study was initiated there were three villages in the study area, in which 19 user groups were established. Three user group forests were selected for the purposes of this study. The district forest service and the staff of the Adaba-Dodola integrated forest management project were involved in the selection process. The selection was made taking into account the representativeness of the sample forest areas in terms of:

- altitudinal variation,
- time of establishment as a user group forest,
- forest area per user household,
- livestock density in tropical livestock units,
- access to local markets.

Additionally, the accessibility of the sample forests to be used as demonstration centres for the testing, implementing and monitoring of the proposed silvicultural treatments was considered.

As there is strong inclination on the part of the user groups to follow their respective village lines, the sample forest areas were selected in such a way that they represented the three villages. Accordingly, the forest areas attended by the Jaldo, Gede and Changiti user groups were selected from the villages of Bura-adelle, Deneba and Berisa respectively to serve as case studies for this research (Fig. 4.1).

The features of the selected forest areas are described in Tab. 4.1. The lower edges of the three selected forest areas are almost at the same altitude. However, the uppermost limit of the forest areas slightly varies from one to another. With respect to time of establishment as a user group forest, the three forest areas vary amongst one another by a period of one year.

Changiti forest had the highest forest area per user household followed by Jaldo and Gede forests whereas the reverse order is true in terms of livestock density. This indicates that pressure on the forest area attended to by the Gede user groups was high compared to the other two. This is simply because of irregularities in settlement patterns in the forests. However, it is important to note that the carrying capacity of the forests in the study area was determined to be 12 hectares per household (UNCOVSKY 1998). This means that the number of user households did not exceed the carrying capacity threshold in all the three selected forests. In terms of access to local markets, Changiti forest was the most accessible followed by Gede and Jaldo forests.

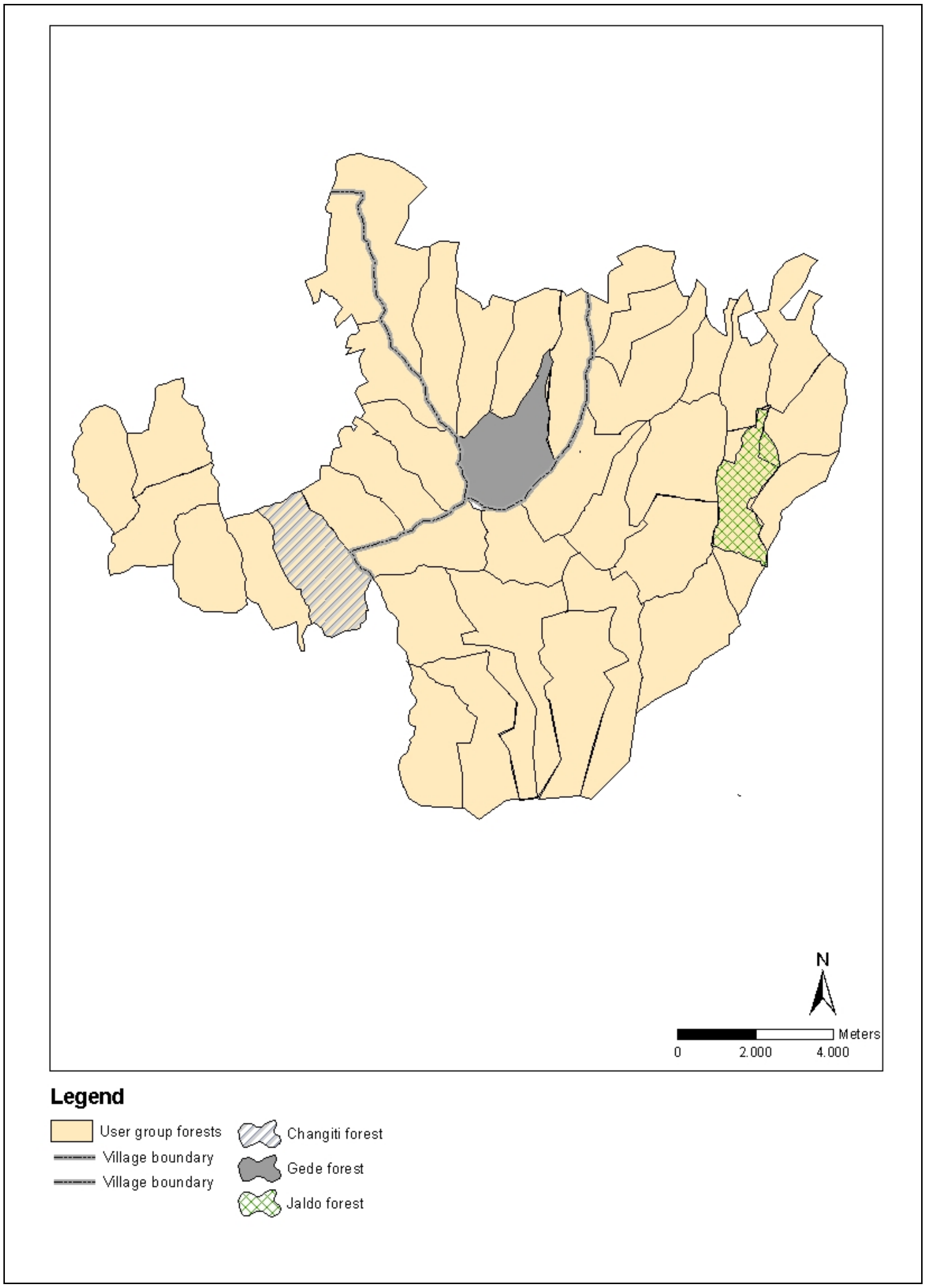

Figure 4.1: Map of the study area and location of the sample user group forests

Table 4.1: Description of the sample forest areas (SCHMITT 2003 and IFMP database)

FEATURES	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Altitude	m.a.s.l.	2600-3200	2600-3300	2600-3400
Time of establishment	year	2002	2001	2000
Size of the forest area	ha	364	554	489
Forest area per household	ha	18	31	17
Livestock density/ha	tlu	0.4	0.3	0.6
Distance from Dodola (major local market)	km	20	10	15

4.2.2 Local classification of tree species

The different tree species occurring in the forests were classified based on the diameter that can be attained at maturity. As there is no adequate information about the rotation age and growth rate of the species, the classification was made based on personal observations, discussion with members of the user groups and local experts who have local knowledge of the species. This classification should be improved through long-term monitoring and research inputs. Based on the local classifications the species were categorised according to two groups:

Group 1 species: attaining a diameter of $\geq$ 40 cm at maturity

This category included the major timber species used mainly for the production of lumber and construction materials (Tab. 4.2). From personal observation it was known that species like *Juniperus excelsa* and *Podocarpus falcatus* tend to form heavy spiral grain above this diameter. From discussions with members of the user groups it was also understood that they prefer medium sized trees to oversized ones. This is because of difficulties in felling, processing and transporting timber of larger dimensions. The slow growing nature of the species also discourages users from waiting for trees to attain bigger dimension.

Group 2 species: attaining a diameter of ≥ 25 cm at maturity

Most of the species in this group are currently not used for lumber production. They are used as firewood, charcoal, local construction materials and in the production of farm implements. According to the members of the user groups it made no sense to wait for the species in this group to attain larger sizes as they are not used for lumber production.

Table 4.2: Local classification of tree species based on diameter at maturity

GROUP	DIAMETER AT MATURITY cm	TREE SPECIES
1	≥ 40	*Juniperus excelsa, Podocarpus falcatus Hagenia abyssinica, Ekebergia capensis, Scheffleria abyssinica, Olea europea sbsp. africana* and *Mytenus species*
2	≥ 25	*Hypericum lanceolatum, Rapanea melanphloeos, Nuxia congesta, Buddleya polystachia, Erica arborea, Pittosporum viridiflorum* and others

4.2.3 Inventory of potential crop and mature trees

Information about the composition and structure of the forest are indispensable for the planning and implementation of silvicultural improvement treatments. To generate this information inventories were conducted in the three selected forests.

4.2.3.1 Criteria for the selection of potential crop trees

Potential crop trees were selected from young regrowth in the forests on the basis of quality and vitality. The quality of the young regrowth selected as potential crop trees should be good enough to justify further management. However, in the case of the investigated forests, which are very degraded, it is not reasonable to set high quality standards.

At the initial stage, the existing healthy young trees should be accepted as they offer the only chance to renew the forests, unless good quality regrowth is established by planting. Moreover, the quality criteria can be improved in the long run. Therefore, in the context of this study the following selection criteria were used to identify the potential crop trees:

- Healthy young trees without damage to the main stem.

- > 2 m in height for both group 1 and 2 species, based on the assumption that they are above the reach of the animals and will escape further browsing damage.
- < 40 cm and < 25 cm diameter for group 1 and 2 species respectively, based on the assumption that any management intervention aimed at trees above this size may not have a significant impact on improving the quality of the trees.
- No forking above breast height. If there is forking below breast height the best shoot will be selected.
- In case of patches of regrowth, the minimum distance between the selected trees should be 4 m.

4.2.3.2 Defining potential crop tree classes

Potential crop tree classes were defined based on the abundance and distribution of potential crop trees in the forests. The reason for this is that future interventions focus on the tending and promotion of these trees to improve the production potential of the forests. As discussed in chapter 3, the optimum number of crop trees that can be accommodated in a selection forest type taking into consideration the grazing needs of the user groups was found to be 170-210 per hectare. Details of the selection system and associated management interventions will be provided in chapter 5.

Based on the optimum number of crop trees referred to above, the presence of at least 10 % (i.e. 20 potential crop trees per hectare) of the total at the initial stage was regarded as sufficient to start the transformation process. The same number of potential crop trees is of course expected in the coming decades. For future management interventions three potential crop tree classes were defined (Tab. 4.3).

Table 4.3: Potential crop tree classes

POTENTIAL CROP TREE CLASS	POTENTIAL CROP TREES no./ha
Sufficient	≥ 20
Moderate	5-15
Deficient	0

The per hectare values of the potential crop trees were obtained by multiplying values per plot by 5, as a sampling intensity of 20 % is used in the forest inventory (compare chapter 4.2.3.4). As a result, all per hectare values are a multiple of 5. This created a gap between potential crop tree classes even though there are no omitted values.

4.2.3.3 Quality criteria for mature trees

Quality class criteria for mature trees belonging to the important timber species were developed together with the members of the user groups based on suitability for lumber production (Tab. 4.4).

Table 4.4: Quality classes for standing mature trees of timber species

QUALITY CLASS	DESCRIPTION
1	-Straight and cylindrical stem, -branch-free bole up to 4 m height, -no damage to the main stem.
2	-Slight twist on the main stem, -some part of the stem usable for lumber.
3	-Not suitable for lumber production.

With the help of these criteria the status of the standing mature trees in the forests was assessed.

4.2.3.4 Inventory design

A systematic sampling technique was applied to assess the abundance and distribution of potential crop trees and mature trees in the three selected forests.

The following procedures were used to establish the sample plots:

- Overlaying of a 100 x 100 m grid net across the entire forest area **(**Fig. 4.2), which implies one plot per hectare.
- Establishing sample plots with the size of 2000 m^2 (r = 25.23 m) around each intersection on the grid net, the equivalent of 20 % of a hectare. GPS

(geographic positioning systems) and a handheld compass were used to locate the plot centres.

- From the centre point, using a string with the length of the plot radius, the sample plot was fixed. In plots located on slopes the Vertex distance meter was used to correct the slope distance.

4.2.3.5 Data collection

Within each of the sample plots defined in section 3.2.3.4 the following information was collected:

- Number and species of potential crop and mature trees,
- diameter at breast height for both potential crop and mature trees measured with a diameter tape,
- quality class of the mature trees of the timber species.

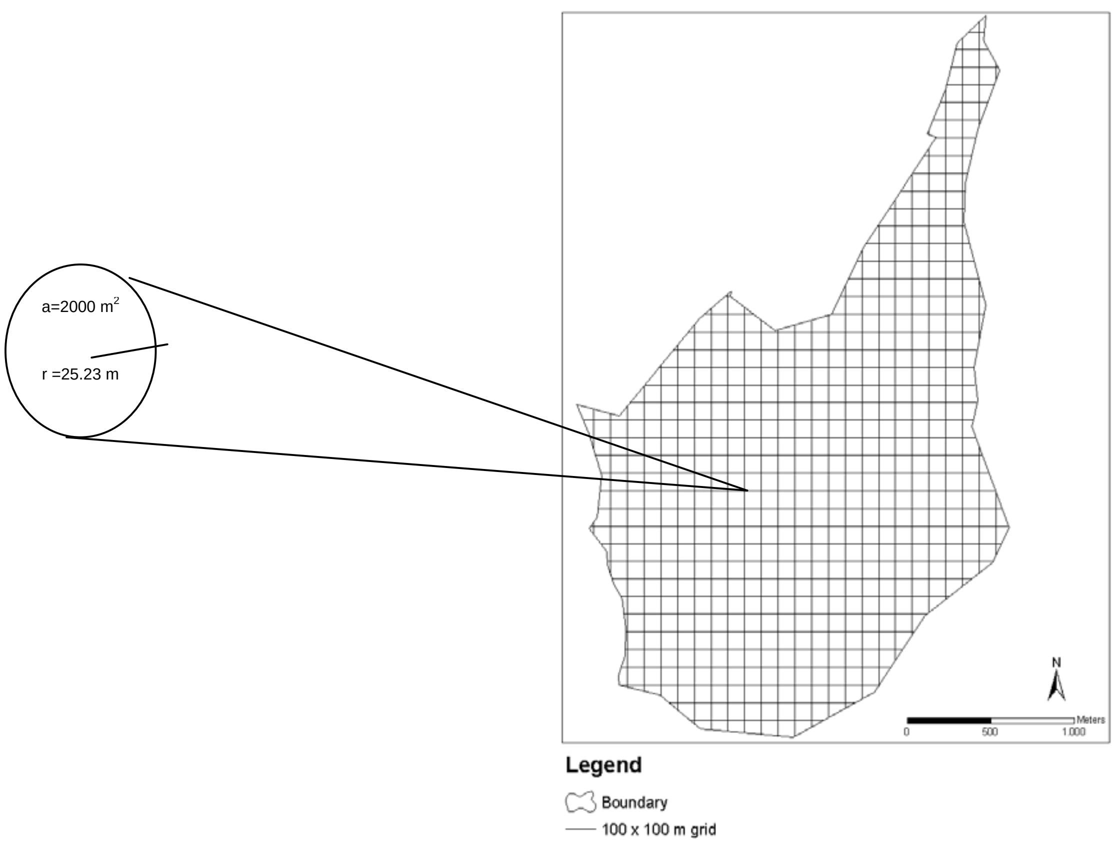

Figure 4.2: Layout of sample plots in Gede forest

4.2.4 Data analysis

4.2.4.1 Descriptive analysis

The data collected were first tabulated and analysed using descriptive statistical tools. The descriptive analysis showed that the distribution of the number of potential crop and mature trees as well as their respective basal areas is positively skewed. Even after transforming the original data set using the commonly used log (x) and square root (x) methods it was not possible to satisfy the assumptions of the normal distribution. In such a data set, the sample mean and related statistical measures may not appear representative. However, they are used in this study, as they are still better suited to presenting the data obtained for the investigated forests than the statistical measures used for skewed data.

4.2.4.2 Spatial analysis

To complement the results from the descriptive analysis, the spatial distribution of the potential crop and mature trees was analysed using ArcView GIS software. In particular, the spatial distribution of potential crop tree classes and of the three timber species was analysed, according to altitude, settlement patterns and rivers. The altitudinal classes employed for this analysis followed the prevailing forest formation in the forest areas, which is described in Tab. 2.1. However, due to the different range of occurrence of the forest formations, the widths of the altitudinal classes are not the same.

The species mixtures of the potential crop trees along the altitudinal gradient were also analysed using the same software. The proportion of a particular species in a given altitude class was computed as follows:

$$\text{Proportion of species `X` (\%)} = \frac{\text{no. of individuals of the species}}{\text{total number of individuals of all species}} \times 100$$

4.3 RESULTS

4.3.1 Potential crop trees

4.3.1.1 Abundance of potential crop trees

The difference in the number of plots between the forest areas is due to their differences in size (compare Tab. 4.1). Although the inventory was so designed that there would be one plot per hectare, the number of plots measured in each forest area does not equate precisely to the size of the forest area. The reason for this is that plots with a radius exceeding the distance to the forest boundary were excluded.

The inventory results showed that there are an average of 13-21 potential crop trees/ha in the studied forest areas (Tab. 4.5). The coefficient of variation of the sample means was > 100 % for the three forest areas reflecting a high degree of variation between the plots. The difference in the abundance of potential crop trees in the three forests corresponds to the prevailing pressure both in terms of user households and livestock densities (compare Tab. 4.1).

Table 4.5: Summary of the potential crop tree (pct) statistics

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Number of plots	no.	318	491	480
Mean Coefficient of variation	no./ha %	18 ± 122	21 ± 114	13 ± 138
Median	no./ha	10	10	5
Mode	no./ha	0	0	0
Minimum	no./ha	0	0	0
Maximum	no./ha	120	160	130
Standard error	no.	1.2	1.1	0.8
Sampling error ($p < 0.05$)	%	14	10	12

In all three forest areas the median value is lower than the average, showing that the sample distribution is positively skewed. This is because of the high frequency of empty plots as reflected by the mode. Additionally, a wide range is observed between the minimum and maximum values.

However, the standard error of the sample means seems reasonable. The standard error is an estimate of the standard deviation of the sampling distribution of the sample means. It reflects the amount of variation that occurs between the sample means. Whereas sampling error is an error that arises because the data are collected from only a portion of the population rather than the entire population. It explains the difference between the sample mean derived from the sample and the true value. Although the sampling was intensive, measuring 20 % of each forest area, the sampling errors are still high.

Abundance of potential crop trees according to species

The abundance of tree species is described as follows:

- *Juniperus excelsa* was found to be the most abundant species in all three investigated forest areas (Fig. 4.3). The level of abundance of *Juniperus* also showed a degree of similarity in two of the three forest areas.
- *Podocarpus* was the second most important species in Jaldo forest, but declined in abundance in the remaining two forest areas.
- Potential crop trees of *Hagenia* were found to be rare across the forest areas.
- The abundance of the group of other species, consisting mainly of *Rapanea melanphloeos* and *Hypericum lanceolatum*, was found to be similar in two forest areas, and was as abundant as *Juniperus* in Gede forest.

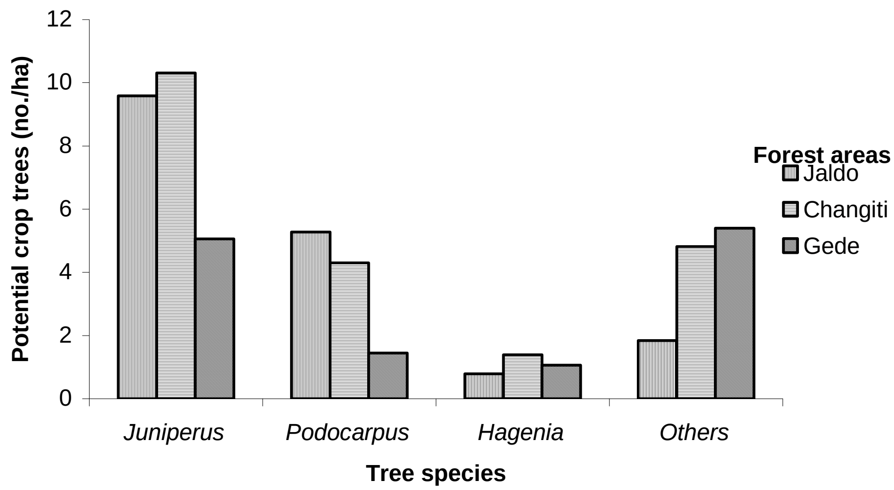

Figure 4.3: Species distribution of the potential crop trees in the three forests

4.3.1.2 Diameter distribution of the potential crop trees

When all of the recorded species are combined the diameter distribution of the potential crop trees showed a reversed-J distribution only in Changiti forest (Tab. 4.4). In this forest area the majority of the potential crop trees were in the lowest diameter class whereas the intermediate classes were not well represented. In the remaining two forests, on the contrary, there was a good representation of potential crop trees in the intermediate classes. However, the difference between the size classes is quite small.

