Minor Field Studies No 272

Social and environmental issues on the removal of fuel-wood and litter from Eucalyptus stands around Addis Abeba, Ethiopia

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Uppsala, August, 2004
ISSN 1402-3237

Acknowledgements

I would like to acknowledge four people who have been important in this study. First, I would like to thank my supervisor Professor Mats Olsson at the Department of Forest Soils, for his constructive guiding and interest. Secondly, I would like to express my gratitude to PhD Student Mulugeta Zewdie for his assistance during my fieldwork in Ethiopia. He demonstrated great generosity in time and involvement. I also want to mention my gratitude to Professor Fisseha Itanna, Department of Biology at the University of Addis Ababa. His positive attitude and easy-going character helped me in my acclimatization to Ethiopia. At last I want to express my deepest gratitude to my fiancée Monica Olmeda, for here patience and support during the fieldwork.

Abstract

The demand for energy in Ethiopia is high and 95% of the used energy is biomass energy. To meet this demand eucalyptus plantations have been established around the urban centers. The high demand for fuel wood has led to a situation where all biomass is removed. The eucalyptus forest is clear-cut every seven years. In addition to official management activities there is also an extensive removal of shoots and litter. This study has looked at litter-raking and fuel wood collection and how the removal of these plant parts affects soil properties. The hypothesis was that the shoots and litter removed contain a considerable amount of nutrients, and the removal of these components contributes to depletion of soil nutrients. The study has quantified the amount of biomass removed per hectare and year in eucalyptus plantations north of Addis Ababa (i.e. Mt. Intoto). The plant parts have later been categorized into subcomponents and separately analyzed in terms of carbon, nitrogen, phosphorus, potassium, calcium, sodium and magnesium. The total removal of nutrients per hectare and year is then related to the soil nutrient pool.

Keywords: eucalyptus, litter removal, soil properties, nutrient status, Addis Ababa

Tables

Figures

Appendixes

Table of contents

1. Introduction

1.1. Background

Ethiopia is one of the poorest countries in the world and the demand for fuel wood is high. Biomass fuel contributes to 95 % of the total energy consumption in Ethiopia. Furthermore, 96.2% of the total consumption of the biomass fuel is used in the household sector; i.e. as firewood (Bekele. W. 2002). This has led to an increasing deficit of fuel (Mariame 1996). Some studies suggest that 90 percent of the annual forest harvest is used as firewood. Most households in Ethiopia use traditional means to prepare their food. A study from the town of Kelle in Southern Ethiopia shows that up to 91 % of the households use an open fire for cooking and baking. The same study states that 91 % of the households use BLT (branches, twigs and leaves); which makes BLT the most important category of fuel wood (Bekele W 2002). The deficit at the present time (2003) is estimated to $32.5*10^6$ m^3 per year (fig. 1). The demand is likely to increase and is believed to double between year 2000 and 2014 (Bekele M 2003).

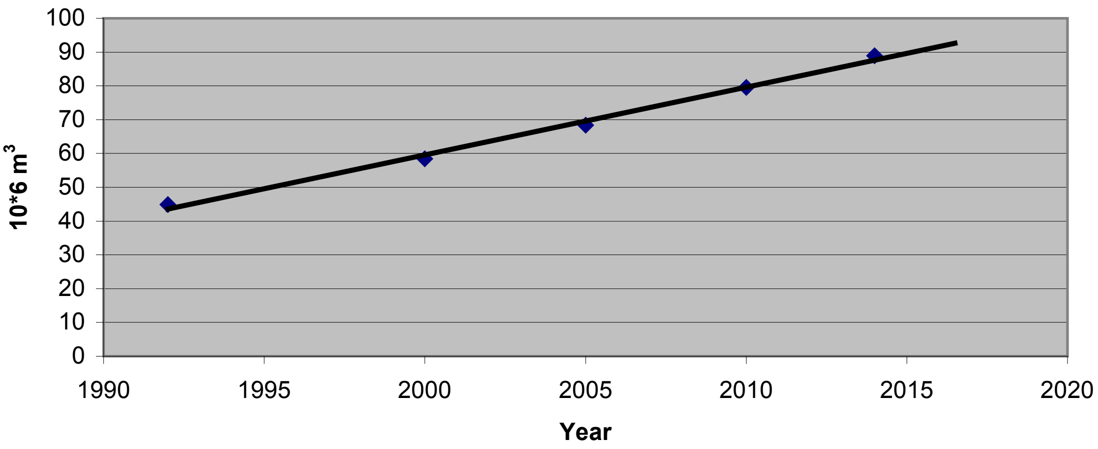

Figure 1. The present demand and the estimated future demand of fuel wood in Ethiopia. (Bekele M 2003)

Ethiopia was never really colonized even though the Italians occupied the country between 1936 and 1941. After the Italians captured the capital in May 1936, the Italians immediately started an ambitious plan of infrastructure and economic development, which also included the forestry sector. Within four years 7000 km of roads were constructed, including more than 8000 bridges and viaducts. The Italian workforce was as large as 60,000 men at any given time. The purpose of this massive construction work was to open up the country's natural resources for exploitation. It was during this Italian interlude that "modern forestry" activities started in Ethiopia. The administration called "Milizia Forestale" had branches in many parts of the country. The Militias duties were defined as supervision of forest exploitation (by the local people), inventory, silvicultural and reforestation work (Bekele 2003).

The natural forest of Ethiopia mainly consists of broadleaf trees mixed with conifer species such as *Juniperus procera and Podocapus falcutus* (Teshome 1998). To meet the increasing demand for firewood Emperor Menenlik II (1889-1913) introduced eucalyptus as fuel-wood species already in late 1880. A French railway engineer

(Mondo-Vidaillet) was employed and he established plantations of 15 eucalyptus species, mainly Bluegum eucalyptus (*Eucalyptus globulus* (Fig. 2). The total area planted with eucalyptus in Ethiopia today is more than 100 000 hectares (Henry 1973). These plantations are mostly located around cities and the largest plantation is nowadays located around Ethiopia's capital Addis Ababa. This is due to the fact that the demand for fuel wood is particularly high close to urban centers such as Addis Ababa with a population of 5 million people. The eucalyptus plantations North of Addis Ababa (i.e. Mt. Intoto region) have a total area of approximately 12 000 hectares (Based on available maps).