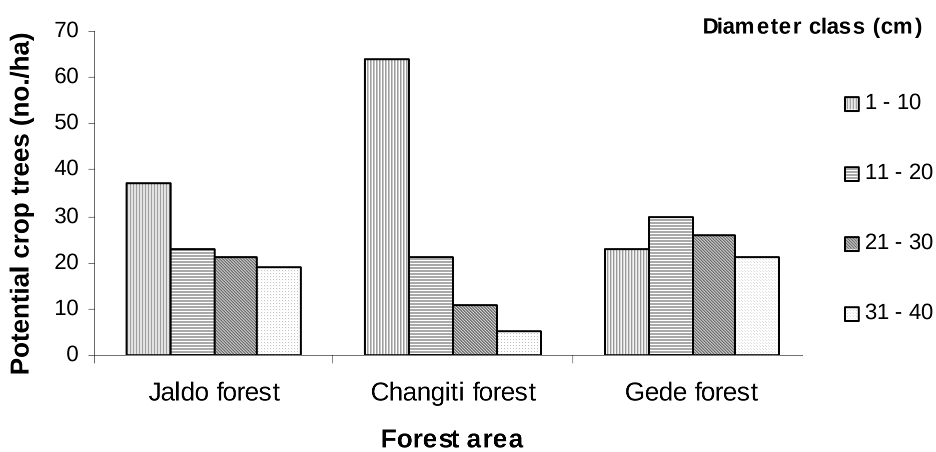

Figure 4.4: Diameter distribution of the potential crop trees in each forest area

Diameter distribution of the tree species

The diameter distribution of each tree species is described as follows:

- *Juniperus excelsa* followed a reverse-J distribution in only one forest area, with a high proportion of individuals in the lowest size class (Fig. 4.5). In contrast, in the other two forests, the intermediate size classes were well represented whereas the proportion within the lower classes was low.
- *Podocarpus falcatus* followed a reverse-J distribution in all three of the forests, although the shape of the curve varied amongst the forest areas. Between 50-75 % of the individuals were in the lowest size class.
- The distribution of *Hagenia abyssinica*, on the contrary, was very irregular in the three forest areas. In Jaldo forest there was a lower proportion of individuals in the intermediate classes while the upper two classes were almost entirely absent in Changiti forest. In Gede forest it followed a J-shape distribution.
- In the case of the other species, individuals in the 30-40 cm diameter class were lacking in all three of the forest areas. This is because most of the species in this group reach maturity at 25 cm diameter (compare Tab. 4.2) and individuals above this size were not recorded as potential crop trees.

4.3.1.3 Spatial distribution of the potential crop trees

The existence of a high degree of variation between the plots in the investigated forests, which is described in Tab. 4.5 above, was also confirmed by the results of the GIS analysis. The spatial distribution of the potential crop trees was not homogenous across the entire forest area (Fig. 4.6). The distribution showed variation according to altitude, location of the settlements and rivers.

Spatial distribution as a factor of altitude

The spatial distribution of the potential crop trees revealed variation along the altitudinal gradient (Tab. 4.6).

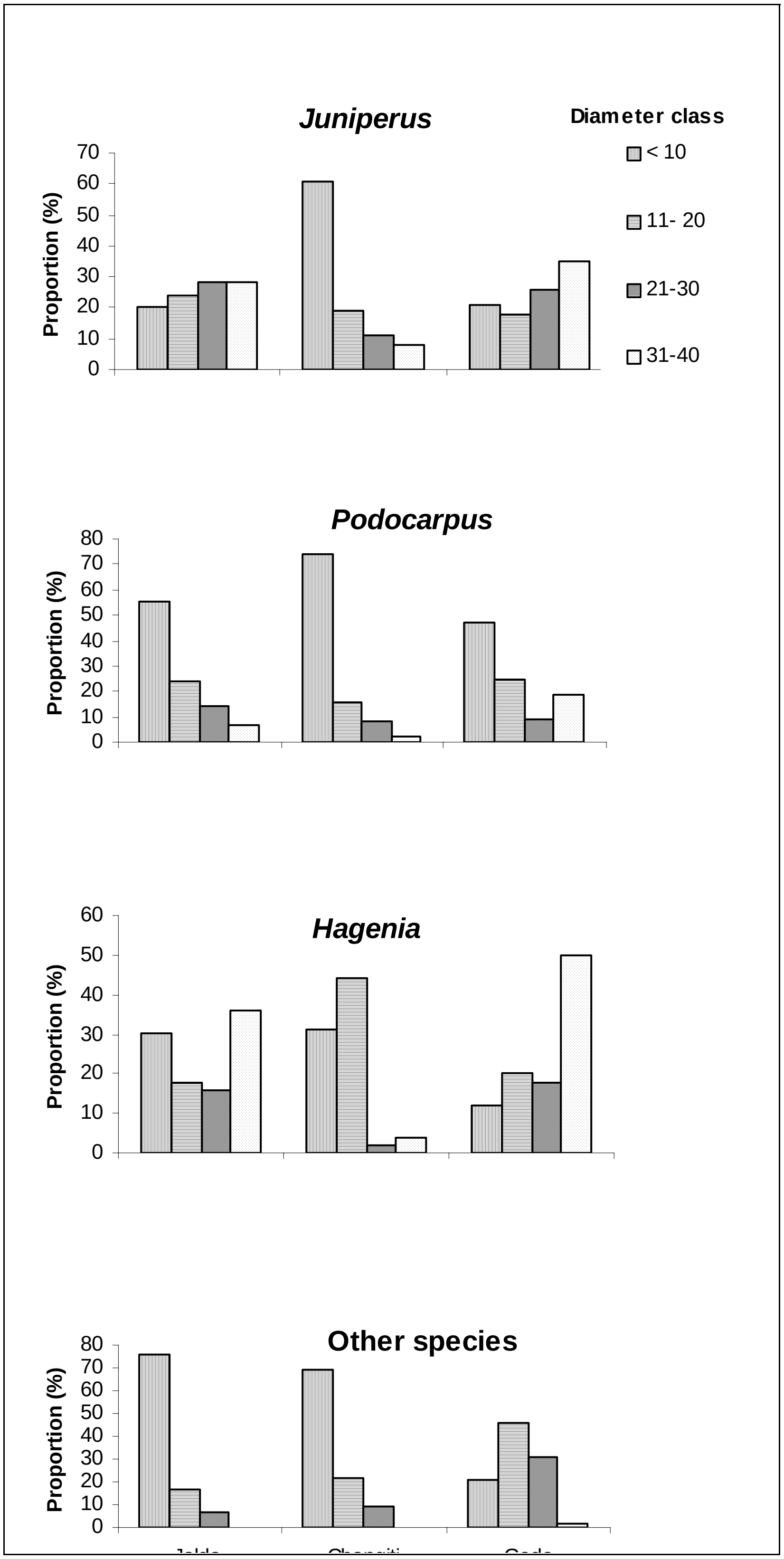

Figure 4.5: Diameter distribution of the potential crop trees according to tree species

Table 4.6: Proportion of potential crop tree classes (%) along the altitudinal gradient

ALTITUDE m.a.s.l.	FOREST AREA								
	JALDO			CHANGITI			GEDE		
	≥ 20	5-15	0	≥ 20	5-15	0	≥ 20	5-15	0
2600-2840	44	20	36	50	14	36	57	29	14
2840-3000	38	34	28	54	25	21	32	35	33
3000-3400	23	40	37	30	33	37	26	32	42

In all three forests the proportion of areas where there were sufficient numbers of potential crop trees/ha (≥ 20) decreased by half from the lower altitudes to the higher altitudes. Conversely, the proportion of areas with moderate numbers of potential crop trees/ha (5-15) increased from the lower to the higher altitudes except for in Gede forest. The upper zone revealed the highest proportion of areas with no potential crop trees. This may reflect the poor establishment of species like *Hagenia abyssinica*, which naturally occur at this altitude.

Spatial distribution as a factor of the location of settlements and rivers

The patchy distribution patterns of the potential crop trees in the investigated forests might be the result of the fragmented land uses, as settlements, open pastures and farm plots are very scattered in the forests. Open pastures and farm plots are usually associated with settlements. As can be observed from Fig. 4.6, the areas around settlements bore no or only few potential crop trees. This can be attributed to the impact of grazing, as livestock tend to remain around the settlement longer than anywhere else, but even then the impact of grazing was not evenly distributed around the settlements. The situation at the northern tip of Changiti forest (Fig. 4.6) is a good example of this. Here the right side of the settlement was devoid of potential crop trees whereas to the left there was a high density of potential crop trees nearby. This was due, on the one hand, to the terrain features, with the forest dwellers mostly establishing their settlements at the foot of the hill. Consequently, livestock tended to graze downhill than uphill. On the other hand, the location of water points also influences the spatial distribution of grazing pressure. Although it appears as if there were a lot of rivers in the investigated forests, livestock can only access them at certain points because of terrain features. As a result, these areas closer to the water points, which were usually also close to the settlements, were heavily grazed because of frequent passing of livestock.

4.3.1.4 Species mixture of the potential crop trees along altitudinal gradients

The species mixtures of the potential crop trees showed variation with altitude (Tab.4.7). The proportion of the three timber species decreased from about 90 % at the lower altitudes to 60 % at the upper altitudes. Moreover, the two indigenous conifers *Juniperus excelsa* and *Podocarpus falcatus* accounted for about 85 % of the number of potential crop trees/ha at the lower altitudes, whereas their proportions decreased with a rise in altitude. Conversely, the proportion of the other species increased from the lower to the upper altitudes.

Table 4.7: Species mixtures of potential crop trees along altitudinal gradients

ALTITUDE m.a.s.l.	TREE SPECIES				
	JUNIPERUS %	*PODOCARPUS* %	*HAGENIA* %	**SUM** %	OTHERS %
2600-2840	*40*	*46*	*2*	***88***	*12*
2841-3000	*53*	*20*	*6*	***79***	*21*
3001-3400	*48*	*2*	*11*	***61***	*39*

In terms of species, *Juniperus excelsa* was the most abundant species, accounting for about 50 % of the potential crop trees counted at all three altitudinal ranges. The proportion of *Podocarpus falcatus* decreased from the lower to the upper altitudes. The reverse was true for *Hagenia abyssinica*.

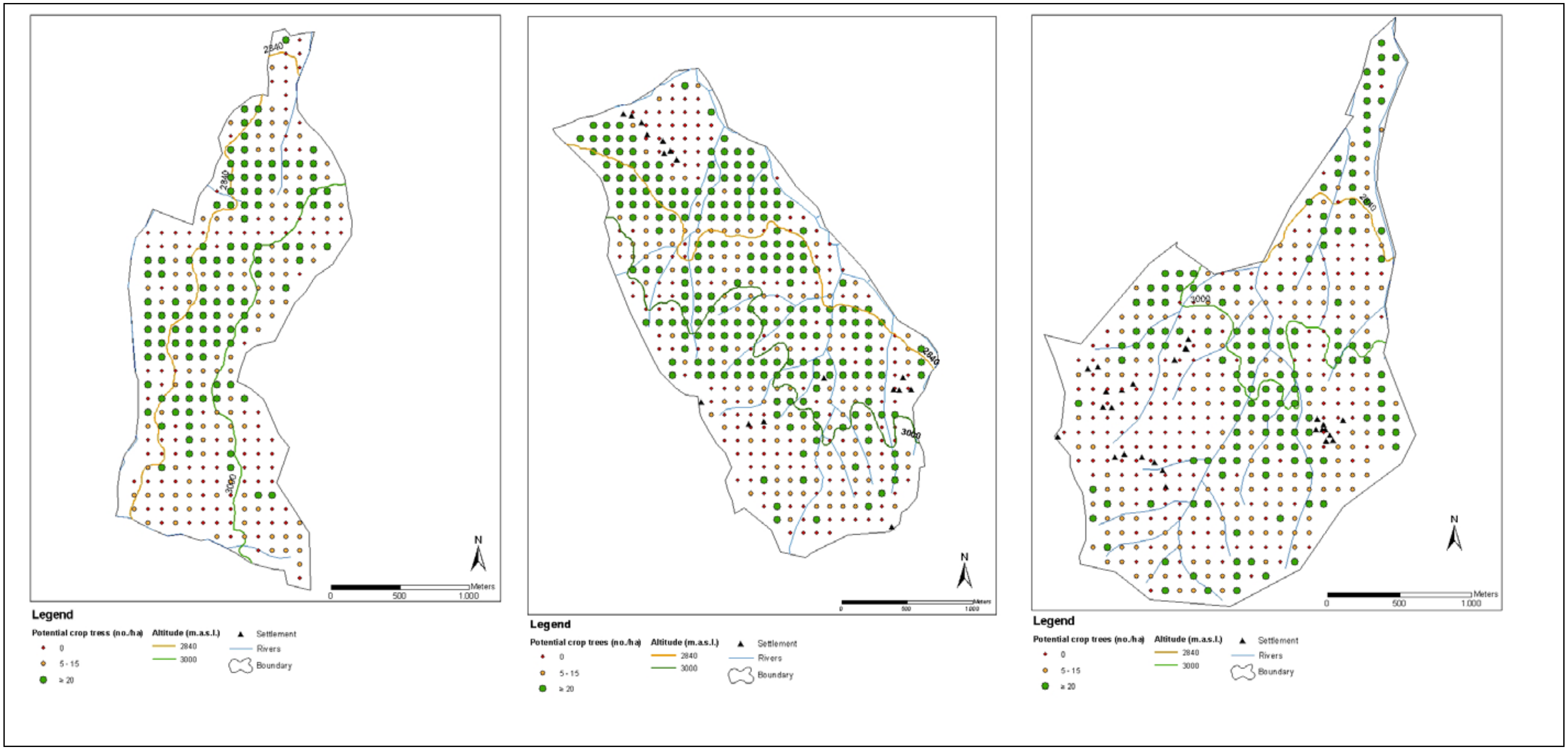

Figure 4.6: Spatial distribution of potential crop trees in the investigated forests (from left to right: Jaldo, Changiti and Gede forests)

The spatial distribution of the three timber species also showed different patterns according to altitude, and location in relation to settlements and rivers:

- *Juniperus excelsa*

The potential crop trees of *Juniperus* were found to have a wide range of occurrence (Fig. 4.7). However, it showed a patchy distribution, with small groups scattered in the forests. At the lower and middle altitudes it occurs close to the settlements whereas it rarely occurs close to the settlements at the upper altitude. No clear pattern was observed with respect to the occurrence of the species in relation to rivers.

- *Podocarpus falcatus*

Podocarpus occurred in a narrow range, mainly at the lower altitude and the lower part of the middle altitude (Fig. 4.8). Remarkably, it also occurred in a few plots of the upper zone in Jaldo forest. Within its range the abundance of potential crop trees is quite reasonable, with potential crop trees also found close to the settlements.

- *Hagenia abyssinica*

Potential crop trees of *Hagenia* are quite rare (Fig. 4.9) and were hardly ever observed close to the settlements, which was attributed to its susceptibility to browsing. Where it occurs it is associated with steep riverbanks, valleys and inaccessible areas with dense shrub cover. From all the three forest areas, it was observed most abundantly in one localised area in Changiti forest. Field observation and discussions with members of the user groups revealed that this particular area had been burned over before it regenerated.

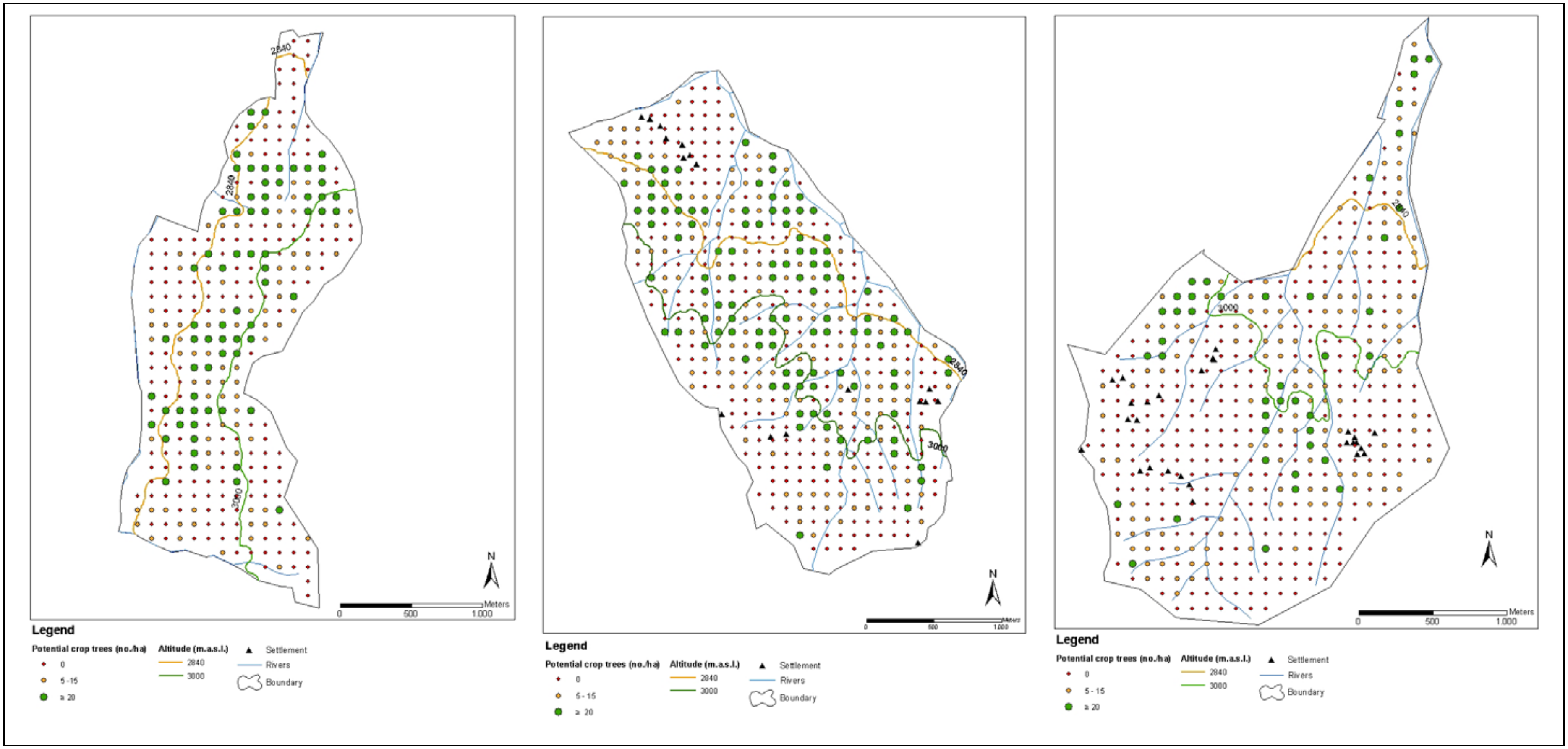

Figure 4.7: Spatial distribution of *Juniperus* potential crop trees in the investigated forests (from left to right: Jaldo, Changiti and Gede forests)

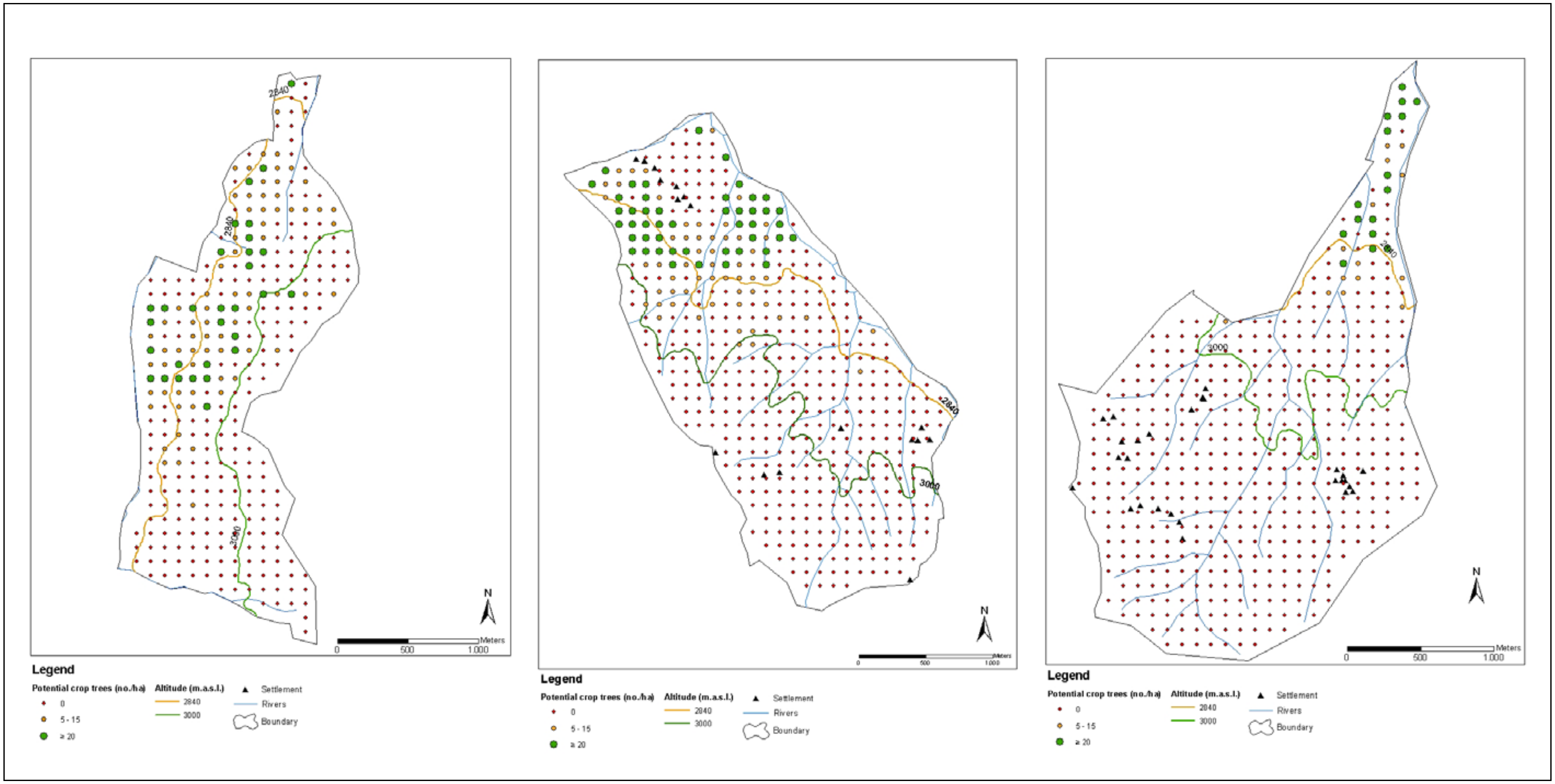

Figure 4.8: Spatial distribution of *Podocarpus* potential crop trees in the investigated forests (from left to right: Jaldo, Changiti and Gede forests)

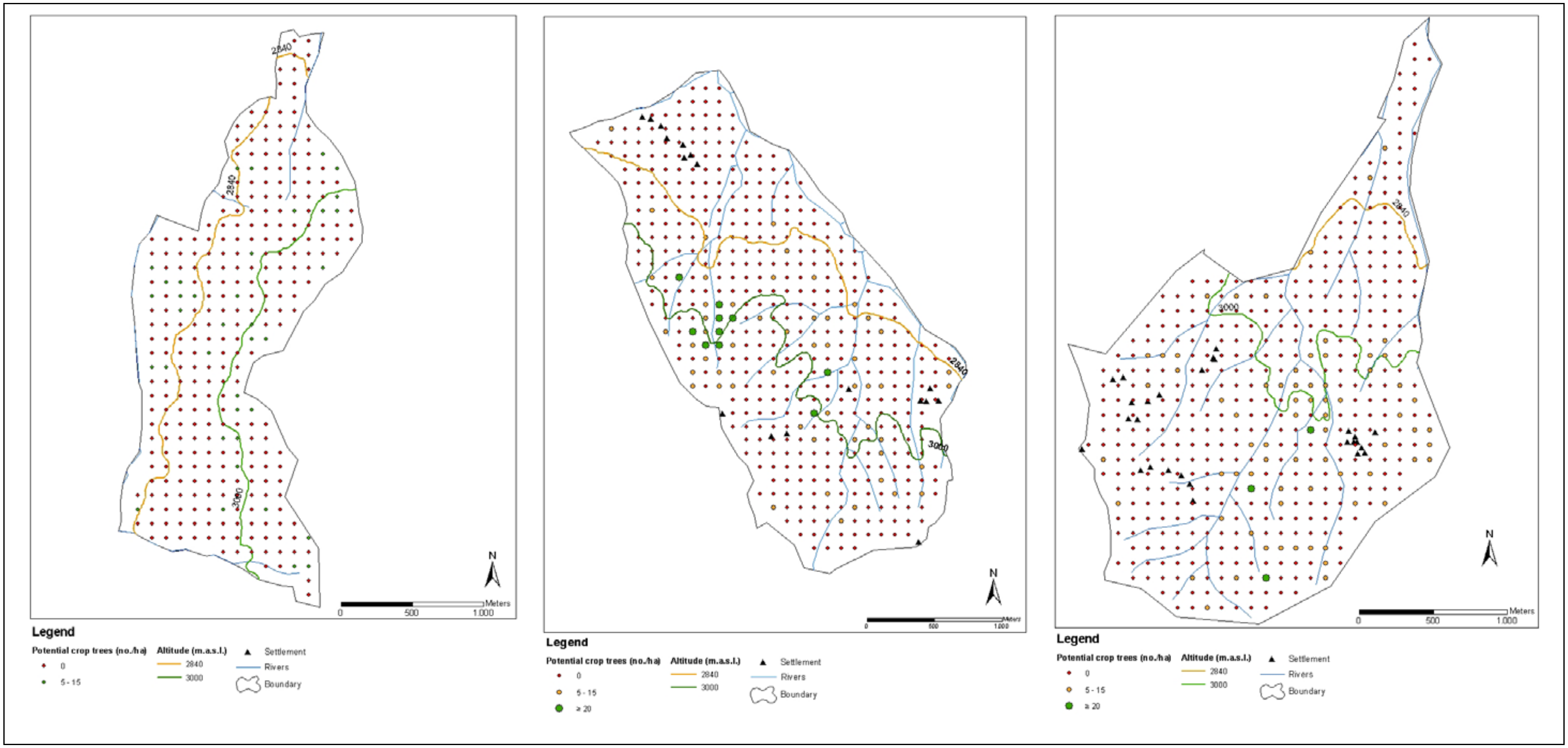

Figure 4.9: Spatial distribution of *Hagenia* potential crop trees in the investigated forests (from left to right: Jaldo, Changiti and Gede forests)

4.3.2 Mature trees

4.3.2.1 Abundance of mature trees

The inventory results showed that there are an average of about 37-41 mature trees/ha in the studied forest areas (Tab. 4.8). There is a minor difference in the abundance of mature trees amongst the investigated forest areas.

Table 4.8: Summary statistics of abundance of mature trees/ha

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Number of plots	no.	318	491	480
Mean Coefficient of variation	no./ha %	41 ± 59	39 ± 80	37 ± 70
Median	no./ha	40	35	35
Mode	no./ha	35	0	0
Minimum	no./ha	0	0	0
Maximum	no./ha	150	150	140
Standard error	no.	1.3	1.4	1.2
Sampling error (p <0.05)	%	6	7	6

Unlike in the case of the potential crop trees, the coefficient of variation of the sample means is 60-80 % for the three forest areas, reflecting less variation between the plots. The median values are slightly lower than the mean showing that the sample distribution is positively skewed. There was a high frequency of empty plots in Changiti and Gede forests, as reflected by the mode. Similar to findings for the potential crop trees, there is a wide range between the minimum and maximum values. However, the standard error and the sampling error of the sample means are acceptable. This is due to more or less uniform distribution of old and over mature trees across the entire forest areas (compare Fig. 4.10).

4.3.2.2 Spatial distribution of mature trees

The results of the GIS analysis confirmed the existence of less variation amongst the plots with respect to spatial distribution of mature trees in the investigated forests, which was already presented in Tab. 4.8. The mature trees were more or less uniformly distributed over the entire forest areas in contrast to the potential crop trees (Fig. 4.10). This is because trees of poor quality were seldom removed during past illegal logging activities, irrespective of their location within the forests. There is also a tradition of leaving scattered trees standing around settlements, as well as on farm plots and open pastures. Consequently, the spatial distribution of mature trees didn't show a clear trend with respect to altitude, or the location of settlements and rivers.

Abundance of mature trees according to species

The abundance of mature trees in terms of tree species is described as follows:

- *Juniperus excelsa* was found to be the most abundant species in the three forest areas (Fig 4.11). It accounted for 83 %, 85 % and 61 % of the total number of mature trees in Jaldo, Changiti and Gede forests respectively.
- The mature *Podocarpus falcatus* trees were very rare in the forests, in contrast to its good representation amongst the potential crop trees.
- The abundance of mature *Hagenia abyssinica* trees was better than was reflected in the number of potential crop trees. However, most of the remaining trees were over-sized and of very poor quality.
- The abundance of mature trees of other species in the forests was low. This was because most of the species in this group, which were classified as group 2 (compare Tab. 4.2), attain smaller sizes at maturity than the timber species. According to criteria developed to identify potential crop and mature trees, individuals < 25 cm in diameter and of poor quality were neither regarded as potential crop nor mature trees. This resulted in a low representation of these species in the inventory results.

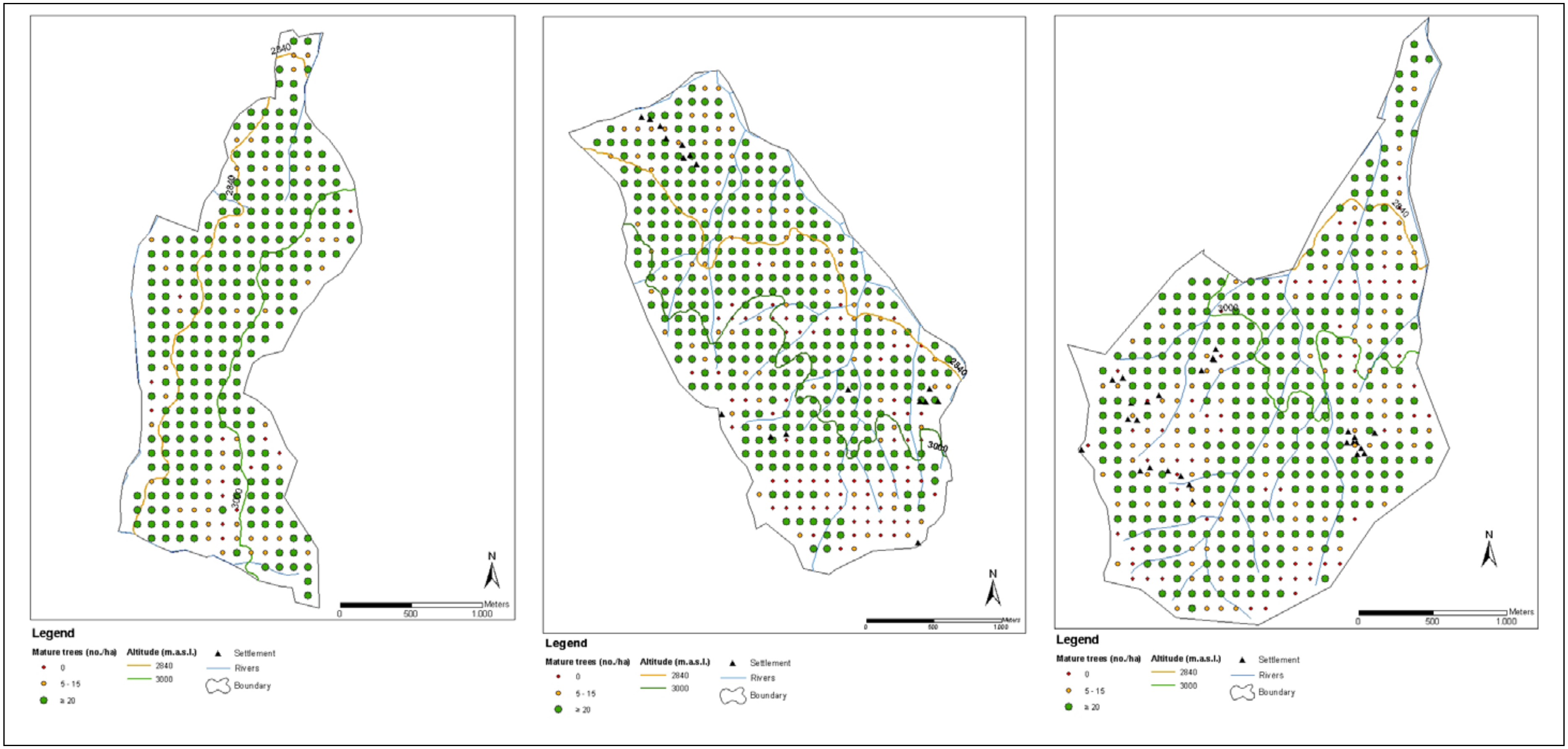

Figure 4.10: Spatial distribution of mature trees in the investigated forests (from left to right: Jaldo, Changiti and Gede forests)

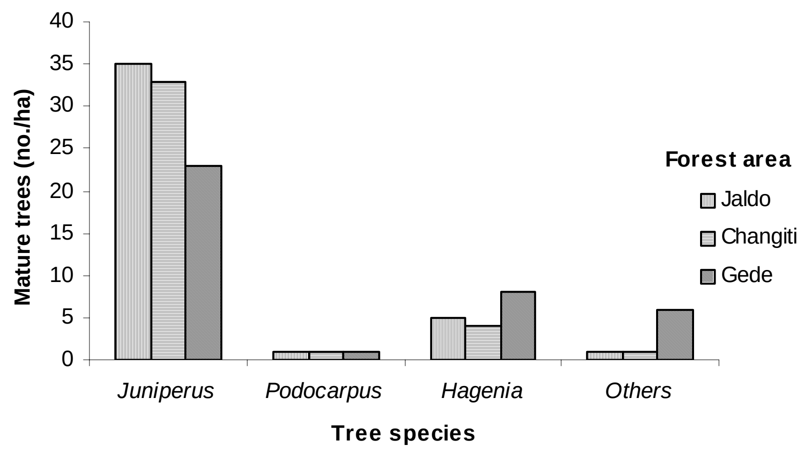

Figure 4.11: Species distribution of the mature trees in the three forest areas

4.3.2.3 Basal area

In terms of basal area, *Juniperus* accounted for about 70-80 % of the totals in the investigated forests (Tab. 4.9). This reflects the dominance of the species within these forests. However, poor quality and over-sized trees contributed the great majority. The contribution of *Podocarpus* to the basal area was very small, in line with its low number of mature individuals in the forests. Unlike *Podocarpus*, *Hagenia* contributed up to 25 % of the basal area due to the presence of poor quality and over-sized individuals. The contribution of other species was insignificant due to the lack of mature individuals as described earlier.

Table 4.9: Basal area and proportion of tree species

BASAL AREA AND SPECIES PROPORTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Basal area	m^2/ha	22	29	22
Juniperus	%	81	82	71
Podocarpus	%	3	5	1
Hagenia	%	16	13	25
Others	%	---	---	---

4.3.2.4 Quality class distribution of the mature trees

The study results showed that the majority of the available mature trees of the three timber species were in the quality class 2 (Fig. 4.12). From this result it is not difficult to conclude that class 1 trees were already extracted during the earlier illegal loggings.

Quality distribution according to tree species

The quality class distribution of the tree species is described as follows:

- As mentioned earlier, *Juniperus* was the most dominant species in the forests. However, most mature trees belonged to the second quality class.
- In the case of *Podocarpus* it was observed that mature individuals were absent generally, irrespective of quality class.
- *Hagenia* also accounted for a low number of mature individuals. Of those sampled, individuals of the best quality were very rare in the forests compared to those of the second and third quality classes.

4.3.3 Proportion of potential crop tree classes

The survey of the potential crop trees revealed that > 30-45 % of the total areas of the investigated forests possessed sufficient numbers of potential crop trees/ha. (Fig. 4.13). In this part of the forests it is possible to begin liberation of the existing potential crop trees immediately while at the same time ensuring further recruitment in the coming decades to reach the target set for the transformation period. A considerable proportion of the forest areas also possessed a moderate number of potential crop trees, which require only minimum inputs to achieve the targets. A total of 30-40 % of the forest area exhibited no potential crop trees at the time of study. These areas included settlements, farm plots, open pastures and park type forest stands. The absence of potential crop trees in these areas doesn't necessarily imply the complete lack of regrowth. However, the young plants observed didn't qualify for selection as potential crop trees.

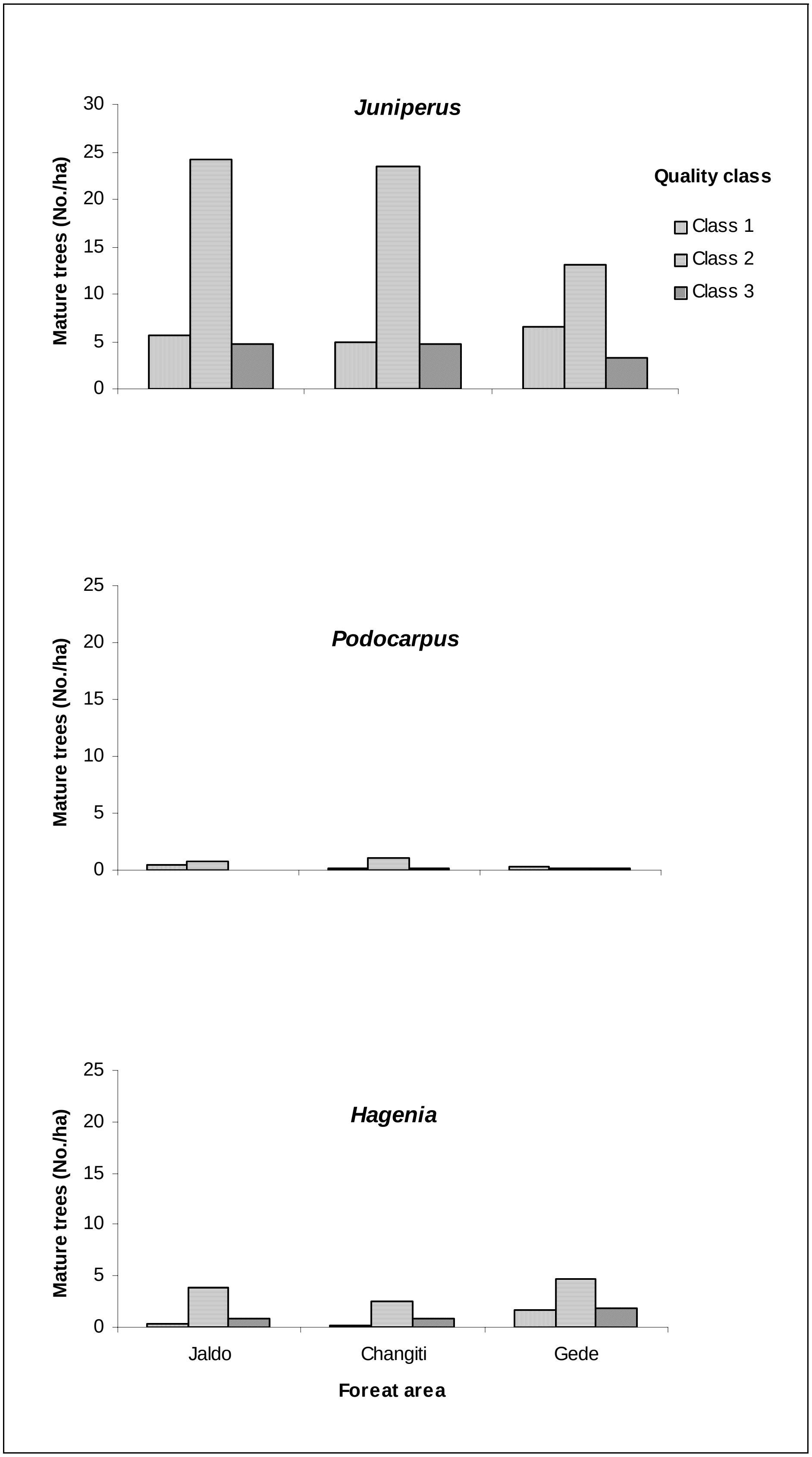

Figure. 4.12: Quality class distribution of the mature trees in the three forest areas

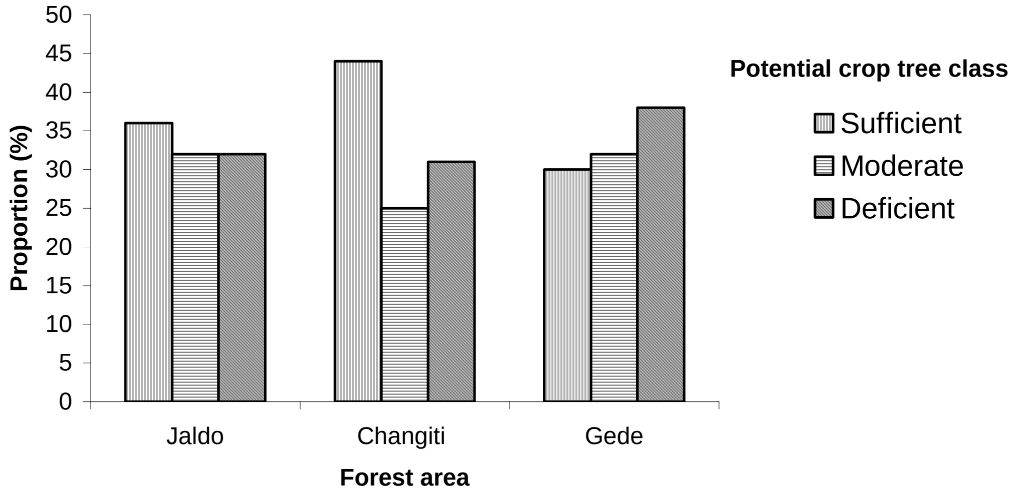

Fig. 4.13: Proportion of potential crop tree classes in the three forest areas

4.3.4 Relationship between the abundance of potential crop and mature trees

There is a very weak correlation between the abundance of potential crop trees and mature trees recorded in the investigated forests, as reflected by very small correlation coefficients (Fig 4.14).