Figure 2. Eucalyptus globulus

The Bluegum eucalyptus is native to Australia and its neighboring islands. *Eucalyptus globulus* is one of the most widely cultivated of Australia's native trees. It well established in all continents apart from the South Pole. *Eucalyptus globulus* is a medium to very tall forest tree, and has the potential to reach a height of 70 meters under ideal conditions; but is more commonly 15-25 meters. The trunk can reach 2 meters in diameter. The tree has a rough, grayish bark, which is shed on the upper trunk and branches in long ribbons. (http://farrer.riv.csu.edu.au/ASGAP/e-glo.html), Bluegum eucalyptus is an important source of fuel wood in many countries. Its high productivity and low requirement make it unique as a fuel wood species. It burns freely, leaves little ash, and produces good charcoal. It is also widely used as pulpwood. The wood is unsuitable for lumber because of excessive cracking, shrinkage and collapse after drying. (http://www.fs.fed.us/database/feis/plants/tree/eucglo/management_considerations.html

1.2. Management

The eucalyptus production around Addis Ababa is generally based on coppice shoots. Up to 2000 stumps per hectare with an average of 4 shoots per stump (Woldu 1998) give a high potential for biomass production up to 46.6 m^3* ha^{-1}*$year^{-1}$ (Teshome 1998). The trunks are harvested during a clear-cut every 7^{th} year. All types of plant material are removed during the harvest: trunks, branches, twigs and leaves. Only the stumps are left to generate numerous coppice shoots (Fig. 3). On average, 4-5 shoots are left to grow until the next clear-cut. A thinning operation is done after 3-4 years. The productivity of stumps decreases from one generation to the next, and after five generations it is not considered to be sufficiently high. When the next plantation is to take place, stumps might be removed, but this has anyhow not yet generally occurred in the Addis Ababa area because the stumps still are sufficiently productive. The stumps contain a considerable amount of biomass because the trunks are cut about 0.5-1 meter above the forest floor. That is one of the reasons why officials want to remove the stumps; the stumps could be used as fuel. Secondly, the stumps are predicted to cause future problems when planting and harvest are to take place.

Figure 3. Harvest of the eucalyptus. The coppice shoots on the stumps can be seen in the foreground.

In addition to this official harvest and management there is also a non-official harvest of litter, shoots, and harvest residues. This activity is referred to as litter raking. People will literally go out and rake the forest floor for litter (Fig. 4). This is an effect of the extreme scarcity of fuel. Everything is collected, even dry leaves and twigs. Litter raking and fuel wood gathering is a continuously ongoing activity. A study by "Forest project 4[1] states that approximately 15000 people gather eucalyptus fuel wood and litter on a daily basis around Addis Ababa. Many of these people are assumed to be dependent upon access to eucalyptus biomass, either through the use of eucalyptus fuel in the own household or through collection for commerce.

Figure 4. A young brother and sister are busy collecting litter from the forest floor.

2. Hypothesis and aims

The main hypothesis for the study is that shoot and litter components that are removed through fuel wood collection and litter raking contain a large amount of nutrients, resulting in a significant loss of nutrients and organic matter from the sites, and thereby have a negative impact on soil properties.

[1] Forest project 4 is the state forest enterprise responsible for the forest management around Addis Ababa.

The overall aim of the study is to quantify the amount of nutrients being removed from the eucalyptus plantations through fuel wood collection and litter raking. This is called "non-official removal" (Fig. 5).

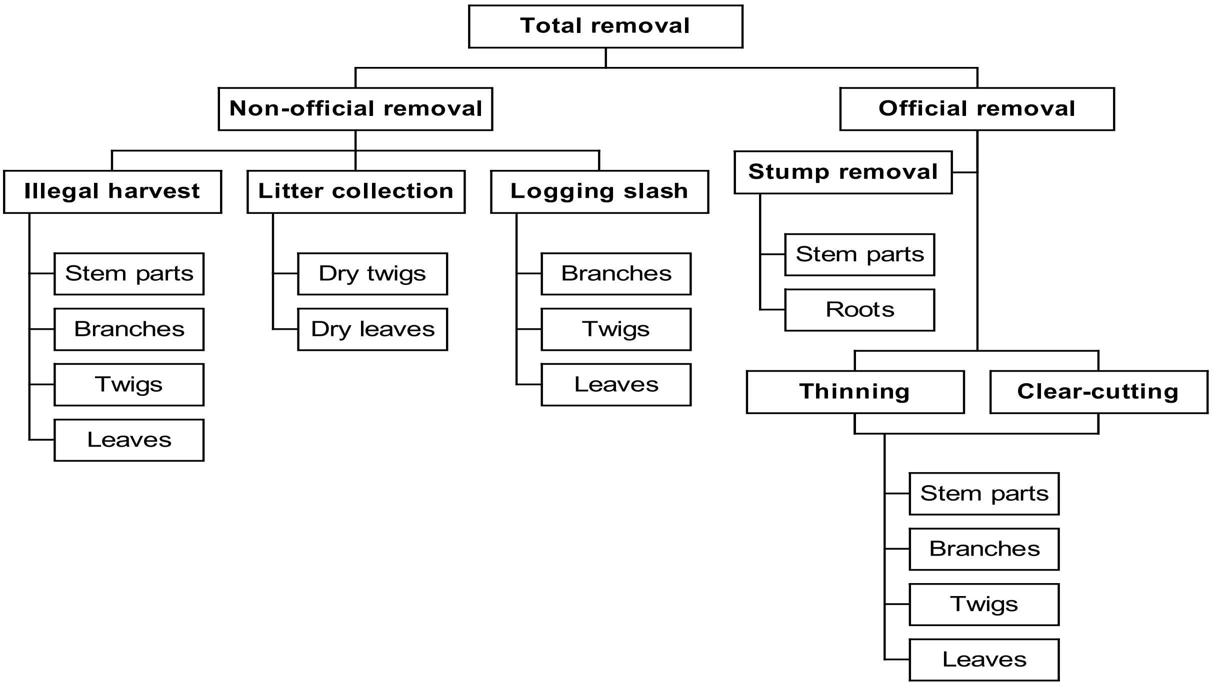

Figure 5. Schematic illustration of the removal of different types of biomass.