4.4 DISCUSSION

4.4.1 Methodological aspects

A high degree of variation between the plots was observed with respect to the abundance of potential crop trees. The high frequency of empty plots coupled with the presence of some highly stocked plots contributed to the variation. The fragmented land use and intermingled forest types in the forest areas, which are very difficult to practically classify into homogenous units, are the main reasons for the variation. Consequently, the sampling distribution was not normal. Even after transformation of the original data for normality it was not possible to satisfy the assumptions of the normal distribution. Nevertheless, statistical measures for normal distribution were applied to the original data as they can still present the data better than statistical measures for skewed distributions.

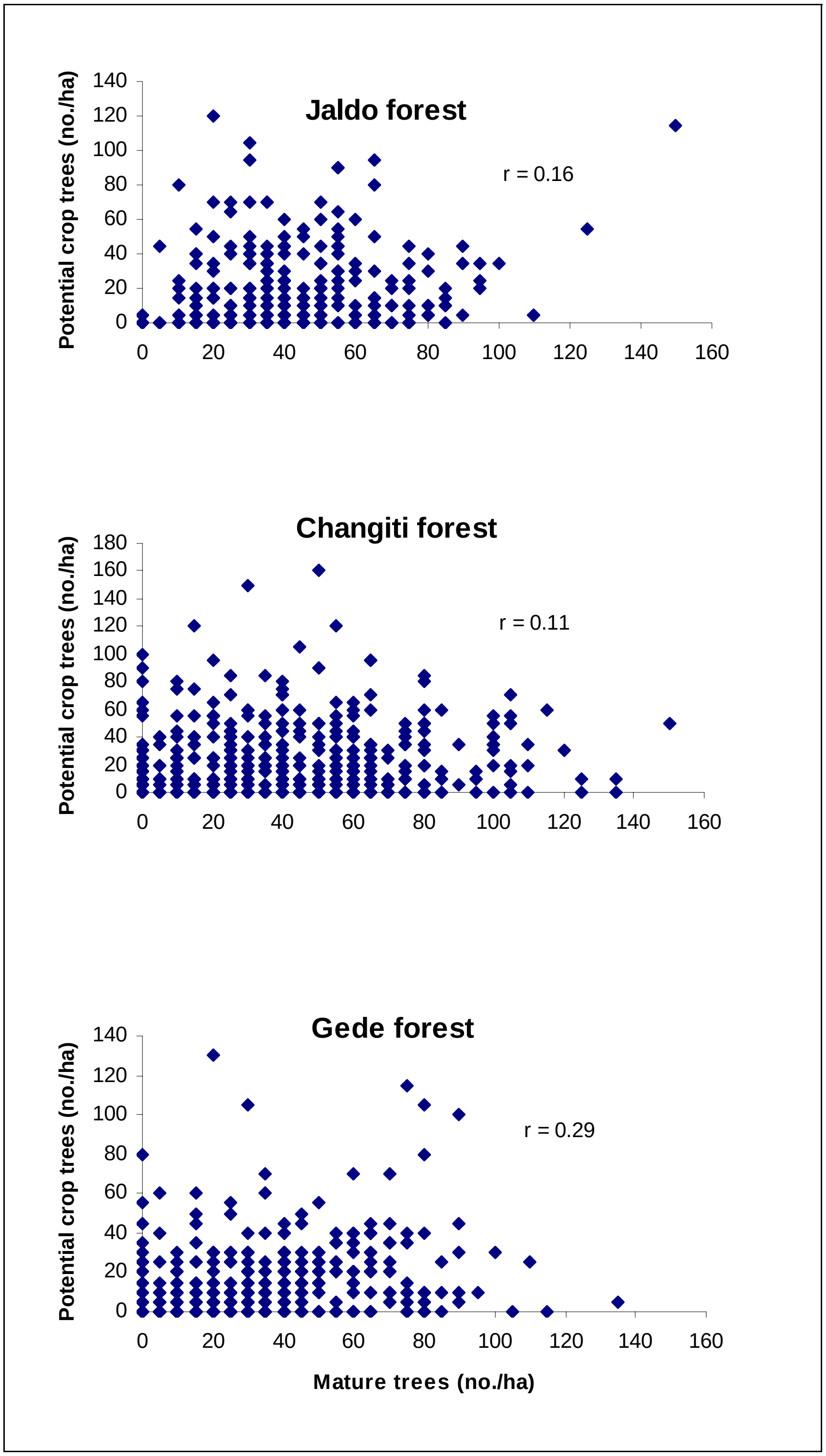

Figure 4.14: Correlation between mature and potential crop trees in the three forests

According to FREESE (1962), regardless of the distribution that a variable follows, the means of large samples tend to follow a distribution that approaches the normal and may be treated by normal distribution methods. This is the reason why the standard errors of the sample means are quite acceptable even though the coefficients of variation were quite high. This allows for comparison of the subsequent periodic inventories with an acceptable level of confidence.

However, the variation observed among the plots with respect to the abundance of mature trees is low compared to that of the potential crop trees. This is because of a more or less uniform distribution of over-sized trees of less value over the entire forest area. As a result, the sampling errors of the sample means are quite reasonable compared to those of the potential crop trees.

One possible means of reducing the sampling error is to increase the sample size. The 20 % sampling intensity used in the case of this study corresponds to that already used by the forest service to conduct periodic monitoring of the forest areas. Field-testing conducted by the integrated forest management project together with the district forest service to check the feasibility of different sampling intensities showed that it would be too expensive to further increase the sampling intensity. Therefore, it is hoped that future management interventions will harmonise the variations amongst the plots by regenerating areas of poor regrowth and tending areas with excessive regrowth.

4.4.2 The current status of the potential crop trees

The abundance and distribution of potential crop trees are the key factors for future planning and the implementation of silvicultural interventions in the investigated forests.

4.4.2.1 Species distribution of the potential crop trees

The two indigenous conifers, *Juniperus excelsa* and *Podocarpus falcatus*, account for the great majority of the potential crop trees found at the lower altitude. In addition to its occurrence at lower altitudes, *Juniperus excelsa* is also dominant in middle and upper altitudes, which makes it the most abundant species in the investigated forests. Similarly, studies conducted in montane forests in East Africa (BUSSMANN 2002) indicated that *Juniperus* is dominant species, even at higher altitudes. The two species, particularly *Podocarpus falcatus*, are reported to be less susceptible to browsing (TESFAYE *et al*. 2002 and TADESSE 1999), unless there is shortage of fodder on the forest floor. Consequently, they can be regarded as key species for the rehabilitation of the forests in the context of the user group forests where grazing cannot be avoided.

Unlike the two conifers, the potential crop trees of *Hagenia abyssinica* were found to be rare in the investigated forests. This is consistent with the results of previous studies (REGASSA 2003, HOLWEG 1998 and TADESSE 1999). The same authors also described *Hagenia* as the preferred tree species browsed by all types of livestock. The areas where the potential crop trees of *Hagenia* occurred were mostly characterised by steep riverbanks, and inaccessible and dense shrub covered areas. Its susceptibility to browsing implies the need for protection and care for the young regrowth until it outgrows the browsing zone.

It was also observed during the fieldwork, and confirmed by the members of the user groups, that the potential crop trees of *Hagenia* were more frequently found to occur in groups in burned over areas together with *Juniperus*. A similar observation was reported by BUSSMANN (2004). However, the use of fire as a management tool to initiate regrowth is debatable in the high forest areas of Ethiopia, bearing in mind the devastating fire that occurred in the year 2000.

4.4.2.2 Size distribution of the potential crop trees

The size class distribution of the potential crop trees showed an irregular pattern in the three investigated forests. Some size classes were over-represented whereas others were missing. This can be attributed to the impact of grazing on the smaller size classes. The localised patchy type of grazing causes more damage in some areas whereas other areas are less utilised. The selective cutting of the intermediate size classes during past illegal logging might also have contributed to the low representation of intermediate size classes. However, the impact varies from species to species:

• *Juniperus excelsa*

The potential crop trees of *Juniperus* showed a reverse-J population structure in only one forest area. This is partially in line with the findings of COURALET (2004), indicating a stable population structure of *Juniperus* in Adaba-Dodola forest. However, in the other two forest areas the lower size classes are not sufficiently represented. The higher livestock density could be one of the causes for the lower abundance or complete lack of the lowest size classes in Gede forest. However, grazing is not the only factor that affects the establishment and growth of young regrowth in the forests. TADESSE (1999) found no difference in the abundance of small-sized individuals under closed forest conditions between grazed and non-grazed forests. *Juniperus* is generally known for its low establishment potential under the closed canopy of mature parent trees (TEKETAY and BEKELE 1995 and FRIIS 1992). BUSSMANN (2002) also reported the sporadic occurrence of *Juniperus* regrowth under heavy shade and dense vegetation cover.

As a light demanding species its regeneration is adapted to forest clearings, gaps and forest edges where there is bright light. In the absence of such conditions there is a tendency towards colonisation of small gaps by broadleaf species. Field observations revealed that tree species like *Rapanea melanphloeos* occupy small gaps in park-type stands of *Juniperus*. This implies the need for active opening of the canopy to enhance the recruitment of the potential crop trees of *Juniperus*. REGASSA (2003) recorded high numbers of regrowth in intensively logged over forest areas with open canopies when compared to forests under user group management, which are subject to regulated use.

• *Podocarpus falcatus*

Podocarpus is the only species that showed a reverse-J diameter distribution in all three investigated areas. However, 50-75 % of the potential crop trees were found to be < 10 cm in diameter. This is in agreement with studies conducted by TEKETAY and BEKELE (1995) in the Wof-washa dry afromontane forest, which showed about 80 % of the *Podocarpus falcatus* individuals to be in the 2-6 m height class. On one hand, this can be attributed to its unpalatability to livestock. On the other hand, it reflect the existence of well-established seedling banks on the forest floor. Formation of seedling banks under the forest canopy is the major regeneration strategy of woody species in dry afromontane forests (TEKETAY 1997 and TEKETAY and GRANSTROM 1995). The lack of intermediate or pole-sized individuals may also be explained by past selective felling (TESFAYE *et al.* 2002).

• *Hagenia abyssinica*

The size class distribution of *Hagenia* varied greatly between the forest areas. There is an abrupt difference between successive size classes. The occurrence of even-aged groups in very localised areas after major disturbances like fire creates exceptionally high proportions of some size classes whereas others are missing. Apart from browsing, high ground competition and intensive shading are reported to limit the regeneration of *Hagenia* (BUSSMANN 2004).

4.4.2.3 Association between potential crop and mature trees

The absence of a strong correlation between potential crop and mature trees might be because of the difference in establishment strategy of the tree species in the forest. The potential crop trees of shade tolerant species such as *Podocarpus falcatus* establish well under the canopy of mature trees, whereas light demanding species such as *Juniperus excelsa* and *Hagenia abyssinica* require the presence of canopy gaps and open areas for establishment. This difference shows the existence of monodominant and mixed late successional species forming mosaics (FETENE and FELEKE 2001).

Thus, the findings of this study reveal that there are some factors influencing the recruitment of potential crop trees in the investigated forests other than grazing. This calls for the careful selection and implementation of appropriate management interventions, as shall be discussed in chapter 5.

4.4.3 The status of mature trees

The study results showed that *Juniperus excelsa* contributed 60-85 % the total number of mature trees, the equivalent of 70-80 % of the total basal area. This is consistent with a previous study conducted by REGASSA (2003), who reported that *Juniperus* accounts for 70 % of the total basal area.

Podocarpus falcatus and *Hagenia abyssinica* made up only a small amount of the mature standing stock. A high market demand for the two species has contributed to their over-extraction (Tab. 4.10).

Table 4.10: Local market price of the three timber species (SCHMITT 2003)

TREE SPECIES	LOCAL PRICE EURO/M^3
Juniperus	68
Podocarpus	91
Hagenia	100

The great majority of the available mature trees were over-sized trees of poor quality, implying that the best quality trees had already been extracted. This finding is supported by a stump analysis conducted by REGASSA (2003). It showed that 80 % of the stumps recorded were within the diameter range of 10-50 cm. This could be due, on the one hand, to the better quality of trees in the indicated sizes. On the other hand, the ease of felling, processing and transportation of these intermediate dimension trees using locally available tools might have caused their over-exploitation. This implies the need for capacity building in relation to the development of efficient tools and techniques in order to encourage the user groups to utilise the over-mature trees, which will in turn increase the growing space available to the potential crop trees.

4.4.4 Sufficiency of the potential crop trees to transform the forests

In chapter 3 it was stated that the optimum number of trees that can be maintained as final crop trees taking into account forest grazing was found to be about 170-210/ha. Assuming a transformation period of 100 years, 20 recruits/ha per decade was deemed to be sufficient in the context of the user group forests to achieve the final target of about 200 crop trees/ha. This study has revealed that 30-45 % of the total areas of the investigated forests have at least 20 potential crop trees/ha. Therefore, while tending forest areas with sufficient potential crop trees it is possible to regenerate areas with poor and moderate regrowth.

Studies conducted into the natural regeneration potential of the investigated forests indicated that about 240 seedlings/ha can be obtained under current conditions, of which 86 % are non-browsed and healthy (REGASSA 2003). This suggests the possibility of obtaining a sufficient number of naturally established seedlings that can be recruited as potential crop trees to achieve the optimum number of crop trees at the end of the transformation period.

However, a rotating grazing system has to be introduced to protect and regenerate at least 10 % of the forest area per decade. This is necessary to facilitate the regeneration of poor regrowth areas and the establishment of threatened species like *Hagenia abyssinica*. In addition, young plants < 2 m height could be fenced individually or in groups by thorny bushes, branches of trees or other materials available in the forest. Existing thorny shrubs and other natural features that serve as natural fences by sheltering young seedlings from browsing should be also preserved. This practice will increase the survival rate of wildlings.

4.5 CONCLUSION

The findings of this study support the hypothesis that there is a sufficient number of established young regrowth to rehabilitate the existing degraded forests taking into account the grazing needs of the user groups. The investigated forests have the potential to be transformed into managed selection forests through a potential crop tree focused management. However, the selection and release of the existing potential crop trees from their competitors is a crucial factor to enhance their continuous development.

Equally important is the continuous recruitment of potential crop trees by regulating grazing through rotational grazing schemes. This requires a management system in which the timber and livestock production is carefully planned, implemented, monitored and adjusted based on continuous field observation. The silvicultural interventions required for such a system will be discussed in chapter 5.

5 SILVICULTURAL MANAGEMENT TOWARDS MULTIPLE USE

5.1 INTRODUCTION

Forests provide multiple products and services to the members of the user groups and the surrounding communities at large. The user groups expect the continuous availability of these products and services in sufficient amounts. Consequently, matching the demands of the users with the production capacity of the forests is the challenge of the time, both for foresters and for the user groups. To this end, there is a need for a management system that maintains the multiple functions and improves the production capacity of the forests in order to meet the growing needs of the user groups.

Based on the prevailing socio-economic conditions described in chapter 2 and the current status of the user group forests presented in chapters 3 and 4, a multiple use management system is proposed for the sustainable management of the forests. This system combines timber and livestock production while maintaining the other functions of the forests. To maintain these functions, a silvicultural system that fits the forest management objectives set by the stakeholders concerned as well as condition of the forest in question must be selected. Improvement treatments and harvest levels in line with the selected silvicultural system are then necessary.

Silvicultural management of the user group forests can only be successful if grazing is regulated. Therefore, the fodder production capacity of the forests and the existing livestock densities are evaluated to define sustainable livestock stocking rates. Subsequently, mechanisms to regulate grazing are suggested. The need to monitor the impacts of the proposed management practices and to re-adjust them where necessary based on field observations and research inputs is also emphasised.

5.2 FOREST MANAGEMENT OBJECTIVES

The following management objectives have been defined based on the current use patterns and future expectations of the user groups as well as the conservation interest of the forest service:

- **Timber production**

The user groups depend entirely on the forests for the wood products required to meet their subsistence needs, both for consumption and the generation of additional income. The main forest products include firewood, lumber and local construction materials. They want to be able to extract these products from the forests continuously.

- **Livestock production**

Livestock production is one of the major livelihood strategies of the members of the user groups. The forests provide fodder and shade for their livestock. Hence, the grazing service provided by the forests cannot be excluded from forest management.

- **Catchment protection**

Maintaining at least the existing level of forest cover is an absolute precondition demanded by the forest service when granting user rights to the user groups. The reason for this is the importance of the forests as sources of perennial rivers that provide water to the surrounding communities and a hydropower plant, in addition to serving as protection against soil erosion. The user group forests also harbour diverse plant and animal species. Therefore, the management system that is going to be implemented is expected to preserve the protection function of the forests.

- **Ecotourism**

The unique landscape and forest formations along the altitudinal gradients are the main tourist attractions for the ongoing development of ecotourism in the area. This scheme is currently providing local employment and additional income to the members of the user groups, who are in turn able to reduce pressure on the forest resource. To ensure the continuous flow of these benefits there is a need to preserve the aesthetic values of the forest.

- **Non-wood forest products**

Beyond the products and services mentioned above, the forests provide a wide variety of non-wood products such as medicines and food (honey, fruits, leaves, mushrooms and spices).

To achieve these objectives the need to designate riparian zones, silvicultural pathways to be followed and grazing management components are discussed in the coming subchapters.

5.3 DESIGNATION OF RIPARIAN ZONES

5.3.1 Introduction

As described in the management objectives, timber production is not the only objective of the management of the user group forests. Maintaining the other functions of the forests may mean the setting aside of some areas for certain purposes. However, it is not possible to designate different areas for the different functions because of the scattered and intermingled land use patterns in the forests. The settlements, farm plots and open pastures are widely scattered making the delineation of such areas very difficult from the point of view of forest management.

Nevertheless, the designation of riparian zones was found to be feasible. In the study area there is a tradition of preserving trees along riverbanks. Even during illegal logging in the past when there was no sense of ownership and responsibility, the local communities did not fell trees around water points and riverbanks. The reason for this was their understanding of the protection value of these strips, quite apart from serving as shade for their livestock during watering. With the exception of the watering points, most of the riparian zones lie in deep valleys and in inaccessible areas due to which they are also important wildlife habitats. Moreover, these areas are economically important as they provide water for a hydroelectric dam constructed further downstream. Some of the rivers also provide fish to local communities. Therefore, the protection of riparian zones from logging helps to maintain the functions indicated.

5.3.2 Materials and methods

All the rivers occurring in the investigated forests were buffered using an Arc-GIS software fixed-width buffering approach (BETTINGER and WING 2004). As there is no guideline available to determine the most appropriate width of the buffers in the context of the user group forests a width equivalent to a tree height, which is approximately 30 m, was applied to both sides of the rivers. This gives a total buffer width of 60 m. In cases where a river borders two forest areas one side of the river is buffered for each forest area. The buffer area was then calculated using the same software.

5.3.3 Results and discussion

Riparian zones account for 5-19 % of the investigated forest areas (Tab. 5.1). Jaldo forest has only a small proportion of riparian area, with only a few water sources and rivers flowing through the forest. Changiti and Gede forests on the contrary have comparatively large riparian zones, equalling around one-fifth of their whole area. Furthermore, the results of the spatial analysis showed that the riparian zones are distributed over the entire area in the two forests (Fig. 5.1).

Table 5.1: Proportion of riparian and timber utilisation area

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Forest area	ha	364	554	489
Riparian zone	ha	17	98	94
	%	*5*	*18*	*19*
Timber utilisation area	ha	347	456	395

The timber utilisation area is obtained by subtracting the area of the riparian zone from the total forest area.

Activities to be permitted or prohibited in riparian zones vary from place to place based on the management objectives. In the case of user group forests where these areas are exempt from logging it is deemed adequate that their functions be maintained. In return, the forest service has to exempt the user groups from the payment of rent for those areas. This will encourage the user groups to continue protecting these areas that benefit not only the user groups but also the communities downstream. In addition, institutions such as the Ethiopian electric light and power authority, which is benefiting from the protection of the watershed at no cost to itself, should support the user groups in their efforts at sustainably managing the forests. Payments for such off-site benefits from the forests enjoyed at local, national, regional and global levels contribute greatly to the improvement of the livelihoods of the user groups (ANGELSEN and WUNDER 2003).