In addition, there was also an aim to increase knowledge of the wood collector's social situation, such as: what are the reasons for collecting fuel wood and litter?, what are the gains?, do they have alternative occupations?, etc. The main purpose was to get an understanding of how dependent people are on the eucalyptus plantations and how they use them.

3. Sites and methods

3.1. Site description

The study was conducted at the Intoto-mountain range just north of Addis Ababa. 38°45´E, 9°00´N. Intoto is located on the so-called Central plateau of Ethiopia. The altitude range in the study area is between 2550 and 2900 meters. The annual rainfall is about 1100 mm. There are two rainy seasons per year. The shorter one lasts from March until May, and the longer takes place from July to September. Most of the rain comes in July and August. The annual average temperature for Addis Ababa is 16.3°C, but because temperature decreases with altitude it is likely that the average temperature at the study sites is 2-3 degrees lower than the temperature in the city, being located lower. The sites are located 100-350 meters higher than Addis Ababa.

The basement upon which all the younger formations were deposited contains the oldest rocks in the country, the Precambrian, with ages of over 600 million years. The Precambrian contains a wide variety of sedimentary, volcanic and intrusive rocks, which have been metamorphosed to varying degrees. The younger geology of the study sites basically consists of Tertiary volcanic deposits formed from volcanic activity during the Cenozoic era some 11-71 million years ago. The typical catena in the mountain of Intoto is characterized by Nitisols at higher locations. Further down the hills Cambisols have been formed from deposits of erosion material from the higher located Nitisols. Furthest down the mountain, and in depressions, Vertisols have been formed from the finest erosion material (Fig. 6). All these soils are considered fertile. The color is blackish brown due to a high content of basalt, a rock type that generally has a considerable weathering potential.

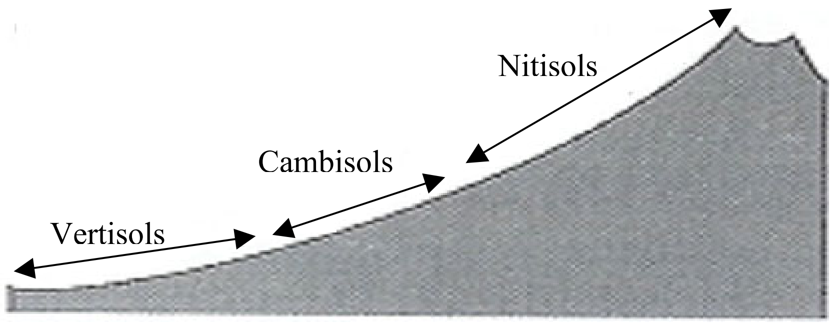

Figure 6. The typical catena at the study-site (Mt. Intoto).

Large areas at the study-site show severe erosion where the soil has been washed away and the bare bedrock is exposed (Fig. 7). Sheep and cattle heavily graze the forest floor and their hoofs destroy the grass roots, which in combination with heavy rain showers during the rain season and dry topsoil the rest of the year, leads to a high risk of increased erosion.

Figure 7. Exposed bare bedrock.

3.2. Inventory of the removal activity in order to establish study sites

In order to establish representative study sites an observation study was conducted during one week. Forest officials and local people were interviewed about strategic places where trails and roads that are used to transport biomass merge. The purpose was to establish knowledge of the number of strategic checkpoints where biomass is transported down to the city. We found that the number of potential checkpoints was 15. All the biomass that is transported down to the town is passes through these checkpoints. From these 15, six were randomly selected for the studies where the number of fuel carriers was counted. This means that 40% of the potential checkpoints were used. The checkpoints that were to be used for counting carriers were distributed along the mountain range, from Kotebe in the east to Sansusi in the west. *(Map, appendix 1)* It should be mentioned that all the collected biomass is not brought to the city. Village people in the countryside also consume some fuel from the studied forests. Nevertheless this can be considered as a minor part and is neglected in this study.

3.3. The amount of biomass removed at each checkpoint

Each of the six chosen checkpoints was carefully investigated for one week. All fuel brought down to the city was counted, i.e. fuel wood from eucalyptus, fuel wood from other species and cow dung. One person per checkpoint was hired to count and separate the different types of fuel. The counting was done Monday through Sunday from 07.00 - 19.00, the time during which the transportation of wood takes place (i.e. dawn to dusk). The people that were hired were first trained for one day in order to make sure they understood the task and realized the importance of accuracy. It also helped us to synchronise the categorisation of burdens and thereby lower the degree of arbitraryness.

3.3.1. The inventory form

The inventory form had to 1: be easy to work with and 2: Designed to enable easy differentiation of biomass types into categories. Because different types of biomass contain different amount of water and nutrients we wanted to know the proportion of the different plant parts. Two weeks were spent in developing and adjust the form in a way that gives as exact results as possible. We ended up with 5 main categories that in turn were divided into “carried by humans” or “carried by donkeys”. The categories are named H 1-5 (human load) and D 1-5 (donkey load) (Fig. 8).

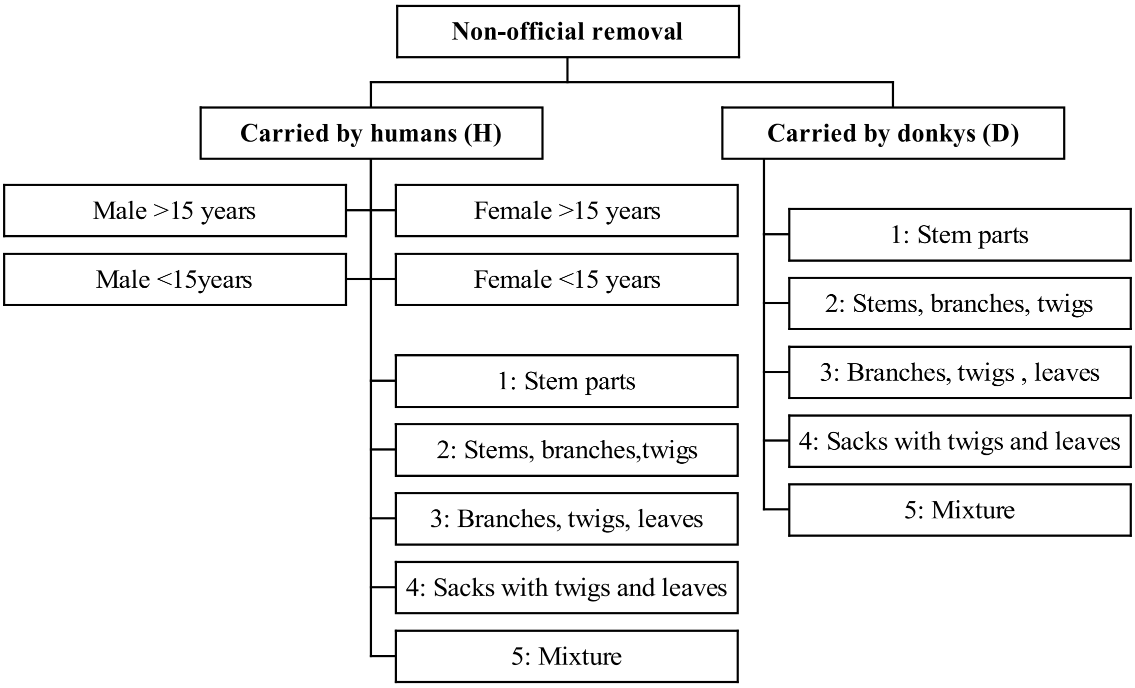

Figure 8. The studied categories carried out from the forest. Note that children/females and males are separated. This is not relevant in the nutrient removal study but was a part of the social study that was being conducted parallel (3.10.).

3.4. Field analyses

The total weight of the bundles was determined in the field (later converted to dry-matter content) at the time of removal. Different types of biomass evidently contain different amount of water and were believed to contain different amounts of nutrients. Therefore, the different bundles were categorized (Fig. 8) and furthermore analysed separately. In total, 42 bundles from the different categories were purchased for analyses. The burdens were analysed in three steps.

1. The total weight of the burden was measured on a scale.

2. We recognized seven different types of biomass in the bundles. Therefore we separated each burden into its subcomponents (Fig. 9). The components were 1: green leaves, 2: dry leaves (litter), 3: fresh twigs, 4: dry twigs (litter), 5: branches, 6: stem parts, and 7: bark. The percentage for each biomass type in each bundle category was then calculated

3. Apart from the bark category, three samples were taken from each biomass category listed in 2 above. The weights of the 18 (six biomass types and tree replicates) samples were determined directly after collection and then measured after drying in the oven. That gave the dry matter content at the time of removal. The results are given as mean values and standard deviation.

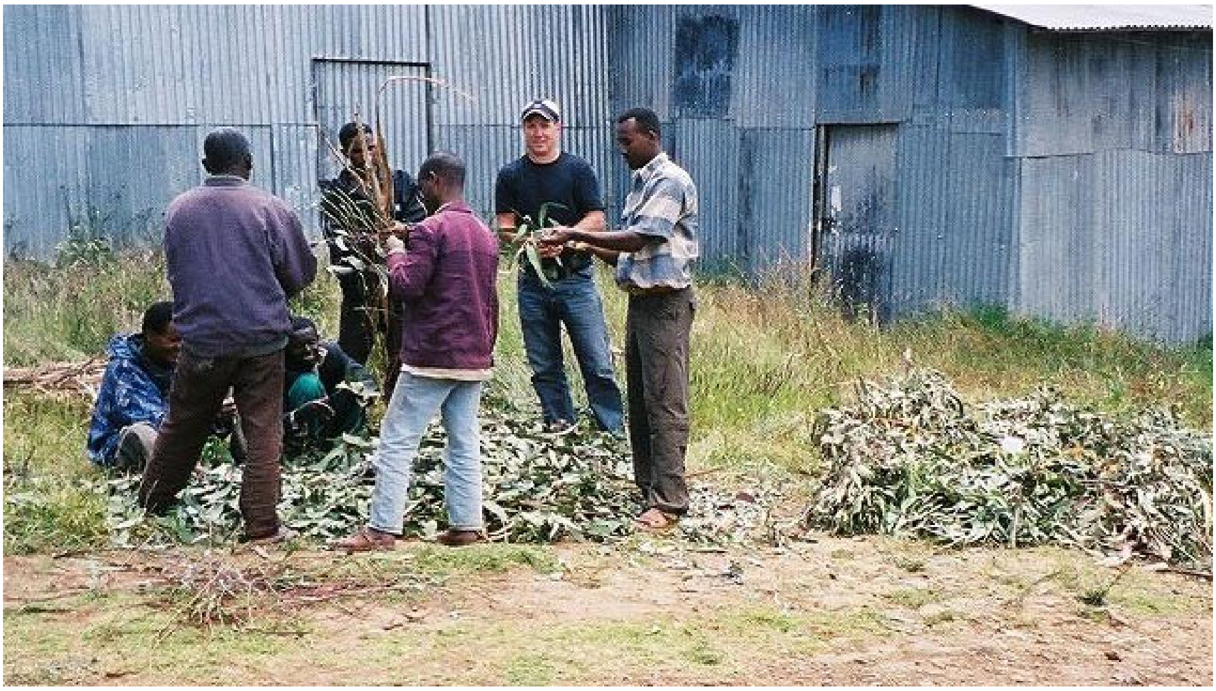

Figure 9. Separation of a bundle.

3.5. Laboratory analyses of the biomass

For the analyses, three samples per biomass group (1-6) were sampled from randomly chosen bundles. (No samples from bark were taken). The samples were subsequently analysed for dry-matter content and elemental composition.

Dry-matter content was determined as the oven-dry percentage on the day of removal (expressed as dry-matter weight in percentage of fresh weight). The samples were dried at 105^{o}C for 24 hours. Element analyses were carried out on air-dried samples and results subsequently recalculated to content per oven-dry weight.

Total organic carbon and nitrogen contents ere analysed by dry combustion, with a "Leco 1000", elementary analyser. The calibration curve was done with a stable organic substance, sulfamethazin, containing 51.78% C, 11.52% S and 20.13% N. A homogenised biomass sample of 0.06-0.4 gram was balanced down to four decimals. The samples were then ignited at 1250°C as oxygen was added, where after carbon and nitrogen are converted into gaseous form and determined in a so-called IR-cell. The reference was analysed every tenth run to make sure the process is stable.