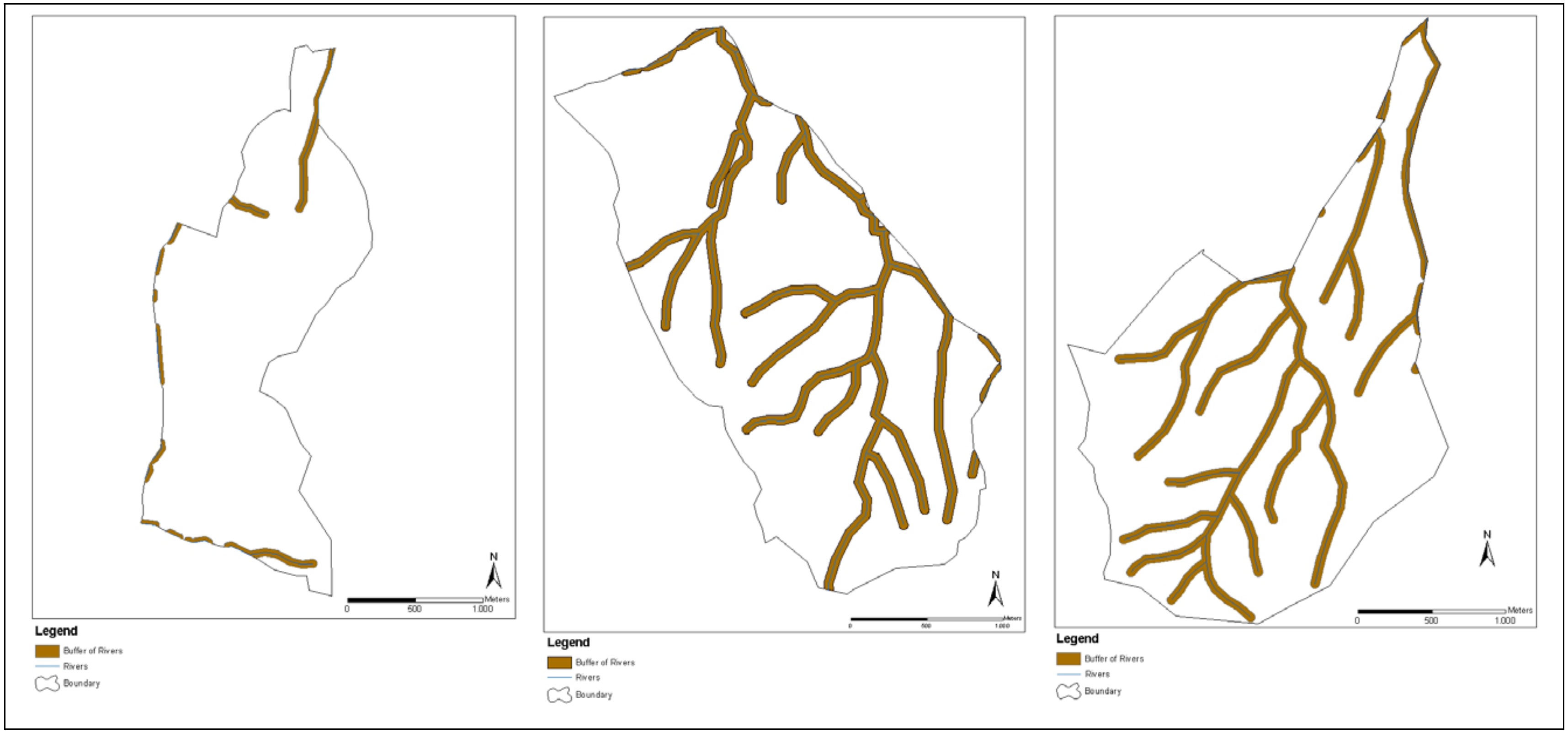

Figure 5.1: Spatial distribution of riparian zones (from left to right: Jaldo, Changiti and Gede forests)

5.4 SILVICULTURAL PATHWAY INTO MANAGED SELECTION FORESTS

5.4.1 Introduction

The user groups expect a wide range of products and services from their forests, unlike the conventional timber oriented management observed in state and private forests. This is also in line with the recent widespread recognition that forests can no longer be managed only for timber but also to meet other livelihood needs. Consequently, there is a need for a system of silvicultural management that not only maintains continuous forest cover but also provides benefits at short intervals.

The investigated forests mainly consist of poor quality trees, as most of the best quality trees have been extracted illegally in the past. This calls for the implementation of improvement treatments to enhance the production potential of the forests, both in terms of quantity and quality of production. This will in turn improve the value and the capacity of the forests to accommodate the growing demands of the user groups. To this end, treatments that are important in the context of the user group forests and possibilities to realise them are presented and discussed.

5.4.2 Gradual transformation systems

The principal objective of transformation is to create a favourable regeneration environment for desirable species (LAMRECHT 1989). The same author also described the process of gradual transformation into managed selection forests as the floristic and structural homogenisation of the original growing stock to increase the proportion of marketable species without substantially altering the natural structures of the stands. This process predominantly relies upon natural regeneration, which has the following advantages:

- lower transformation costs,
- greater stability of the stands,
- maintaining the multiple forest functions,
- lower risks.

Adopting a management system with such qualities is of great importance in the context of the user group forests where there is limited financial capital available to invest in forest management.

5.4.3 Selection of an appropriate silvicultural system for the user group forests

The purpose of silviculture is to create and maintain the kind of forests that will best fulfil the objectives of the owner/user within the capacity of local site and stand conditions (NYLAND 2002, SMITH *et al.* 1997 and LAMRECHT 1989). Hence, the selection of a silvicultural system for the user group forests was made based on the forest management objectives and the current status of the forests. The silvicultural system regarded as the appropriate system for the transformation of the degraded user group forests into managed selection forests is single tree selection.

5.4.3.1 Description of the single tree selection system

A single tree selection system forms uneven-aged stands and involves the selective removal of individual trees here and there at short intervals (NYLAND 2002). Under this system harvesting causes very few changes to the structure and composition of the forests. The continuous forest cover and the array of age classes in the resulting selection forests makes it ideal for managing forests with multiple use objectives, where protection against soil erosion, aesthetic values and riparian zones are also important (NYLAND 2002 and SMITH *et al.* 1997). From this point of view, the single tree selection system addresses the management objectives of the user group forests.

5.4.3.2 Stand treatment components

Like many other silvicultural systems the single tree selection system consists of three stand treatment components, namely:

- regeneration,
- tending,
- harvesting.

In even-aged systems, the treatment components are applied separately rather than concurrently (NYLAND 2002). Under these conditions, events move from the regeneration of an age class, to tending during intermediate ages and finally to regeneration after harvesting, at which point the cycle enters the first phase again. Tending treatments are used to influence the development of the stand and are applied until it reaches maturity. Eventually, harvests are carried out to establish a new age class.

In the case of uneven-aged stands the stand treatment components occur in combination. This means regeneration, tending and harvesting take place simultaneously. The stand treatment components are described as follows:

- **Regeneration**

Forest stands can be established through natural or artificial regeneration:

- The process of natural regeneration involves the renewal of forests by means of self-sown seeds. Most of the species in the study area naturally regenerate through self-sown seeds.
- Artificial regeneration involves direct seeding, as well as planting.

- **Tending**

During tending operations more emphasis is given to the promotion of preferred individuals that remain in the forest as potential crop trees. These trees will be released from competitors in order to accumulate the stand increment on the main contributors to the value of the forest. This phase enables the attainment of the targeted tree dimensions within the shortest possible period of time. Treatments applied at this stage are referred to as improvement treatments. The term improvement covers all operations carried out in growing stands intended to improve future yields (LAMPRECHT 1989). It includes a wide range of treatments such as liberation cuttings, selective thinning, pruning and climber cuttings amongst others. Most of these treatments can be integrated and conducted simultaneously in a single operation.

Improvement treatments also produce pre-harvest products through the removal of potential crop tree competitors. This may include the cutting of old trees overtopping the potential crop trees and pole-sized trees in even-aged groups. In the case of the user group forests, improvement treatments contribute to the great majority of the harvest cuttings until a time when the first generation of the potential crop trees reach harvestable dimensions. This is because most of the existing potential crop trees are under competition from the mature and over-mature trees. The cutting of overtopping old trees improves the growth of potential crop trees.

- **Harvest**

Harvesting involves the extraction of trees that have reached the desired dimensions through selection cutting. Selection cutting is the practice of harvesting the final crop trees on an individual or group basis, which in turn initiates the establishment of a new age class. The time interval between the subsequent treatments and the number of years it takes to grow a tree to maturity determine the number of age classes in an uneven-aged stand (NYLAND 2002).

In the case of user group forests, selection cutting is possible in two ways:

- By harvesting the existing mature trees in areas with high densities and a closed canopy. In such areas, in most cases, there are no or only very few potential crop trees. Removing some of the mature trees through selection cutting will open the canopy and initiate natural regeneration, in addition to producing some timber for the user groups.
- Harvesting the 'final' crop trees when the one time 'potential' crop trees have reached the desired dimensions. However, this option is only possible once the first generation of potential crop trees reaches maturity.

5.4.3.3 Advantages and disadvantages of the single tree selection system

Like many other systems the single tree selection system has both advantages and disadvantages, which are described here in the context of the user group forests (Tab. 5.2).

Table 5.2: The advantages and disadvantages of the single tree selection system (NYLAND 2002, MCELHINNY 1999, SMITH *et al*. 1997 and DANIEL *et al*. 1979)

ATTRIBUTE	ADVANTAGES	DISADVANTAGES	COMMENTS IN THE CONTEXT OF USER GROUP FORESTS
Species composition	- favours shade tolerant species.	- unfavourable for the establishment and growth of light-demanding species.	- the relatively open forest condition arising from the integration of grazing will enable the establishment of both species types.
Timber production	- production of high quality stems as tending focuses on the best crop trees. - continuous flow of products at short intervals due to frequent intervention. - flexibility; option to retain trees for harvest at a later stage based on market conditions.	- needs regular diagnostic inventory for each felling operation. - skilled personnel for selecting and marking the potential crop trees. - logging damage to the residual stand and increased soil compaction due to frequent activities (when machines are used). - high logging costs and low efficiency because of small harvest per unit area.	- the continuous flow of products at short intervals suits the needs of the user groups. - the existing periodic monitoring method can generate the required information. - requires training on selection of potential crop trees and low impact logging. - the user groups do not use harvesting machines and the traditional pit-sawing method is adapted to felling and processing single trees. - intensive commercial logging is not the objective at the moment.
Catchment protection	- reduced soil erosion because of continuous forest cover and varied forest structure. - better undergrowth - protection of riparian zones. - favourable habitat for wildlife.	- increased threat of browsing to young plants due to increase in wildlife population.	- maintains the protective functions of the forests. - discussion to introduce controlled hunting underway, which not only reduces the negative impacts of wildlife but also generates additional income.
Aesthetic value	- more natural looking than even-aged stands. - small and scattered changes due to harvesting events.		- it sustains the ongoing ecotourism scheme.

5.4.4 Materials and methods

5.4.4.1 Determination of the allowable cut

Planning period

There is scant information about the growth rate of the species present in the user group forests. In particular, there is no reliable information about the periodic and annual increments of the investigated forests, which makes it difficult to determine the sustainable allowable cut. A dendrochronological study conducted by COURALET (2004) established diameter-age relationships for *Juniperus excelsa*. According to this relationship, a period of about 130 years is required to obtain harvestable trees of ~ 40 cm in diameter. However, studies conducted in East African montane forests indicated that *Juniperus* could reach 9 m height in twenty years and 30 m after 80-90 years (BUSSMAN 2004). KOLLERT and TESHOME (1997) suggested 70-100 year rotation periods for *Juniperus* for the production of merchantable logs for sawn timber. No reliable growth information was found for *Podocarpus* and *Hagenia*. Based on the rudimentary information available and discussion with elders in the user groups it was assumed that the three timber species attain harvestable dimensions after one hundred years provided that the necessary silvicultural interventions are implemented to promote the growth of the potential crop trees (compare Tab. 4.2). Adopting this planning period, a working plan with an option for revision after ten years is considered best suited for operational purposes.

Developing a periodic allowable cut model

Potential crop tree focused management is the main principle in the management of the user group forests. As a result, the determination of the allowable cut was based on the recruitment rate of the potential crop trees and the amount of mature trees available in the forest. Based on the one hundred year planning period, it is assumed that the first generation of potential crop trees reach for harvest at the end of the ninth decade. Until then the existing mature and over-mature trees should be utilised gradually. One option to do this is to evenly distribute the existing mature trees over the nine decades.

Accordingly, the currently available mature trees in a given forest area is divided by nine decades to get the possible allowable cut threshold for one decade.
However, the utilisation of the existing mature trees is only possible if there is recruitment of potential crop trees on the ground to ensure the continuity of the forests. This implies that the user groups will be allowed to harvest the allowable cut set for the decade only if the required amount of the potential crop trees have been recruited in the preceding decade. To attain the optimum number of crop trees set for the planning period, which is estimated to be about 200 crop trees/ha, a minimum recruitment rate of 10 % is expected every decade.

Nevertheless, not all of the recruited potential crop trees will reach the final cut due to mortality. During the selection process mortality was partially considered and accounted for by spacing potential crop trees at least 4 m from one another. This measure is not enough to cover absolutely the risk of damage that might happen during the frequent improvement treatments and harvests. This necessitates increasing the expected recruitment rate per decade by taking into consideration a certain mortality rate. At the moment there is no information about the mortality rate of the potential crop trees in context of this study. Therefore, a mortality rate of 5 % has been assumed for the potential crop trees. This means out of the potential crop trees recruited each decade 5 % will die before they reach the end of the rotation. This implies that the recruitment rate per decade should be at least 10.5 % of the total in order to account for the mortality rate, rather than 10 %. Based on these assumptions the periodic allowable cut for the user group forests was calculated as follows:

$$AC = \frac{RR \times PACT}{ERR}$$

where as: AC = allowable cut/ha/decade,

RR = recruitment rate per hectare of the last decade in %,

PACT = periodic allowable cut threshold per hectare; equals the number of mature trees per hectare divided by nine decades,

ERR = expected recruitment rate per hectare and decade considering mortality (i.e. 10.5 %).

The total number of trees to be extracted from each timber utilisation area in a decade can then be obtained by multiplying the allowable cut per hectare by the size of the timber utilisation area.

Determination of the annual allowable cut

The user groups cannot wait ten years between periodic harvests, as they depend on the forests for their subsistence needs. This calls for the conversion of the periodic allowable cuts into annual cutting levels. Accordingly, an annual allowable cut was derived from the periodic allowable cut by dividing the periodic allowable cut per timber utilisation area by the number of years in the period. This gives the number of mature trees that can be harvested per year in the timber utilisation area. The annual allowable cut was then determined in terms of species based on the species distribution of mature trees in the forests.

The annual allowable cut was expressed in terms of volume using the volume functions (Tab.5.3) developed by CHAFFEY (1979). This is only for the consumption of experts, as most of the members of the user groups do not understand this unit. The volume functions were developed for trees with diameters > 30 cm.

Table 5.3: Volume functions for the dominant tree species (adapted from CHAFFEY 1979)

TREE SPECIES	VOLUME FUNCTION
Juniperus excelsa	Log_e Volume = 2.19 x Log_e ^{dbh} – 8.45
Podocarpus falcatus	Log_e Volume = 2.08 x Log_e ^{dbh} – 7.72
Hagenia abyssinica	Log_e Volume = 1.70 x Log_e ^{dbh} – 6.54
Other species	Log_e Volume = 2.24 x Log_e ^{dbh} – 9.00

Using these functions the volume of a mature tree with an average diameter was first calculated for the respective species. Then the volume of the average tree was multiplied by the number of mature individuals of the species provided in the annual allowable cut. The volume of all the tree species was summed to obtain the annual allowable cut in terms of volume. Furthermore, the annual allowable cut per forest area was compared to the current annual wood consumption in respective forest areas based on an annual level of consumption of about 6 m^3 per household reported by SCHMITT (2003).

Diameter-limit cutting

In a single tree selection system an approach widely used is the regulation of yield through the control of the diameter distribution (MARQUIS 1978). The trees to be harvested are defined based on a minimum harvestable diameter. In the context of the user group forests the diameter-limit is just a flexible threshold that helps to identify trees ready for harvest and those that should remain in the forests. This provides the situation specific flexibility not only to keep some trees above the diameter limit in the forest but also to utilize a certain number of trees below the limit when necessary. For the user group forests the diameter-limit at maturity is deemed to be 40 cm and 25 cm for group 1 and group 2 species respectively (compare Tab. 4.2).

5.4.4.2 Determination of liberation treatment levels

Treatments

As described in chapter 4, most of the potential crop trees in the user group forests are in the lower size classes. Liberation treatments are very important to promote the growth of these trees by releasing them from their competitors. However, the number of competitors to be removed in order to release the potential crop trees is not known. To assess this, two liberation treatments were tested in one of the three user group forests used for the previous investigations, namely Changiti forest. The treatments are described as follows:

1. Liberation of potential crop trees from overtopping competitors.
2. Liberation of potential crop trees from competitors on all sides.

Treatment plots

In order to test the aforementioned treatments, six rectangular plots were established in Changiti forest. These plots will also be used as permanent plots in the future to monitor the impact of improvement treatments on the growth of the crop trees.

Rectangular plots were used for their ease of establishment, and because it will be easier to fix and identify the plot corners during future monitoring. GPS was used to establish the plot corners. However, due to the terrain features and the accuracy of the equipment it was not possible to establish a perfectly rectangular shape. As a result there was a slight variation in the size of the plots although the plan had been to establish plots with a size of 0.50 ha. As the main objective here is to determine the proportion of the potential crop trees and their competitors in a given area the difference in size and shape of the plots will not have any significant impact on the results.

The treatment plots were established based on the natural occurrence range of the three dominant species (*Juniperus, Podocarpus* and *Hagenia*). Two plots were established per species (Tab.5.4). One of the two plots was placed in areas with a sufficient number of potential crop trees while the other was placed in areas with a moderate number of potential crop trees.

Table 5.4: Description of the treatment plots

PLOT NO.	ALTITUDE m a.s.l.	PLOT SIZE ha	PLOT DESCRIPTION	
			STAND TYPE	VARIANT
1	2600-2840	0.45	*Podocarpus* dominated open forest	Moderate number of potential crop trees
2	2600-2840	0.48	*Podocarpus* dominated open forest	Sufficient number of potential crop trees
3	2600-2840	0.50	*Juniperus* dominated open forest	Sufficient number of potential crop trees
4	2840-3000	0.50	*Juniperus* dominated park type forest	Moderate number of potential crop trees
5	3000-3300	0.48	*Hagenia-Juniperus* open forest	Sufficient number of potential crop trees
6	3000-3300	0.47	*Hagenia-Juniperus* park type forest	Moderate number of potential crop trees
Total plot area		**2.88**		

The placement of treatment plots followed the natural occurrence of the species:

- For *Podocarpus* the two plots were placed at the lower altitude, as it occurs in this part of the forests.

- *Juniperus* is dominant or co-dominant over the entire forest area. Therefore, the plot with a sufficient potential crop trees was established at the lower altitude whereas the one with a moderate number of potential crop trees was set up at the middle altitude. This corresponds with a decrease in the abundance of potential crop trees along the altitudinal gradient.
- The plots for *Hagenia* were established at the upper altitude, which is the natural occurrence range of the species.

The location of the treatment plots is presented in Fig. 5.2.

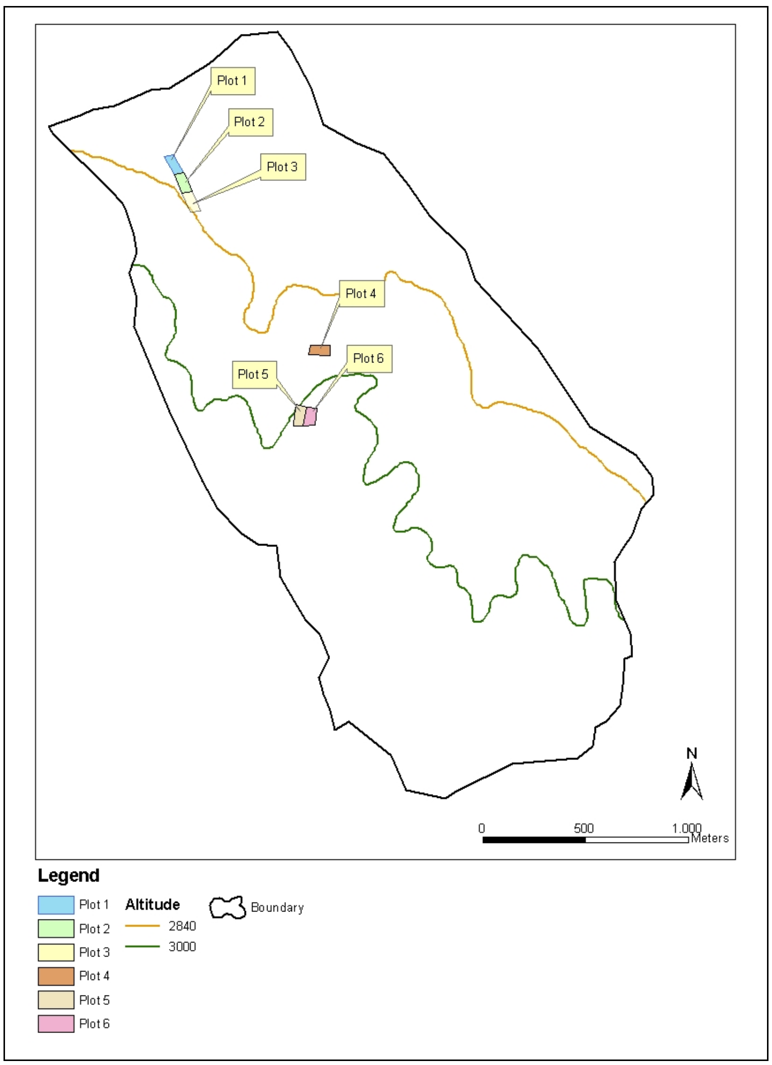

Figure 5.2: Location of the treatment plots in Changiti forest

Treatment procedures

After establishing the plots the following procedures were employed to test the two treatments:

- Selection of the potential crop trees per plot using the selection criteria developed earlier (compare section 4.2.3.1),
- marking them by pruning the lower branches,
- recording the species,
- recording the spatial position,
- measuring the diameter and height,
- marking and measuring overtopping competitors for the first treatment,
- marking and measuring trees competing with potential crop trees from the side in addition to overtopping competitors for the second treatment,
- recording competitors located outside the plots but competing with the potential crop trees recorded within the plots.