Total phosphorus, potassium, sodium, calcium and magnesium in the litter components (dry leaves and dry twigs) were analysed through an ICP-analysis. A sample of 1 gram was dissolved in 20 ml 35% HNO_3. During the dissolving process was the temperature stepwise increased up to 120°C. When dissolved, the slurry was diluted till 50 ml (10% HNO_3)

Mulugeta Zewdie at the Department of Forest Soils at SLU provided the concentrations of P, K, Na, Ca and Mg from an ongoing research project. The "International livestock research institute" (ILRI) performed those analyses through their standard methods (ILRI 1997).

3.6. Area estimation

A crucial task in order to establish the relevance of the study was to put the removal of biomass and nutrients in relation to an area. We were interested in:

1: The total area of the eucalyptus plantations at Mt. Intoto and its surroundings.

2: The total area corresponding to each of our six checkpoints.

Delineation of the total area as well as of the areas corresponding to the checkpoints was based on map information and field observations. (Fig. 10) For these area estimations we were provided with maps by Zerihun Tadesse who works for the state forest enterprise called "Forest project 4[*1]". The maps described plantation boarders to the north, west and east of Addis Ababa.

Figure 10. Tobias Olsson and Zerihun Tadesse during the work with the estimation of the catchment areas.

3.7. Determination of removal per hectare

The removal per hectare was calculated from the data of removal of bundles per checkpoint divided by the catchment area that corresponded to each checkpoint. For example, if 20 kg biomass was carried out and the catchment area was 5 hectares, it means that 4 kg per hectare is removed. The removal was calculated for each checkpoint and as an average for all six checkpoints.

3.8. Correlation to weekly average output

The fuel collecting activity is an all-year-round activity, and the study only took place during one week in a two-months period of time. Therefore, there was a need to somehow convert the removal to an annual weekly average. I talked to numerous people and the opinion was that people collect fuel-wood with a certain frequency during the rainy season and with another frequency during the rest of the year. Consequently it was decided to divide the year into these two categories. In order to find out how the frequency differs between these two seasons we interviewed a number of people. Although the interview study was run parallel to this study this question was added to the questionnaire form. In total 20 people were interviewed in this matter.

1: How many bundles do you collect during one week during the rainy season?

2: How many bundles do you collect in a week during the rest of the year?

3.9. The interview

There are two common languages around Addis Ababa, Amharic and Oromic. Most people spoke one or the other. Two translators were hired to carry out the interview: One was skilled in English and Amharic and the other was skilled in English and Oromic. The interview took place during five weeks (October/November 2003) and was carried out at different marketplaces around Addis Ababa. Altogether 200 interviews were conducted.
The questions that were of interest:

1. How many burdens are collected per week?
2. How many hours are spent collecting fuel-wood, raking litter and transporting fuel wood?
3. What is the gain?
4. How important is the access of eucalyptus fuel for the family's well being?
5. Are there other tree species that people prefer to eucalyptus?

3.10. Observations from the counting study (3.3.)

In conjunction to the counting study we also differentiated the fuel carriers in terms of gender and age. It seemed that most females and children that are doing this work. Our approach was to investigate the percentage of women and children. The counting study was conducted from 07.00-19.00 during one week. The fuel-collectors were divided into four groups.

1: Females over 15years
2: Females under 15 years
3: Males over 15 years
4: Males under 15 years

(People under age 15 were considered to be children.)

The differentiation whether people were older or younger than 15 was done through estimation or sometimes, when necessary, by asking the person in question. The local people that were employed to conduct the study also made this differentiation.

4. Results

4.1. Number of fuel-wood burdens brought out per checkpoint.

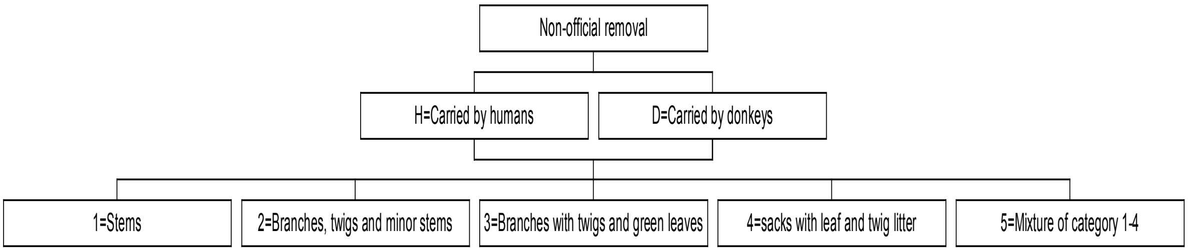

Figure 11. Key to the burden categories.

The total number of observations at all checkpoints was 15833. This number includes only loads of eucalyptus. In addition, there were also 1543 observations of other fuel (i.e. cow dung and other wood than eucalyptus). Note that eucalyptus during this study contributed to 91% of the total fuel that was carried to Addis Ababa through the checkpoints.

Table 1. The number of removed eucalyptus fuel wood burdens in each category, the mean value and the standard deviation (S.D.)
(The locations of the checkpoints are marked on map, attachment 1.)

Category	Ragual C	Intoto	Kotebe	Gojam	Sansusi	Ragual II	Mean	S.D.
1.H	130	435	268	344	201	111	248	126
1.D	80	343	403	211	269	118	237	126
2.H	113	1208	133	415	81	131	347	439
2.D	21	28	56	73	135	49	60	41
3.H	272	1418	368	808	122	290	546	486
3.D	297	599	208	1054	234	307	450	327
4.H	106	1555	652	131	105	171	453	579
4.D	37	58	58	143	103	133	89	44
5.H	106	197	99	251	141	137	155	58
5.D	11	34	11	194	2	65	53	73
Total eucalyptus	1173	5875	2256	3624	1393	1512	2639	1820
Övrigt	95	247	251	49	14	97	126	101
Total fuel	1268	6122	2507	3673	1407	1609	2764	1875

Intoto had the highest inflow of biomass with 37% of the total amount of counted fuel wood carriers *(fig. 12).* The number of counted eucalyptus biomass burdens per checkpoint and week ranged from 1173 to 5875.

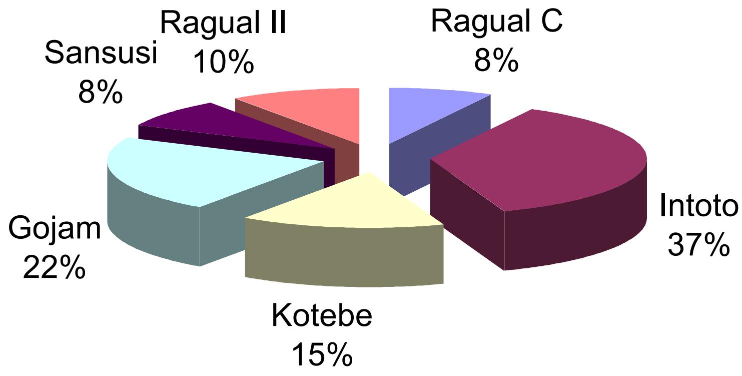

Figure 12. Number of bundles at each checkpoint as % of the total number of observed burdens (15883).

4.2. Results from the field analyses

The average weight of bundles carried by humans was 34 kilograms and the average weight of burdens carried by donkeys was 28 kilograms. The figures for 2.D., are missing and the weight was assumed to be the same as for 2.H. (Table 2)

Table 2.The average weight and the standard deviation (S.D.) of each bundle type. (Explanation of the category types, figure 11).

	1.H	1.D	2.H	2.D	3.H	3.D	4.H	4.D	5.H	5.D
Average	27	22	34	34	41	26	33	20	33	33
S.D.	11.8	6.0	23.9	23.9	22.5	3.2	19.3	0	6.6	6.6

The fractions of biomass components within the burdens were measured. One can, for example, see that green leaves contribute to 43% of the weight in category 3 (Branches with twigs and leaves).

Table 3. The percentage of different biomass types within the burdens as percent of the fresh weight and the standard deviation (S.D.)

Category	Biomass type	Average fraction (%)	S.D.
1	Stem parts	100	0
2	Twigs	57	20.5
	Branches	29	2.1
	Stem parts	13	17.8
3	Green leaves	43	9.6
	Twigs	21	5.9
	Branches	26	9.8
	Bark	10	11.5
4	Dry leaves	87	10.3
	Twigs	7	2.0
	Branches	6	8.3
5	Green leaves	28	35.8
	Dry leaves	45	35.2
	Twigs	13	7.9
	Branches	14	8.5

4.3. Laboratory results

The dry-matter content in litter leaves was only slightly higher than in fresh leaves. This is due to the fact that the burdens are left to dry for some time before they are carried to the city and pass the checkpoints. One sample per biomass group was used for the analysis of dry-matter content.

Table 4. The dry-matter content on the day of removal (% of fresh weight).

	Green leaves	Litter leaves	Fresh twigs	Litter Twigs	Branches	Stems	Bark
Dry-matter content day of removal	87	90	74	87	74	84	Not measured

The nutrient analyses were combined (table 5). The category "green leaves" is seen to have a nutrient content much higher than the other tree compartments. The stem wood, on the other hand, contained much less nutrients than any other group.

Table 5. Results from the nutrient analyses. The numbers are given as the average percentage and standard deviation (S.D.) of dry-weight.

Biomass type		C %	N %	P %	K %	Ca %	Mg %	Na %
Green leaves	Average	46.6	1.04	0.11	0.96	1.87	0.21	0,09
	S.D.	0.32	0.18	0.02	0.22	0.49	0.09	0,03
Litter leaves	Average	46.7	0.34	0.03	0.29	2.15	0.19	0,10
	S.D.	0.71	0.06	0.01	0.06	0.19	0.04	0,01
Fresh twigs	Average	44.0	0.35	0.06	0.59	1.20	0.09	0,04
	S.D.	0.48	0.06	0.02	0.16	0.32	0.05	0,02
Litter twigs	Average	41,2	0,23	0,04	0,47	1,37	0,13	0,05
	S.D.	0.29	0.01	0.00	0.03	0.60	0.03	0,02
Branches	Average	41.8	0.23	0.05	0.32	0.47	0.06	0,02
	S.D.	0.69	0.05	0.02	0.12	0.15	0.00	0,01
Stems	Average	44.2	0.16	0.04	0.16	0.14	0.03	0,01
	S.D.	0.33	0.04	0.03	0.06	0.06	0.02	0,01
Bark	Average	45.0	0.16	0.06	0.45	1.32	0.15	0,04
	S.D.	1.17	0.03	0.02	0.14	0.38	0.08	0,01

4.4. The size of the catchment areas

The size of the whole eucalyptus plantation at Mt. Intoto and its surroundings was estimated to be 12000 ha from our available maps. One can see (table 6) that the estimated total catchment area from the six checkpoints in this study is 49 % of the total area. The catchment areas for checkpoints Ragual II and Ragual church are to some extent overlapping but this has taken into account.

Table 6. The size of the catchment areas that correspond to each checkpoint, and the % of the total eucalyptus plantation in the Mt. Intoto area (Total 12000 ha).

	Sansusi	Gojam Bare	Ragual II	Ragual church	Intoto	Kotebe	All
Size (Ha)	750	825	925	725	1250	1450	5925
Percent of total	6	7	8	6	10	12	49

4.5. Conversion to weekly average removal

The interviews revealed that people collect 29% less bio-fuel during the rainy season. The rainy season was then estimated to last for 90 days. During the dry season when the study was conducted 5.2 burdens were collected, on average per week, and during the rainy season 3.7 burdens per week. This means that the weekly average was 92% of the number of burdens during a dry season week. The removal per year was subsequently calculated as the number of burdens during the observation week*52*0.92.

Table 7. Number of burdens removed per week and the average number of burdens in one year, based on the number of burdens during the observed week and the interviews.

Category	1.H	1.D	2.H	2.D	3.H	3.D	4.H	4.D	5.H	5.D
Burdens per week	1489	1424	2081	362	3278	2699	2720	532	931	317
Burdens per year*	71230	68120	99550	17320	156820	129120	130130	25450	44540	15160

*: Loads per week*52*0.92

4.6. Removed amount of biomass and nutrients per hectare

The total amount of dry matter biomass was 3526 $Kg*ha^{-1}*yr^{-1}$ (Table 8). The coefficient of variation is rather high because it takes in to account the variation in removal at different checkpoints and the variation in the analyses.