Data analysis

The spatial distribution of the potential crop trees in the plots was analysed using Arc-GIS software. The proportion of the potential crop trees and competitors was analysed using descriptive statistics.

5.4.4.3 Setting treatment intervals

Intervals between successive improvement treatments may range from 5-30 years. In a management system where interventions focus on the promotion of selected potential crop trees the time period for improvement treatments is not necessarily the determining factor in conducting treatments (TENNIGKEIT 2000), as these trees can be tended at any time when there is an intervention demand. However, setting treatment intervals is helpful for operational purposes.

Based on the planning period of one hundred years discussed earlier, a treatment interval of ten years was proposed for the user group forests. This implies that the entire area of a given forest will be treated once in a decade. To this end, the user groups can set annual targets to achieve the target for the decade. One option can be to treat 10 % of their forest area annually. This target can be flexible provided that the target set for the period is achieved at the end of the period.

5.4.4.4 Demonstration of treatments

The two treatments described above and other improvement treatments were demonstrated in the three forest areas. In addition to the members of the user groups from the three forest areas, the representatives of adjacent user groups were invited to the on-site demonstration of the treatments. Forest experts from the district forest service and the Adaba-Dodola integrated forest management project were also involved. All of the treatments were demonstrated using locally available tools. At the end, discussions were held to get feedback on the demonstrated treatments. These discussions highlighted a number of the potentials and limitations of the treatments.

5.4.5 Results

5.4.5.1 Periodic allowable cut

The periodic allowable cut for the three forest areas was calculated based on the allowable cut model described in section 5.4.4.1. The number of mature and potential crop trees available in each forest area is obtained from the previous investigation (compare Tab. 4.8 and 4.5). The three forest areas were found to have the same periodic allowable cut threshold, as they possess almost comparable numbers of mature trees (Tab. 5.5).

However, they have different actual periodic allowable cuts because of the difference in the number of potential crop trees recorded in the forests. In Jaldo forest, where the number of potential crop trees is less than the minimum recruitment rate (i.e 10.5 % of the total number of trees for the planning period), the allowable cut per decade is less than the allowable cut threshold. In the case of Changiti forest the allowable cut per decade equals the allowable cut threshold, as the number of potential crop trees is equal to the expected minimum recruitment rate. Gede forest has the lowest allowable cut per decade because of its low number of potential crop trees.

Table 5.5: Allowable cut based on the current status of the three forest areas

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Current status:				
Mature trees	no./ha	41	39	37
Potential crop trees	no./ha	18	21	13
Allowable cut threshold/decade	no./ha	4	4	4
Allowable cut/decade	no./ha	3	4	2
Periodic allowable cut per decade per forest area	no.	1041	1824	790
Annual allowable cut per forest area	no.	104	182	79

The periodic allowable cut per forest area is obtained by multiplying the allowable cut per decade by the size of the timber utilisation area in the respective forests (compare Tab. 5.1). The greater the size of the timber utilisation area the higher the allowable cut will be. The annual allowable cut is obtained by dividing the periodic allowable cut per forest area by the number of years in the period, which in this case is ten.

The periodic allowable cut table is produced based on the possible potential crop tree recruitment rate and allowable cut threshold (Tab. 5.6). This will help to determine easily the periodic allowable cuts after each periodic forest inventory.
The table can also be used in the other user group forests in the research area not included in this study.

The higher the recruitment rate of the potential crop trees, the greater the periodic allowable cut. However, if the potential crop tree recruitment rate per decade is > 10.5 % (i.e. expected recruitment rate per decade) the periodic allowable cut will remain the same with the allowable cut threshold set for the decade. Cutting more than the allowable cut threshold planned for the decade will result in lower harvests in the coming decades.

Table 5.6: Periodic allowable cut table

PCT recruitment rate %	**Allowable cut threshold per period** no. of mature trees/ha									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
2	0.2	0.4	0.6	0.8	1.0	1.1	1.3	1.5	1.7	1.9
3	0.3	0.6	0.9	1.1	1.4	1.7	2.0	2.3	2.6	2.9
4	0.4	0.8	1.1	1.5	1.9	2.3	2.7	3.0	3.4	3.8
5	0.5	1.0	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8
6	0.6	1.1	1.7	2.3	2.9	3.4	4.0	4.6	5.1	5.7
7	0.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7
8	0.8	1.5	2.3	3.0	3.8	4.6	5.3	6.1	6.9	7.6
9	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.9	7.7	8.6
10	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.6	8.6	9.5
11	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
12	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
13	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
14	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0

At the same time, the higher the allowable cut threshold, the greater the periodic allowable cuts. The allowable cut threshold depends on the number of mature trees currently available in the forests. Some forest areas that have not been intensively logged in the past can have a high allowable cut threshold due to the high stocking of mature trees. Even so, such areas are characterised by the low availability of potential crop trees, which balances the periodic allowable cut.

5.4.5.2 Simulated distribution of potential crop and mature trees

The distribution of potential crop and mature trees was simulated for the planning period based on the recruitment rates and periodic allowable cut. This distribution is described using Changiti forest as an example (Fig. 5.3).

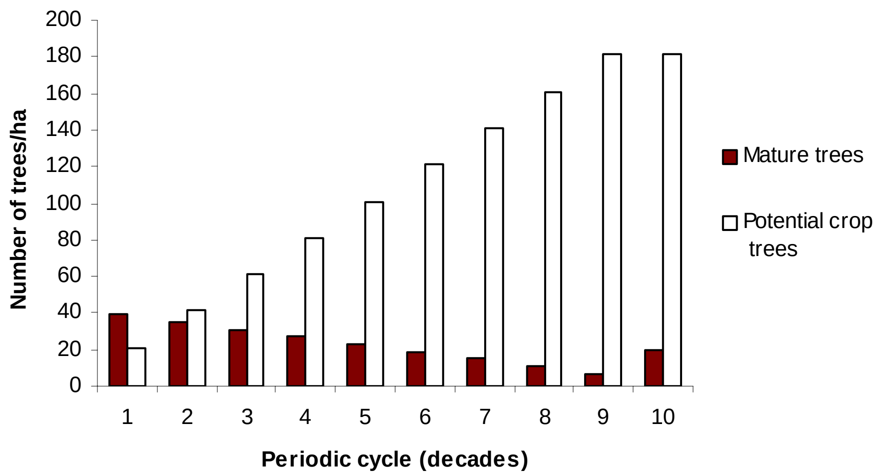

Figure 5.3: Distribution of potential crop and mature trees during the planning period (adapted from HUSS 2002)

At the beginning of the first decade there are 39 mature and 21 potential crop trees in the forest. The currently available mature trees will gradually be utilised until the end of the ninth decade. By the beginning of the tenth decade it is hoped that the first generation of potential crop trees will have reached harvestable size. After this, the periodic allowable cut will be equal to the amount of potential crop trees recruited per decade.

However, the periodic cycle in the context of the user group forests is not equal to a cutting cycle. As the user groups cannot wait ten years between harvests, it is deemed best that they harvest 10 % of the periodic allowable cut annually. This will result in a relatively even distribution of all age classes in the forests.

5.4.5.3 Annual allowable cut in terms of tree species and volume

The number of trees to be cut annually per tree species occurring in the forests is obtained based on the tree species proportions of mature trees in the respective forest areas (Tab.

5.7). This will help the user groups to guide their timber utilisation based on the abundance of the species in the forests.

Table 5.7: The species distribution within the annual allowable cut per forest area

DESCRIPTION	FOREST AREA					
	JALDO		CHANGITI		GEDE	
	no./ha	m^3	no./ha	m^3	no./ha	m^3
Juniperus	87	291	155	604	48	183
Podocarpus	2	8	5	34	1	3
Hagenia	13	45	4	56	17	49
Others	2	---	18	---	13	---
Total	**104**	**344**	**182**	**694**	**79**	**259**

As described in chapter 4, *Juniperus* is the most abundant tree species in the forests. Accordingly, it accounts for the greatest proportion of the annual harvests. The contribution of *Podocarpus* and *Hagenia* is found to be small due to their under-representation in the forests.

The annual allowable cut is also computed in terms of volume. However, because of the badly formed over-mature trees in the forests, which are characterised by large diameters at breast height but short boles, it seems that the volume of the three timber species is over-estimated. Moreover, the function used to estimate the volume of the other species under-estimated their volume. This might be due to differences between the species for which the function was developed and the species recorded in this study.

5.4.5.4 Comparison between annual allowable cut and wood consumption

The annual allowable cut determined for the three forest areas was compared with the current annual consumption by the respective user groups. The annual consumption per forest area is obtained by multiplying the annual consumption per household (compare Tab. 2.5) by the number of households using a given forest area. The result reveals that the current rate of wood consumption in the three forest areas is far lower than the allowable cut (Tab. 5.8). Therefore, it can be stated that the calculation of the annual allowable cut based on the model developed in this study is on the safe side.

Table 5.8: Annual allowable cut and wood consumption per forest area

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Annual allowable cut	m^3	344	694	259
Current annual wood consumption	m^3	120	108	168
	%	*35*	*15*	*65*

5.4.5.5 The liberation treatments

Spatial distribution of the potential crop trees in the treatment plots

The spatial distribution of the potential crop trees showed differences between the plots (Fig. 5.4, 5.5). In most cases, the potential crop trees are distributed in small groups in the plots though there are also some solitary ones. In the plots in areas with sufficient potential crop trees (no. 2, 3, 5), there is a more or less even distribution of the potential crop trees over the entire plot. In plots located in areas with moderate potential crop trees (no. 1, 4, 6), there are only a few potential crop trees scattered in the plots. This implies the need for management interventions in such areas to enhance the recruitment of potential crop trees.

Species distribution of the potential crop trees in the plots

The number of potential crop trees of each of the tree species recorded in the treatment plots is presented in Tab. 5.9.

- *Juniperus* occur in all plots except in one located in a *Juniperus* dominated park type forest. This plot is characterised by an extremely high basal area, mainly contributed to by mature *Juniperus* trees, coupled with a closed canopy favouring the regeneration of shade-tolerant understorey species that can survive in small canopy gaps such as *Rapanea melanphloeos*.
- *Podocarpus* potential crop trees are found only in the first three plots located at the lower altitude, which are located within the natural distribution range of the species.
- The potential crop trees of *Hagenia* are found only in a single plot in a Hagenia-Juniperus forest type (compare Tab. 5.9). During the fieldwork it was observed

that this plot is located in a burned-over area. Most of the potential crop trees of the species occur in groups, which look even-aged. They are associated with potential crop trees of *Juniperus* and some fire resistant plants.

- The proportion of the potential crop trees of other species is very small in all of the plots except in one plot located in a *Juniperus* dominated park type forest. In this plot all of the potential crop trees found are *Rapanea*.

Table 5.9: Species distribution of the potential crop trees in the treatment plots

TREATMENT PLOT		BASAL AREA m²/ha	POTENTIAL CROP TREES NO./HA				TOTAL
No.	Plot description		*Juniperus*	*Podocarpus*	*Hagenia*	Others	
1	*Podocarpus* dominated forest type with moderate PCT	41	27	35	---	---	**62**
2	*Podocarpus* dominated forest type with sufficient PCT	15	25	75	---	2	**102**
3	*Juniperus* dominated forest type with sufficient PCT	38	124	14	---	2	**139**
4	*Juniperus* dominated park type forest with moderate PCT	85	---	---	---	36	**36**
5	*Hagenia-Juniperus* forest type with sufficient PCT	15	137	---	77	2	**216**
6	*Hagenia-Juniperus* park type forest with moderate PCT	25	21	---	---	6	**27**

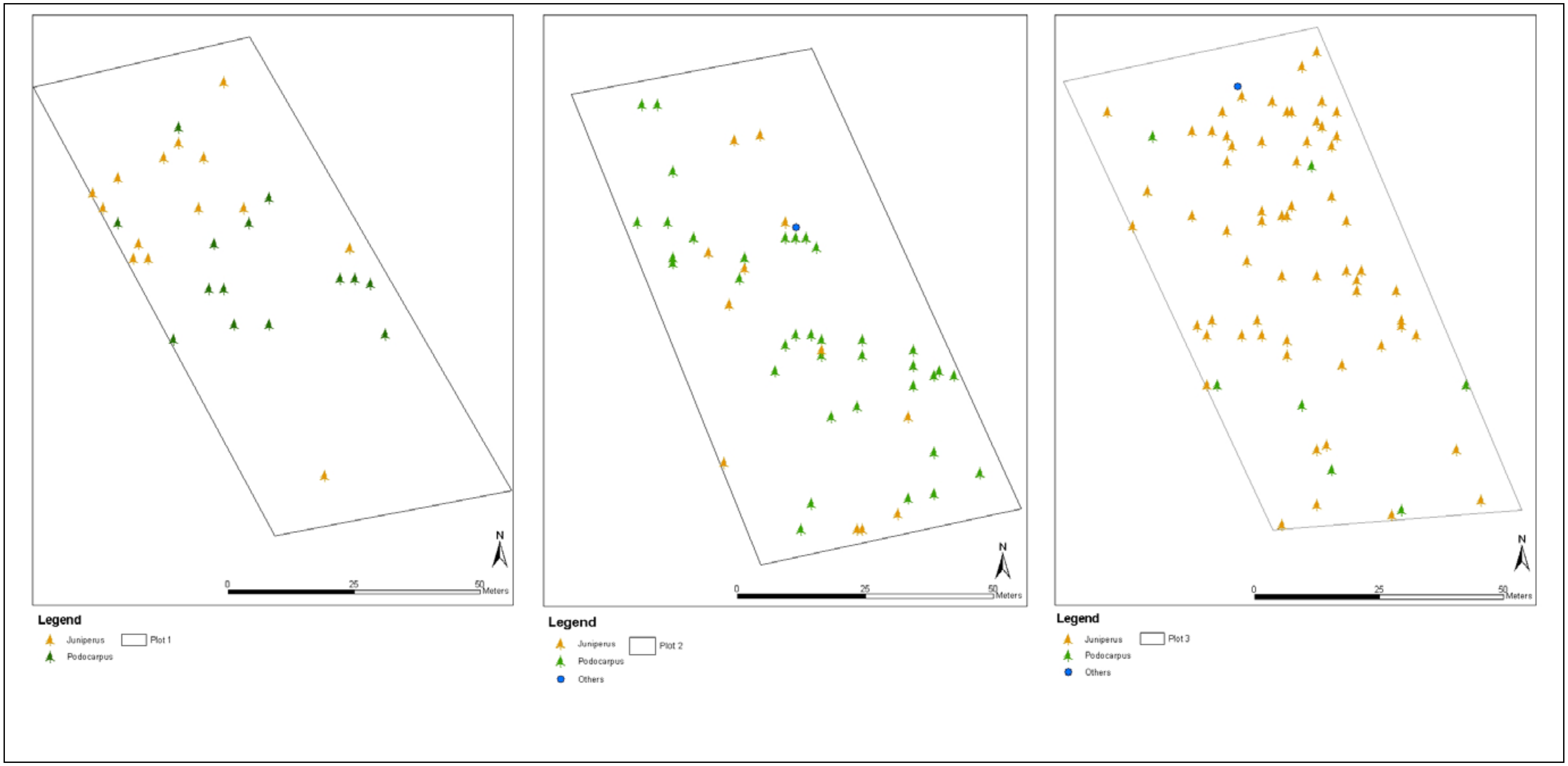

Figure 5.4: Spatial distribution of potential crop trees in the treatment plots (from left to right: plot 1, 2 and 3)

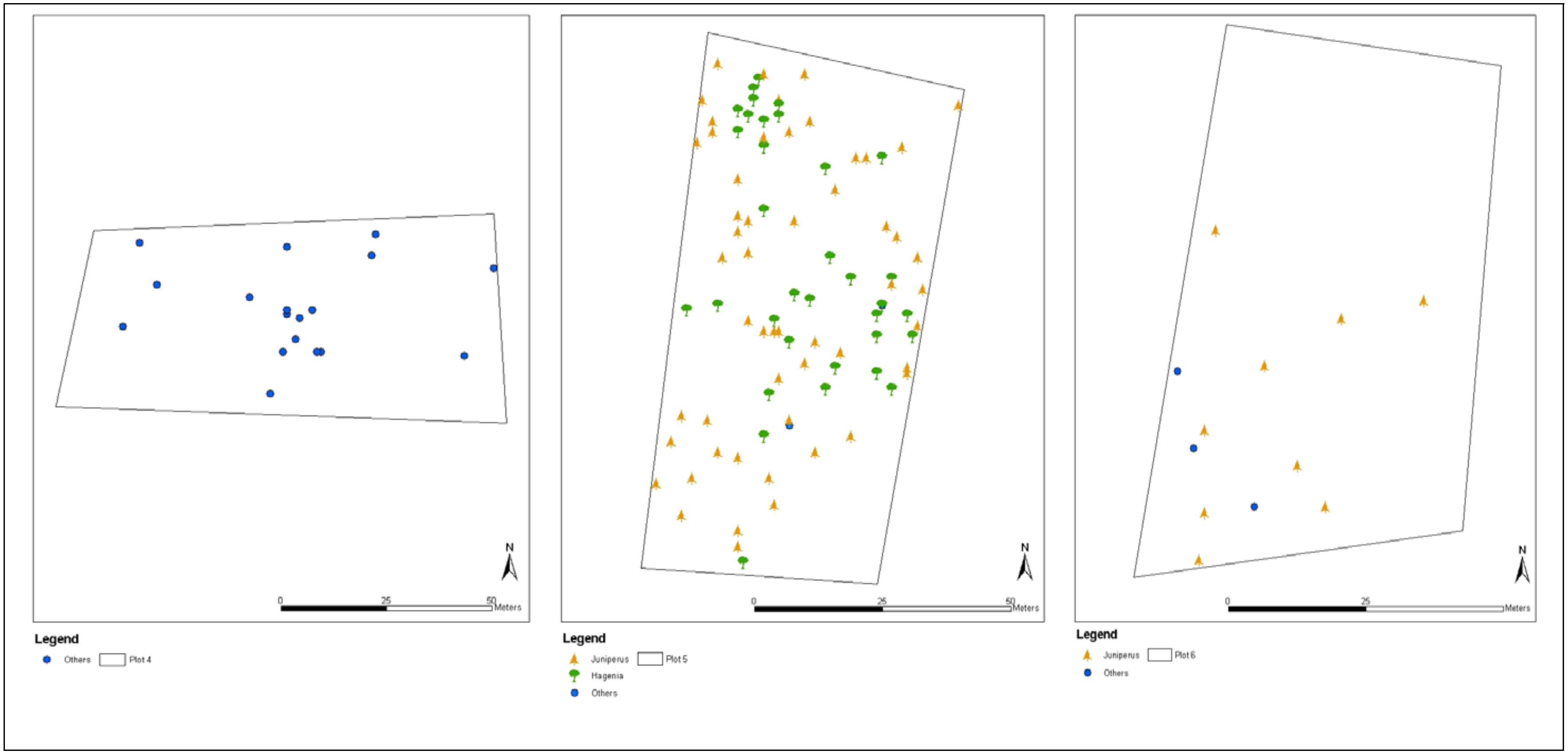

Figure 5.5: Spatial distribution of potential crop trees in the treatment plots (from left to right: plot 4, 5 and 6)

5.4.5.6 Timber extraction through liberation treatments

Ratio of potential crop trees to competitors

The number of competitors to be cut during the liberation treatments varies between plots, as the number of potential crop trees to be liberated also varies from plot to plot. However, the results of the liberation treatments in Changiti forest showed that on average one competitor should be cut for every six potential crop trees in the case of treatment 1 and four in the case of treatment 2 (Tab. 5.10). These rates are very low compared to intervention levels in intensively managed forests.