Table 8. The total removal of biomass (dry-weight) and nutrients due to fuel-wood collection and litter raking. The figures are given as removed weight in kg per ha and year.

	Total	Green leaves	Dry leaves	Fresh twigs	Dry Twigs	Branches	Stems	Bark
Biomass	3530	770	890	280	366	530	560	130
Carbon	1590	360	410	120	150	220	245	80
Nitrogen	15.2	8.0	3.0	1.0	0.8	1.2	0.9	0.3
Phosphorus	2.0	0.8	0.3	0.2	0.2	0.3	0.2	0.10
Potassium	14.3	7.4	0.3	1.7	1.7	1.7	0.9	0.7
Calcium	47.2	14.4	19.0	3.4	5.0	2.5	0.8	2.1
Magnesium	4.8	1.6	1.7	0.3	0.5	0.3	0.2	0.2
Sodium	2.2	0.67	0.89	0.11	0.18	0.11	0.17	0.06

4.7. Result from the social study

4.7.1. Results from the interviews

The main results from the interviews are:

- 83% of the interviewed people claim that access to fuel wood is crucial for their family's well-being.
- The collection and trading of fuel wood is the only income for most people.

- The interviewed people spend, on average, 6.5 hours per day collecting and transporting fire wood.

- The gain from one day of work is, in average, 5.6 Ethiopian Birr (equal to 5.04 SEK 2004-02-03).

- 100 % of the interviewed people preferred eucalyptus to other species because of its fast growth rate and suitability for cooking and baking.

4.7.2. Observations and results from the counting study

The total number of observed human carriers amounted to a total of 11765 fuel-wood carriers. The result reinforces our hypothesis because 91% of the fuel-collectors were females. Furthermore, 22% were under the age of 15 and were considered as children.

Table 9. The gender distribution and the percentage of children

	All	Sansusi	Ragual I	Ragual II	Gojam Bare	Intoto	Kotebe	%
Women	8629	564	568	797	1724	3765	1211	73
Men	518	14	42	40	36	228	158	4
Juveniles (F)	2106	67	247	59	422	931	380	18
Kids (M)	512	60	38	57	105	220	32	4
Total:	11765	705	895	953	2287	5144	1781	100%

5. Discussion

The available soil data (*Table 10)* are from a study by *Michelsen A. 1993*; that was conducted in Menagesha state forest 50 kilometres west of Addis Ababa. The soil properties are considered to be similar to the soil properties at the study sites in this study, and therefore relevant in a comparison. Both studies are conducted at places that have a parent material of basaltic type and the climate conditions are about the same.

Table 10. Nutrient and organic matter (OM) pools in the soil expressed as kg per ha in the upper metre of the soil

Soil depth	Na	K	Ca	Mg	OM	N	P[2]
0-40 cm	800	1690	16040	3410	307730	1480	20
50-100 cm	1210	2780	18150	4660	63270	410	20
0-100 cm	2010	4470	34190	8070	371000	1890	40

When looking at the removal of nutrients in relation to the soil nutrient pool it is seen that the fuel wood collection and litter removal to some extent affects the soil properties. However, the percentage of the pool that is removed through fuel wood collection and litter raking is a minor part. (Table 11) It was calculated that 4.9 % of the plant available phosphorus in the soil at any given time is removed on an annual basis.

Table 11. The non-official removal as percentage of the total soil nutrient pool

Element	Soil Nutrient bank (kg/ha)	Non-official removal (kg/ha)	Non-official removal/ Soil nutrient pool (%)
C	215700	1600	0.7
N	1890	15	0.8
P	41	2	4.9
K	4470	14	0.3
Ca	34200	47	0.1
Mg	8070	5	0.1
Na	2010	2.2	0.1

In addition to the fuel wood collection and litter raking it is known that clear-cutting and thinning takes place in seven-years cycles. In order to put the results from this study into a more complete context, the removal is calculated as removal per generation (seven years), as discussed below. The stem volume per hectare is approximately 200m^3 per hectare at the time of harvest (Pukkala and Pohjonen 1989). The amount of biomass that is removed during the thinning is roughly estimated to 50 m^3. The ratio of dry weight/fresh volume is 475.5 (Holgén and Svensson 1990). This is converted into nutrient removal per hectare in Table 12. The biomass of nonofficial (i.e. shoots and litter) is naturally much lower; but the high content of nutrients increases its contribution to the total removal (Table 12).

[2] Plant available phosphorous

Table 12. The amount of nutrients removed per generation (7 years) and the percentage of removal accounts for by litter raking and fuel wood collection.

	Harvest (kg/ha)	Thinning (kg/ha)	Non-official (kg/ha)	Non-official % of total
C	42000	10500	11200	18%
N	150	40	110	37%
P	38	10	14	23%
K	150	40	100	35%
Ca	130	30	330	67%
Mg	29	7	33	48%
Na	29	7	15	30%

When comparing the total removal with the soil nutrient pool (Table 13) one may suspect that the overall removal of biomass depletes the soil in terms of nutrients. For example; the removal of phosphorus was 50% higher during one seven-year's cycle, than the available phosphorus in the soil at any given time (Plant available phosphorus). The input of phosphorus is restricted to weathering of the basaltic parent material. The type of basaltic material at the site does often contain phosphorus-rich minerals such as apatite. However, it is doubtful whether the weathering capacity is as high as the removal. The removal of nitrogen might be even more hazardous because the microbial activity is known to be extremely low in eucalyptus plantations such as this one at Mt. Intoto, and the fixation should therefore be considered low. Atmospheric deposition is also limited. The non-official removal contributed to one-third of the total nitrogen that was removed (Table 13).

Table 13. The removal of nutrients per generation in relation to the soil nutrient pool

	Total removal in % of soil pool	Removal due to litter raking and fuel wood collection in % of soil pool
C	30	5
N	15	6
P	151	34
K	6	2
Ca	1	1
Mg	1	0
Na	3	1

6. Conclusions and suggestions

6.1. Conclusions

The results indicate that the non-official removal of biomass from the eucalyptus plantations might affect the soil properties. The concern should mainly be focused on the phosphorus and nitrogen depletion. Further research is needed to establish data on the weathering potential of parent material and for quantifying nitrogen deposition and fixation. It is also clear that many people are dependent on access to eucalyptus fuel-wood. This dependency is due to the need for fuel in their own household and/or through people having fuel wood commerce as their only income. For thousands of people it is crucial to maintain high production in the eucalyptus plantations. The plantations are crucial for people's social situation and survival.