Table 5.10: Ratio of potential crop trees to competitors in Changiti forest (treatment 1 = liberation of potential crop trees from overtopping competitors, treatment 2 = liberation of potential crop trees from competitors on all sides)

TREATMENT PLOT		POTENTIAL CROP TREE no./ha	COMPETITOR no./ha	
No.	Plot description		Treatment 1	Treatment 2
1	*Podocarpus* dominated forest type with moderate PCT	62	9	16
2	*Podocarpus* dominated forest type with sufficient PCT	102	35	58
3	*Juniperus* dominated forest type with sufficient PCT	139	12	38
4	*Juniperus* dominated park type forest with moderate PCT	36	4	8
5	*Hagenia-Juniperus* forest type with sufficient PCT	216	21	29
6	*Hagenia-Juniperus* park type forest with moderate PCT	27	13	15
Sum		**582**	**94**	**164**
PCT to competitor ratio			**6:1**	**4:1**

Proportion of mature and non-mature competitors

Competitors of different sizes are removed in the treatments. Based on the diameter at maturity, described in chapter 4 (compare Tab. 4.2), competitors removed in the treatments are categorised as either mature or non-mature trees with their proportions presented in Tab. 5.11.

Table 5.11: Proportion of competitor trees in terms of maturity (treatment 1 = liberation of potential crop trees from overtopping competitors, treatment 2 = liberation of potential crop trees from competitors from all sides)

TREATMENT	PROPORTION %	
	Mature	Non-mature
1	47	53
2	56	44

Almost half of the competitor trees to be removed in both treatments are mature trees. The remaining half are non-mature trees that can be utilised as poles, farm implements, fencing material and firewood. The non-mature trees are trees which are classified neither as mature trees because of their size nor as potential crop tree due to their poor quality.

Number of competitors to be cut per hectare and decade

Based on the established ratio of potential crop trees to competitors and the average number of crop trees/ha to be liberated, the number of competitors to be cut per hectare is obtained taking into consideration the treatment interval of ten years.

In Changiti forest there are an average of 21 potential crop trees/ha (compare Tab. 5.5). The number of competitor trees that should be cut in order to liberate the potential crop trees is presented in Tab. 5.12. The number of mature and non-mature competitors is also identified on the basis of their proportions and is presented in Tab. 5.11.

Table 5.12: Number of mature and non-mature competitors to be cut/ha/decade in Changiti forest
(treatment 1 = liberation of potential crop trees from overtopping competitors, treatment 2 = liberation of potential crop trees from competitors on all sides)

TREATMENT	COMPETITOR no./ha		
	Mature	Non-mature	**Total**
1	1	2	**3**
2	3	2	**5**

The user group in Changiti forest can cut one mature and two non-mature overtopping competitors to liberate the 21 potential crop trees applying the first treatment. If applying the second treatment, three mature and two non-mature trees that are competing with the potential crop trees on all sides can be removed. The number of mature trees making up the allowable cut has already been determined as 4 trees/ha/decade (compare Tab. 5.5). Hence, the number of mature trees that will be removed applying either treatment is less than the allowable cut.

5.4.6 Discussion

5.4.6.1 The allowable cut model

Currently, there is a considerable number of over-mature trees in the studied forests, which are occupying a lot of growing space while the potential crop trees are mostly in the lower size classes. Consequently, the allowable cut model developed in this study is based on the concept of the gradual harvesting of the existing over-mature trees while at the same time promoting the growth of the potential crop trees. This enables a stabilisation of the deficiencies in the intermediate size classes. However, the transition time required for the potential crop trees to pass from one size class to the next is unknown due to a lack of information on the growth rates of the tree species. It has been assumed that the first generation of potential crop trees will reach for harvest at the end of the ninth decade. By this time the periodic allowable cut will equal the recruitment rate in the first decade. This is only possible provided there is an even flow of growing and aging trees progressing from one size class to the next. To achieve this ideal condition the following measures should be taken:

- Prioritisation of the utilisation of the over-mature and old trees, thereby increasing growing space for the development of potential crop trees,
- enhancing the continuous recruitment of potential crop trees in sufficient numbers,
- liberating potential crop trees from their competitors at the right time,
- monitoring the recruitment rates of the potential crop trees and their development periodically. This will also help practitioners adjust the allowable cut to suit the conditions in the forests.

The model is based on the assumption that the recruitment rates of the potential crop trees will be the same for all decades. However, this may not happen in reality, as there may be a higher rate of recruitment in some decades than in others. In the case of higher recruitment rates, the excess recruitment can be viewed as a reserve put in the bank and used as a counterbalance in the decades when the recruitment rate is lower than expected. Therefore, an increase in the recruitment rate above that which is expected will not result in an increase to the allowable cut beyond the threshold set for the decade in order to avoid shortages in the coming decades, whereas a lower recruitment rate results in a proportional decrease in the allowable cut. It should also be noted that enhancing the recruitment of the potential crop trees alone is not enough unless they are deliberated at the appropriate time. The liberation from their competitors of crop trees recruited during the period just past is an absolute precondition for utilising the existing mature trees.

An unequal recruitment rates during consecutive periods may result in different amounts of crop trees reaching maturity in different decades. In the context of the selection system of forest management that will be practised in the three investigated forests, the difference in the recruitment rate between the different decades will not have a significant impact on the allowable cut. This is possible because of the flexibility within the selection system, namely the capacity to retain some vigorous trees for harvest at a later date and to utilise others that are below the diameter limit when necessary.

The model developed provides the allowable cut levels based on the number of trees in a manner that is understandable to the members of the user groups. Similarly, YADAV *et al*. (2003) suggested simpler forest resource assessment and yield regulation methods that are on the basis of number of stems per hectare for user group forests in Nepal. According to AUS DER BEEK (1997), forest management can only be participatory if local farmers can understand the units used. In the context of the user group forests the slight differences in the volume of annual harvests based on the size of trees to be cut is insignificant compared to the simplicity of the model. Most of the mature trees currently available in the forests are of poor quality. This means that in terms of value there is no great difference between using the bigger or the smaller ones. From the management point of view, cutting more of the bigger trees is advantageous as it will result in more growing space for the development of regrowth.

It is also important to take into consideration the prevailing species proportions in the forests when harvesting trees based on an allowable cut. Although the current consumption does not exceed the allowable cut, the selective cutting of only a few species and the best quality trees may reduce the value of the standing stock in the long run. This implies that utilisation should focus on the more abundant tree species such as *Juniperus excelsa*. During the first few decades it is advisable that the small number of mature *Hagenia* and *Podocarpus* trees existing in the studied forests remain exempt from harvesting. The reason for this is that the few mature trees standing are the only seed sources available to bring about an increase in the recruitment of these species. However, cutting of *Hagenia* and *Podocarpus* should become possible as soon as the mature trees are competing with potential crop trees of the same species.

5.4.6.2 Demand and supply of wood products in the investigated forests

The user groups current level of wood consumption is far lower than the allowable cut. SCHMITT (2003) also highlighted an under-utilisation of wood from the user group forests after comparing the annual wood consumption with the allowable cut based on an annual increment of 1 m^3/ha/year. However, the current annual wood consumption rate per household, which was documented by SCHMITT (2003) and used in this study, did not include the sale of wood to generate additional income by the members of the user groups. As the official sale of wood products by the members of the user groups only started recently there are no adequate data to quantify the amount of wood they supply to the local markets. A general market survey conducted by the Adaba-Dodola integrated forest management project indicated that there is a decreasing trend in the amount of wood products coming from the natural forests due to regulated use by the user groups (AMEHA 2004). This implies that the user groups are more protective than exploitative. A similar observation was reported by AUS DER BEEK (1997) in Nepal. The technical advice from the forest service also tends to be protective.

From discussions held with members of the user groups it is understood that, in most cases, they are utilising trees that have fallen down or were left behind on the forest floor during past illegal logging. They are very cautious when it comes to cutting live trees for fear of causing a reduction of the forest cover, which results in the annulment of the agreement made with the forest service. This can be attributed to a lack of management guidelines containing minimum technical provisions for the management of forests handed over to the user groups. As the result, neither the user groups nor the experts from the forest service know how much can be extracted from the forests on a sustainable basis. Therefore, the allowable cut levels determined in this study are of great significance as an indication of the sustainable extraction limits. However, these need to be adapted and re-adjusted in the coming decades based on developments in the forests.

5.4.6.3 Liberation treatments and harvests

The main goal of the silvicultural treatments in the user group forests is to promote the growth of the potential crop trees by removing their competitors. According to NYLAND (2002), in forests that were previously not subject to planned management, treatments shouldn’t necessarily remove all less-than-perfect trees in a single intervention. Rather he advised a period of adjustment to progressively upgrade stand conditions and gradually develop balanced structures. In the context of the user group forests the first nine decades may be interpreted as a period of adjustment.

Up until the end of the ninth decade, improvement cuttings make up the great majority of the allowable cut. Liberation treatments conducted in Changiti forest revealed that liberating the potential crop trees from overtopping competitors accounts for 25 % of the mature trees harvested under the periodic allowable cut. Liberation cuttings designed to release the potential crop trees on all sides contribute 75 % of the mature trees harvested under the periodic allowable cut. Additionally, the liberation cuttings remove non-mature trees that can be utilised for different purposes. The choice between the two liberation treatments depends on the implementation capacity of the user groups and the forest service, which will be discussed later.

The remaining portion of the allowable cut, that is not the result of improvement treatments, can be met by harvesting mature trees in areas with a high density of mature trees and a closed canopy. This will open the canopy and initiate natural regeneration on the forest floor. As discussed in chapter 4, tree species like *Juniperus* cannot regenerate under the closed canopy of its mature trees. The complete lack of potential crop trees of *Juniperus* in a plot located in a park-type stand, in which the highest basal area is recorded, confirms this argument. The small gaps in the plot were occupied by broadleaf species, mainly *Rapanea*. In the absence of interventions it is likely that such stands will develop into broadleaf forests comprised of shade-tolerant species (BUSSMANN 2004).

5.5 MANAGEMENT OF GRAZING

5.5.1 Introduction

Grazing is still practised in traditional forest management systems in many parts of the world. In mountain environments, where agricultural activities are constrained by climate, animal husbandry is one of the livelihood options available to many farmers. In the Mediterranean region of North Africa, forest grazing is still a popular tradition (KARMOUNI 1997). Forest grazing is also widely practiced in Bhutan and Himalayan coniferous forests (RODER *et al.* 2002 and NORBU 2000). According to MAYER (2003), the multipurpose utilisation of forest resources including forest grazing has a long tradition in the Swiss Alps. It is also a very common practice in the montane forests of Ethiopia (TEKETAY and BEKELE 1995).

The issue of forest grazing cannot be discussed from a solely ecological or legal point of view. According to WANGCHUK (2002), the role of livestock in the socio-economic structure of the rural households has to be examined before making any decision. Livestock production is one of the main livelihood sources for the user groups living in the investigated forests. The forests are the main source of fodder for their livestock. Consequently, it is difficult to exclude grazing from the forest management system without disrupting livelihoods.

In this study the current livestock density was evaluated in relation to the sustainable stocking rate thresholds. Additionally, measures to be taken in order to integrate grazing into forest management are suggested.

5.5.2 Materials and methods

5.5.2.1 Estimation of the fodder production capacity of the forests

The fodder production capacity of the three user group forests was evaluated based on pasture studies conducted by BAPTIST *et al*. (2001). This study investigated the fodder production potential of three pastures in the Adaba-Dodola forest. The proportion of the pasture types and their respective annual dry matter yield was presented in Tab. 2.7. According to the report produced by the 'Woody biomass inventory and strategic planning project' (2001), 10 % of the area of the studied forests lies on slopes greater than 30 %. This part of the forests is considered inaccessible for grazing by livestock. Consequently, such areas were excluded from the estimation of the fodder production capacity of the forest areas.

5.5.2.2 Determination of sustainable livestock stocking rates

Stocking rates represent the amount of grazing stock that the pasture can support without degrading the resource, while keeping the livestock in a good condition (BOUDET 1975). A sustainable stocking rate for the user group forests was determined by matching the fodder production capacity of the forests and the number of livestock grazing in that area.

The current number of livestock grazing in the forests was investigated by SCHMITT (2003), which is already presented in Tab. 2.8. The livestock holdings of the user groups were converted to tropical livestock units. According to WEISER (1998), one tropical livestock unit (tlu) is equivalent to 250 kg live weight, which is approximately one head of cattle, or 10 sheep, 11 goats and 0.7 camels. It is assumed that horses and donkeys are the equivalent of a head of cattle.

Based on the fodder production capacity of the forests and the number of livestock units grazing in the forests, the stocking rate for the user group forests was determined as follows:

$$\text{Stocking rate} = \frac{\text{ADM (kg) per forest area}}{\text{DC x 365 days}}$$

where,

ADM = available dry matter. Based on the 'take half and leave half method' (PRATT and RASMUSSEN 2001): 50 % of the total biomass produced per hectare and year will be available to livestock with the rest left on the pasture to avoid overgrazing.

DC = daily consumption by one tropical livestock unit, which is 6.25 kg of dry matter/day (WEISER 1998). It was also assumed that the livestock graze in the forests throughout the year.

5.5.3 Results

5.5.3.1 Fodder production potential of the forest areas

The fodder production capacity of the three forest areas showed variation in the order of their size (Tab. 5.13).

Table 5.13: Fodder production in selected user group forests

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Size of the forests	ha	364	554	489
Fodder production in dry matter	tonnes/ha	1028	1556	1391
Fodder available to livestock	tonnes/ha	514	778	696

5.5.3.2 Potential and current stocking rates

The potential stocking rates for the three forest areas were obtained based on the amount of fodder available to the livestock in the respective forests and the annual consumption of a livestock unit. The potential of the forest areas showed differences in the order of their respective sizes (Tab. 5.14).

Table 5.14: Potential and current stocking rates in tropical livestock unit (tlu)

DESCRIPTION	UNIT	FOREST AREA		
		JALDO	CHANGITI	GEDE
Potential stocking	tlu	225	341	305
Current stocking	tlu	160	162	308
	%	*71*	*48*	*101*

The current livestock population is almost the same for Jaldo and Changiti forests while the livestock density in Gede forest is almost twice that of the other two forest areas. However, the stocking percent in Jaldo forest is higher than Changiti forest although they have a similar livestock population. This is because of the difference in the fodder production capacity of the two forests (compare Tab. 5.12). The current stocking rate in Gede forest is at its maximum limit, which implies the need to control any further increases to avoid the effects of overgrazing.

5.5.4 Discussion

5.5.4.1 Integrating grazing into forest management

Opinions among foresters, livestock experts, ecologists and communities on grazing as a forest function are still divided. Many foresters believe that cattle grazing and timber production are not compatible. The main argument raised against forest grazing is that animals may damage young regrowth by trampling and browsing. However, the magnitude of damage varies with tree species and the type of animals.

In the investigated forests the two indigenous conifers, *Juniperus excelsa* and *Podocarpus falcatus*, are reported to be less sensitive to browsing, except in situations where there is a shortage of fodder (TESFAYE *et al*. 2002 and TADESSE 1999). *Hagenia abyssinica*, on the other hand, is the species most preferred by all types of livestock. Studies conducted in the mountain forests of the Swiss Alps also indicated that conifers are less sensitive to browsing than deciduous trees (MAYER *et al*. 2003a). Studies conducted in mixed coniferous forests in central Bhutan concluded that browsing damage due to grazing was negligible for conifer species (RODER *et al.* 2002). Therefore, grazing can be integrated into forest management at the lower and middle altitudes of the investigated forests where conifers are the dominant species, provided that the stocking rates do not exceed the sustainable limit set for the forest area. At the upper altitude, where *Hagenia* is dominant, a certain portion of the forest areas should be strictly protected from grazing until the young plants are above the reach of the animals.

The user group forests are characterised by the existence of wooded and open pastures providing different types of fodder. MAYER *et al*. (2003b) reported that a mosaic wood pasture provides herbage of a sufficient quantity and quality that animals are able to select the palatable types.

It is expected that the proposed relatively open forest structure will at least maintain the current fodder production capacity of the user group forests. Additionally, improvement treatments such as pruning and thinning are expected to maintain the space necessary for grazing.

Meanwhile, forest grazing can have also the following benefits provided that it is regulated:

- Diversifying the income sources of the user groups, which in turn reduces their dependence on wood extraction,
- reduction of the fire hazard by minimising the ground vegetation,
- promotion of seed dispersal through movement of animals in the forest,
- enhancing seed germination by disturbing the organic layer and uncovering the mineral soil.

Therefore, grazing can be integrated into the management of the user group forests provided that it is regulated. Measures to regulate it are discussed in the following section.

5.5.4.2 Measures to regulate grazing

To ensure the continuous recruitment of potential crop trees, which are crucial for the continuity of the forests, the type and intensity of grazing should be regulated by implementing feasible measures. The following measures are suggested:

- **Monitoring stocking rates**

The study showed that the current livestock stocking rates in two of the three forest areas are lower than the potential of the respective forests. In Gede forest the current livestock population is at its maximum limit. This implies any further increase in the livestock numbers will have negative impacts on the forest. According to MAYER *et al*. (2003a), the impact of grazing increases with the increase in stocking. Therefore, the monitoring of stocking rates and periodic forest inventories in the user group forests should occur simultaneously. Moreover, the user groups should be encouraged to improve their livestock husbandry system by focusing on the quality of production rather than the number of animals.

- **Rotational grazing**

Although the current stocking rates are not beyond the sustainable limit, the prevailing patchy type of grazing exerts high pressure in some areas while others are not efficiently utilised. Areas close to the settlements and watering points are more frequently grazed by livestock than the remaining parts. Consequently, these areas are over-grazed and devoid of regrowth. Therefore, to distribute the grazing pressure over the entire forest area and efficiently utilise the available pasture in the forests the implementation of a rotational grazing regime is advisable. This can be established based on the existing seasonal shifting of animals between the different pasture types. Open pasture areas, forest and farmlands are some of the areas upon which a traditional grazing regime are exercised.

As discussed in relation to the improvement treatments, 10 % of the forest area should be regenerated every decade. Such areas should remain exempt from grazing until the young regrowth is above the browsing zone. This will increase the chances for establishment of susceptible tree species such as *Hagenia*. Rotational grazing will be practiced on the remaining 90 % of the forest area. In areas where grazing is permitted young plants < 2 m height should be fenced individually or in groups using thorny shrubs, branches of trees or other materials available in the forest in order to prevent damage.

- **Restricting grazing rights for certain livestock types**

The damage caused by grazing varies according to the livestock types. Goats are regarded as the most dangerous in relation to the browsing of young plants. Recognising this problem, most of the user groups in the study area have already banned goats from the regeneration areas. According to MAYER (2003), forest grazing rights in the Swiss forests apply only to cattle, which ultimately discouraged farmers from keeping goats. Therefore, user groups should be encouraged to exclude from their herds livestock types that aggressively browse young plants.

The effect of wild ungulates in browsing young plants should not be ignored either. MAYER *et al*. (2003a) reported that the browsing effect of wild ungulates is three times higher than that of cattle. As witnessed by the members of the user groups, the population of wild animals is increasing after they took over the management of the forests because of reduction in poaching. This in turn increases the threat of browsing. The introduction of controlled hunting will minimise this impact while also generating additional income for the user groups.

5.6 OPERATIONALISATION OF THE PROPOSED INTERVENTIONS

5.6.1 Establishing forest management units

For operational purposes and the coordination of management activities it will be necessary to establish management or working units. Forest management units are usually established based on forest type, age, species and physical features. The spatial analysis of the forest areas, as discussed in chapter 4, showed the mosaic nature of the forests. There is an intermingling of different forest and land use types which makes the establishment of management units based on these features difficult.

The alternative is to establish management units following easily recognisable physical and natural features (rivers, ridges, valleys, trails). It is obvious that such units will not have homogenous conditions. They are, however, recognisable and manageable by the user groups. In the initial stage such units provide greater flexibility until the user groups gain in experience and are able to establish more homogenous units. It is also expected that management interventions in the coming decades will harmonise the variation within the management units by regenerating deficient areas and tending areas with sufficient regrowth. Consequently, the initial management units can be re-adjusted later and sub-units can be created based on experience gained from previous years.

Once established the management units can be used as a basis for rotational grazing. The period of grazing in each unit can be determined based on the size of the units and the availability of pasture. Therefore, the user groups should be encouraged to divide their forest into management units to better plan and coordinate their management interventions.

5.6.2 Periodic working plan

In order to achieve the target set for the overall planning period it is important to develop periodic working plans. The periodic plans should be established and re-adjusted based on the input from the periodic forest inventories providing information about the intervention demand in a particular forest area. Currently there is a periodic forest assessment going on by the forest service and the user groups at an interval of five years. This assessment provides general information about the changes in the forest conditions on the basis of which the contractual terms agreed between the user groups and the forest service are monitored. This five year interval is specified in the contract agreements. At the same time, the inventory is also designed in such a way that it provides information about the recruitment rate of the potential crop trees and availability of mature trees in the forests. Therefore, the results of every second assessment can be used to produce a periodic plan for the coming ten years.

The periodic working plan outlines general activities that should be conducted in the coming ten years on the basis of which a detailed annual operational plan is derived. The type and amount of activities to be conducted in the forests may vary based on the intervention demand of the respective forest areas. However, the following general targets can be used as starting point:

- Regenerating at least 10 % of the forest area per decade. The area set aside for regeneration per decade can be less or more provided that the whole forest area will be covered at the end of the planning period. Priority should be given to areas which are lacking in potential crop trees,
- conducting improvement treatments over the entire timber utilisation area. This includes selecting and liberating at least twenty potential crop trees/ha, pruning them and conducting selective thinnings in even-aged groups,
- undertaking periodic forest inventories to monitor stand development,
- adjusting allowable cut and improvement treatments for the coming decade based on information gained from inventories and field experience.

5.6.3 Annual operational plan

The annual operational plan will be derived from the periodic working plan. It contains a detailed list of the activities and specific silvicultural treatments to be carried out annually in order to achieve the targets set in the periodic plan. At least 10 % of the area under timber utilization area should be tended annually in order to cover the whole forest area in one period. The following steps are suggested for tending activities:

1. Select potential crop trees giving priority to threatened or rare species.
2. Cut/girdle competitors based on the intensity determined for respective forest areas.
3. Thin even-aged groups where there are signs of crown competition. Always favour the more vigorous young plants.
4. Prune the potential crop trees. Pruning should take place after other improvement treatments in order to minimise the number of pruned trees damaged. Altogether 2-3 successive pruning operations are required before the crop trees reach maturity.
5. Protect young plants from browsing based on measures discussed earlier.

6. Transplant wildlings from areas with high densities to areas lacking in regrowth within the natural occurrence range of the species. This method is cost effective in addition to enhancing the use of site-adapted provenances.

5.6.4 Implementation capacity

The successful implementation of silvicultural treatments in selection forests requires trained personnel. During demonstrations of silvicultural treatments it became clear that the user groups are highly interested in implementing the treatments and learning more about the procedures involved. They are committed to investing their time and labour in forest management activities. However, they have very limited skills in relation to the proposed improvement treatments. Furthermore, their tools are generally not of an appropriate quality, type or state of maintenance.

The experts from the district forest service are expected to play a catalyst role, assisting the user groups in the implementation of the silvicultural treatments and in refining them. However, they too have no practical experience of how to carry out the proposed interventions. Therefore, building the capacity of the user groups and local experts is a crucial factor in the successful silvicultural management of the forests. The following are important areas for training:

- Selection, marking and liberation of the potential crop trees,
- low impact logging to reduce damage to the young trees while felling the existing over-mature trees,
- efficient timber processing with locally available tools,
- tool handling and maintenance.

5.7 CONCLUSIONS

The findings of the study indicate that the multiple uses of the forests can be maintained and integrated provided that certain uses are regulated. To this end, the need to protect riparian zones has been highlighted. The protection of these areas is beneficial not only to the user groups but also to a wide range of other stakeholders. Therefore, beneficiaries of the system should support the conservation efforts of the user groups.

Currently, the wood consumption rate of the user groups is lower than the sustainable allowable cut threshold determined in this study. At the same time, the current status of the forests is significantly lower than their production potential. To make the conservation efforts of the user groups even more beneficial and to accommodate the growing needs of the user groups it is necessary to improve the productivity of the forests. To achieve this goal, the introduction of a potential crop tree focused system of silvicultural management is suggested. Improvement treatments in line with the features of the system and which can be implemented using locally available facilities are provided. Nevertheless, the successful implementation of the proposed treatments requires practical training, both for members of the user groups and for the forest experts.

Grazing management is a crucial task facing the user groups if they are to sustainably manage their forests. When regulated, forest grazing can serve as management tool in addition to its contribution to livelihoods. To realise these benefits grazing in the user group forests should be regulated by implementing the measures proposed here.

6 GENERAL DISCUSSION AND CONCLUSIONS

6.1 OVERALL STUDY RESULTS

The findings of this study revealed that the investigated forests have the potential to be transformed into managed selection forests, relying predominantly on minimum input natural processes. The forest areas selected for this study represent the major forest types and species occurring in the study area, although the proportion of the forest types may vary from one user group forest to another. The user groups included in this study also share the same socio-economic background with the remaining user groups in the area. Therefore, the silvicultural management principles and interventions proposed in this study can be adopted in the other user group forests with some adjustments.

6.1.1 Optimum number of crop trees

The study conducted into the crown development of the dominant timber species indicated that about 200 crop trees/ha of different ages and species can be maintained in the investigated forests when the grazing needs of the user groups are taken into account. According to LAMPRECHT (1989), 100-300 evenly distributed potential crop trees are sufficient in number in the context of improvement systems geared towards achieving sustainable management. It is expected that the tree density indicated will create an open forest condition, facilitating the growth of adequate fodder on the forest floor. Moreover, the implementation of improvement treatments such as thinning and pruning will regulate the stand density and maintain the growing space necessary for the purposes of timber production and grazing. However, the relationship between the proposed number of crop trees and the forest undergrowth should be monitored and adjusted based on experience and research inputs.

6.1.2 Silvicultural potential of the user group forests

Forest management cannot be successful or sustainable without an accurate assessment of the forest condition, its capacity to meet the demands of the users and the needs for silvicultural treatments (AUS DER BEEK 1997). The findings of this study revealed that the current status of the user group forests is less than their production potential. The forests are stocked with over-sized trees of poor quality and low value. Such trees not only occupy a huge amount of the available growing space but also suppress the growth of potential crop trees. Nevertheless, about 30-45 % of the areas of the investigated forests possess a sufficient number of potential crop trees and a considerable proportion of the remaining area hosts a moderate number of potential crop trees. This provides the opportunity to improve the productivity of the forests by promoting the growth of the potential crop trees while gradually utilising the available mature trees.

6.1.3 Silvicultural management of the user group forests

The review of the socio-economic conditions disclosed that the user groups depend on the investigated forests for multiple products and services. Harmonising and optimising these functions is a process that cannot be achieved in one go. Equally important is the need to match the demand for different products and services with the potential of the forests to produce. The findings of this study showed that the current levels of wood consumption and grazing do not exceed the sustainable threshold. However, with an increase in the population of the user groups there will be an increase in the demand for the products and services derived from the forests. Consequently, the productivity of the existing forests needs to be improved, both in terms of the quantity and the quality of production in order to accommodate the growing needs of the user groups.

Based on the management objectives, the socio-economic demands and the current status of the forests a single tree selection system is deemed an appropriate means to transform the user group forests into managed selection forests. Adhering to the overall guidelines of this system, a potential crop tree focused form of forest management will be implemented to promote the growth of the young trees that remain in the forests rather than the already mature trees to be harvested. Under this system, nature-based silvicultural techniques requiring a minimum external input will be employed. According to DAWKINS and PHILIP (1998), the use of natural regeneration for stand establishment is a low risk investment requiring little capital.

Therefore, the silvicultural management of the user group forests is based on the following principles:

- Promotion of the existing potential crop trees,
- harvesting mature and over mature trees that compete with the potential crop trees,
- relying on natural regeneration for stand establishment.

However, grazing should be regulated to ensure the continuous recruitment of young regrowth in sufficient quantities.

6.2 OPPORTUNITIES AND CONSTRAINTS

6.2.1 Opportunities

There currently exists an official local wood market for the user groups so that they can sell their products legally. A regulated supply of the products by the user groups combined with controls on illegal wood transactions by the forest service has resulted in increased prices paid for wood products stemming from the natural forests. According to AMEHA (2004), the price of wood products originating from natural forests has increased by 39 % in comparison to when access to the forests was open. Moreover, the user groups are organising themselves into forest cooperatives, a means of strengthening their institutional capacity and bargaining power in order to make use of the opportunities available. An increase in the benefits arising from the system in turn builds the confidence of the user groups and encourages them to enter into sustainable management of their forests.

6.2.2 Constraints

Successful implementation of silvicultural treatments in selection forests requires trained personnel. The user groups and the local experts are very interested in engaging in the correct silvicultural management of the forests. However, they lack practical experience with respect to the proposed silvicultural treatments. The socio-economic studies conducted by SCHMITT (2003) indicated that labour and time are not limiting factors in the management of user group forests. Therefore, on-site training of the user groups and the local experts is a crucial factor for success.

Improving the forest management techniques alone does not guarantee increased benefits from the system unless efficient processing techniques are put in place. The existing on-site conversion of logs through pit-sawing and the transportation of the products manually and using animals is well suited to the harvesting of individual trees scattered throughout the forests. Nevertheless, the efficiency of the method is very low. According to DEMESA (2002), the recovery rate of the traditional pit-sawing technique is 30 %, which implies that there is a lot of wastage. Most of the available tools are of low quality and poorly maintained, which hinders the user groups and prevents them from enjoying greater benefits from their management efforts. This implies the need for training in relation to tool handling and maintenance, and at the same time highlights the necessity to upgrade the processing capacities of the user groups.

6.3 MONITORING AND ADJUSTING THE MANAGEMENT PRACTICES

Planned silvicultural intervention is a novelty in the forests under consideration. Additionally, the silvicultural recommendations made in this study are based on several assumptions made necessary by the lack of relevant information. Therefore, the proposed treatments need to be refined through repeated experimentation, monitoring, and re-adjustments. The establishment of demonstration and experimental plots will help to illustrate the procedures involved in the silvicultural treatments and to monitor their effects on the growth of the forests. The information generated from the experiments will in the long run also contribute towards the improvement of forest management planning in the region.

The improvement treatment plots established during this study can be used as demonstration and experimental plots. However, they are not sufficient given the increasing number of user groups in the study area. More plots should be established in the other forest areas also. Once established the plots can serve as a classroom where the user groups and experts continuously learn how to fine-tune the silvicultural practices.

6.4 RESEARCH NEEDS

- **Growth rate of the dominant species**

There is a big gap in relation to silviculturally relevant information with respect to the growth dynamics of the species occurring in the forests. This is one of the major constraints on the sustainable management of the natural forests in Ethiopia. As it is difficult to investigate the potential of all of the species occurring in the forests at the same time, it is important to focus on the dominant species with greater socio-economic importance initially. The demonstration and experimental plots established during the course of this study can serve as starting points in the monitoring of the growth rate of the dominant timber species. The current protection status of the user group forests also facilitates conditions favourable to the establishment of more research plots.

- **Effects of silvicultural treatments on forest undergrowth and non-wood products**

At the moment, the impact of the proposed silvicultural treatments on the forest undergrowth and non-wood products is unknown. Therefore, the impact of the different treatments and proposed crop tree density on the type, quantity and quality of undergrowth should be investigated. The impact on the production of non-wood forest products should also be investigated.

- **Economic aspects**

Further research into the costs and benefits related to the silvicultural management of the user group forests is necessary. To make the conservation efforts of the user groups even more beneficial it is also important to assess the current forest production chain and to promote value adding activities. The outcome of such studies helps to establish a demand driven forest management.

- **The impact of wildlife on natural regeneration**

It is common practice to place the blame for damage to young plants on domestic livestock that graze in the forest seasonally. However, the impact of wild animals inhabiting the forests throughout the year is usually ignored. Therefore, investigating and understanding the level of damage caused by wild animals will help in the development of corrective measures.

7 SUMMARY

7.1 SUMMARY

The livelihoods of the people living in rural Ethiopia is closely linked to the utilisation of natural resources, particularly forests. However, the exclusion of local people from decisions relating to the use and management of the forests has resulted in a situation whereby they utilise the forest resources illegally and feel no responsibility for the condition of the forests. Consequently, the country's forest resources are diminishing while the demand for forest products and services is increasing.

One possible approach to reverse this trend is to involve forest-dependent communities in decisions made on how best to manage the forests in their locality. This is now a common trend in developing countries in general and in Ethiopia in particular. The forest user groups in the Bale Mountains of Ethiopia are possibly the good example of this, now responsible for the successful management of the previously state-owned Adaba-Dodola forest.

However, the forests placed under the user groups' management are degraded and unproductive. The rehabilitation and sustainable management of the forests require careful planning and the implementation of silvicultural improvement treatments. The user groups are demanding practical technical support from the forest service on how to improve the production potential of their forests. There is little technical expertise available in this regard, however. Therefore, the overall objective of this study is to contribute to the rehabilitation and sustainable management of degraded community forests in Ethiopia by providing locally adapted silvicultural tools and recommendations. The specific objectives of the study were to:

- understand the socio-economic preconditions for silvicultural management,
- estimate the crown development of the dominant timber species,
- investigate the abundance and distribution of young regrowth and mature trees,
- provide silvicultural tools to transform the existing degraded forests to managed selection forests,

- propose a multiple use management system that integrates wood production and grazing while maintaining the other functions of the forests.

A greater understanding of and desire to use the results of the study depended on the active involvement of the user groups during the research process. Therefore, a participatory action research approach is employed, involving the key stakeholders in order to recognise the most pressing problems and to develop workable solutions. This has enabled the user groups to start implementing some of the recommendations made during the course of this study already.

Silvicultural management requires a profound understanding of the existing legal framework, socio-economic and ecological forest conditions. Project reports produced by the Adaba-Dodola integrated forest management project, previous socio-economic studies and the existing forest-related proclamations were reviewed to attain the information required for the silvicultural management of the user group forests.
Furthermore, a detailed inventory of the forest conditions was conducted to determine the abundance and distribution of potential crop and mature trees. The crown development of the dominant species was also investigated.

The study conducted on crown development of the dominant timber species indicated that about 200 crop trees per hectare of different ages and species can be maintained in the investigated forests and at the same time accommodate the grazing needs of the user groups. To attain the optimum number of crop trees for the planning period of 100 years, a minimum recruitment rate of 10.5 % every decade is deemed sufficient. The results of forest inventories conducted in the three forest areas revealed that about 30-45 % of the total area of the investigated forests possess a sufficient number of potential crop trees (≥ 20) while a considerable proportion of the area hosts a moderate number of potential crop trees (5-15). While tending the existing potential crop trees it is also possible to regenerate poor regrowth areas. To achieve this goal, a potential crop tree focused management system is suggested, within the framework of a single tree selection system.

Within the scope of the system, improvement treatments that can be implemented using locally available facilities are prescribed.
The improvement treatment and allowable cut levels are also determined for the investigated forests. However, the successful implementation of the proposed treatments requires practical training, both for the members of the user groups and for the forest experts employed by the forest service.

To maintain and harmonise the manifold functions of the forest a multiple use forest management system is proposed. This also requires that grazing be regulated. The exemption of riparian zones from logging and the preservation of the aesthetic values of the forests are emphasised as well.
Finally, the need to monitor the silvicultural interventions, to re-adjust the proposed management practices where necessary, and the need for further research to fill the current knowledge gaps are highlighted.

7.2 ZUSAMMENFASSUNG

Der Lebensunterhalt der ruralen Bevölkerung Äthiopiens ist eng mit der Nutzung natürlicher Ressourcen, insbesondere von Waldprodukten, verbunden. Nichtsdestotrotz wird die lokale Bevölkerung nicht an Entscheidungen bezüglich der Nutzung und Bewirtschaftung der Wälder beteiligt, was dazu geführt hat, dass die Waldressourcen illegal genutzt werden und die Menschen keine Verantwortung dafür übernehmen, in welchem Zustand sich die Wälder befinden. Folglich gehen die Waldressourcen des Landes verloren, während gleichzeitig die Nachfrage nach Waldprodukten steigt.

Ein möglicher Ansatz um dieser Entwicklung entgegen zu treten ist, die von den Waldprodukten abhängigen Gemeinden in Entscheidungsprozesse einzubeziehen, um zu ermitteln wie die örtlichen Wälder bestmöglich bewirtschaftet werden können. Dies entspricht dem Trend in Entwicklungsländer allgemein ebenso wie speziell in Äthiopien. Die Waldnutzergemeinschaften in Äthiopiens Bergregion Bale stellen möglicherweise das beste Beispiel hierfür dar. Sie sind heute für die erfolgreiche Bewirtschaftung des ehemals staatlichen Adaba-Dodola Waldes verantwortlich.

Allerdings sind die von den Nutzergemeinschaften bewirtschafteten Waldflächen degradiert und unproduktiv. Für die Rehabilitierung und nachhaltige Bewirtschaftung dieser Wälder ist eine vorsichtige Planung notwendig, ebenso wie die Umsetzung und Kontrolle der waldbaulichen Tätigkeiten. Die Nutzergemeinschaften fordern von der Forstverwaltung praktische technische Unterstützung, um das Produktionspotential ihrer Wälder verbessern zu können. Es steht jedoch nur wenig technisches Fachwissen zur Verfügung. Demzufolge ist das übergeordnete Ziel dieser Arbeit, einen Beitrag zur Rehabilitation und nachhaltigen Bewirtschaftung der degradierten Gemeindewälder in Äthiopien zu leisten, indem an die örtlichen Verhältnisse angepasste waldbauliche Maßnahmen und Empfehlungen herausgearbeitet werden. Die einzelnen Ziele der Arbeit sind:

- Die sozio-ökonomischen Voraussetzungen für die waldbauliche Bewirtschaftung zu verstehen,
- Die Kronenentwicklung der dominanten Baumarten zu untersuchen,
- Die Abundanz und Verteilung des Jungwuchses und der Bäume zu untersuchen,
- Waldbauliche Maßnahmen zu entwickeln, mit deren Hilfe die degradierten Wälder in bewirtschaftete Plenterwälder überführt werden können,
- Ein multifunktionales Bewirtschaftungssystem zu entwickeln, welches Holzproduktion und Waldweidenutzung unter Beibehaltung anderer Funktionen des Waldes miteinander verbindet.

Damit die Nutzergemeinschaften ein besseres Verständnis der Forschungsergebnisse erlangen und diese bereits während des Forschungsprozesses umsetzen können, wurden sie aktiv in den Forschungsprozess eingebunden. Deshalb wurde ein partizipatorischer Forschungsansatz gewählt, welcher die wichtigsten Akteure einbezieht, um die vordergründigsten Probleme zu identifizieren und praktizierbare Lösungen zu entwickeln.

Waldbauliche Bewirtschaftung verlangt im Vorfeld eine Auseinandersetzung mit den geltenden rechtlichen Rahmenbedingungen und den sozio-ökonomischen sowie den ökologischen Bedingungen. Projektberichte des Adaba-Dodola integrierten

Waldbewirtschaftungsprojekts, sozio-ökonomische und waldbewirtschaftungsrelevante Studien wurden analysiert, um die nötigen Informationen zur Ausarbeitung der waldbaulichen Bewirtschaftungsmaßnahmen für die Waldflächen der Nutzergemeinschaften zusammenzutragen.

Darüber hinaus wurde eine Inventur des Waldzustands durchgeführt, um die Abundanz und Verteilung von potentiellen und vorhandenen Z-Bäumen. Die Kronenentwicklung der dominanten Baumarten wurde ebenfalls untersucht.

Die Untersuchung der Kronenentwicklung zeigte, dass pro Hektar etwa 200 Z-Bäume verschiedener Altersklassen und Baumarten in den untersuchten Waldflächen ausreichen, wenn gleichzeitig die Waldweidenutzung beibehalten werden soll. Um die optimale Zahl an Z-Bäumen für eine Planungsperiode von 100 Jahren zu erreichen, müssen mindestens 10,5% jede Dekade nachwachsen. Die durchgeführte Waldinventur zeigte, dass auf etwa 30-45% der untersuchten Gesamtfläche eine ausreichende Anzahl an potentiellen Z-Bäumen vorhanden ist und ein beachtenswerter Anteil der Fläche eine akzeptable Anzahl an potentiellen Z-Bäumen aufweist. Folglich ist es möglich, Flächen mit einer zu geringen Jungwuchsdichte zu regenerieren, während gleichzeitig vorhandene potentielle Z-Bäume gepflegt werden. Hierfür wird ein Z-Baum orientiertes Bewirtschaftungsverfahren empfohlen. Als Bestandteil des Verfahrens werden unter Ausnutzung der örtlich zur Verfügung stehenden Möglichkeiten qualitätssteigernde Pflegemaßnahmen vorgeschlagen.

Die Pflegemaßnahmen und Hiebsätze werden für die untersuchten Wälder ebenfalls definiert.

Allerdings ist für die erfolgreiche Umsetzung der aufgezeigten Pflegemaßnahmen eine praktische Ausbildung notwendig; für die Mitglieder der Nutzergemeinschaften ebenso wie für die fachlich ausgebildeten Mitarbeiter der Forstverwaltung.

Um die Vielzahl der Waldfunktionen beizubehalten und miteinander in Einklang zu bringen, ist ein multifunktionales Waldbewirtschaftungssystem empfehlenswert. Dies beinhaltet auch, dass die Waldweidenutzung reguliert werden muss. Zusätzlich wird empfohlen Gewässerrandstreifen aus der Bewirtschaftung zu nehmen. Die Art der Bewirtschaftung bewahrt außerdem den ästhetischen Wert der Wälder.

Abschließend wird betont, wie wichtig es ist, den Einfluss der waldbaulichen Eingriffe zu beobachten und die vorgeschlagenen Bewirtschaftungsmaßnahmen gegebenenfalls anzupassen und die noch bestehenden Wissenslücken zu füllen.

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