The future management must be improved to decrease the erosion and to lower the nutrient removal per produced energy unit.

6.2. Management suggestions

The dependency on fuel wood in combination with the scarcity makes land management important. It's of the greatest importance that productivity does not decrease. However, this study indicates an ongoing depletion of nutrients from the soil, which is hazardous for the future production. It is also seen that shoots and litter contribute to the nutrient removal. My suggestion is to extend the growth cycle from the seven used today, to 20-30 years.
The benefits would be:

- High biomass production, eucalyptus production actually increases in terms of biomass per hectare and year until an age of approximately 9 to 11 years, and the production remains high to an age of 20 to 30 years.
  (Mahari A 1996)

- More timber would be produced which increases the economic development in the forestry sector. The price of lumber is up to four times higher than the price for fuel wood.

- The uncontrolled removal of shoots, branches, leaves and litter would decrease drastically, and thereby also the amount of nutrients. In other words this management would produce more energy with a lower input of nutrients. This is really due to the high content of nutrients in the leaves and shoots that today are continuously removed.

- The forest floor would be less disturbed by people collecting wood, which might decrease the erosion to some extent.

- The legislation and praxis could go hand-in-hand. Today, illegal harvesting of eucalyptus shoots is widespread. If the management was based on harvest at mature age, the cutting of trees would be more easily controlled.

The demand however is predicted to increase as long as no other energy means are available, but the suggested management will increase the overall energy production, which increases the possibility to meet the demand. Some predicted problems to overcome are:

- How to distribute the wood. The wood will be available when the harvest takes place about every 30th year. It is crucial to develop a structure enabling average people have access to this wood, because access of collectable wood in the forest will decrease.

- Technically, it is necessary to find out how to process the wood into burnable pieces (i.e. billets). Education and equipment is needed. Especially, it seems that saws are lacking, and handsaws are needed to easily process the trunks into billets. This could probably be helped by small means.

- It is also important to work for modernisation of the sawmill industry. The suggested change in management would drastically increase the access to lumber.

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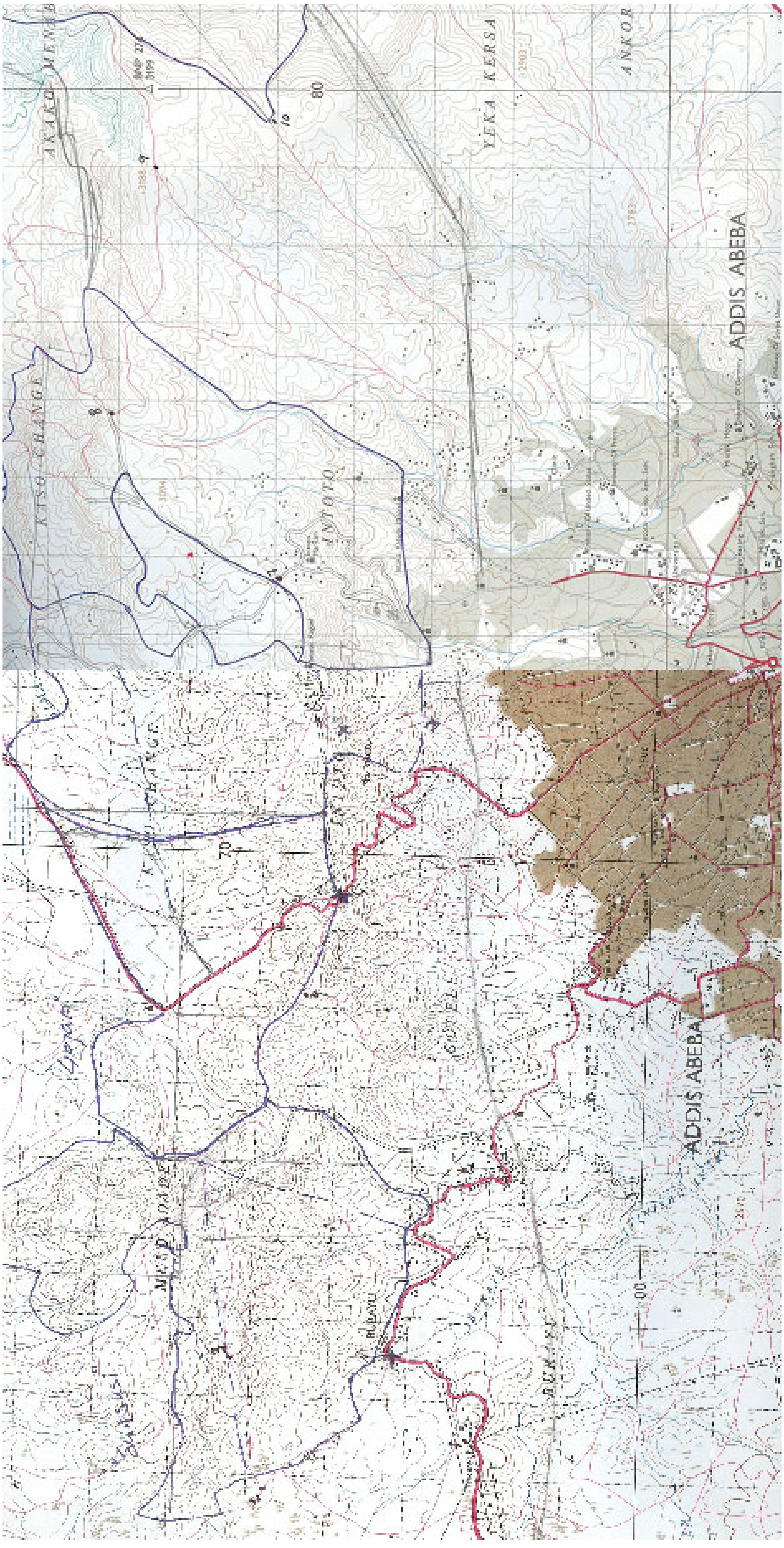
Appendix 1



Appendix 2

Bundle category 3.H.

Bundle category 3.D.

Bundle category 1.D.