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Economic valuation and management of common-pool resources: the case of exclosures in the highlands of Tigray, Northern Ethiopia

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Table of contents

Chapter 1. General Introduction…………………………………...1

Chapter 2. The Economic contribution of forest resource use to rural livelihoods………………………………………..16

Chapter 3. Explaining environmental resource reliance and livelihood strategy choice: an econometric analysis……59

Chapter 4. Valuing soil and water conservation effects of exclosures: an application of cost-benefit analysis (CBA)………...95

Chapter 6. Conclusions and recommendations.……………………191

Definition of local terms used in the thesis

barnetsa	A head dress commonly weaved from plant fibres or leafs and used by local people
belg	The secondary crop season in Ethiopia that covers the period from March to May. In this period rainfall is low and farmers sow short-season crops
chinet	A certain amount of load that a pack animal carry and transport to a certain distance
derg	the short name of a committee of military junta which ruled Ethiopia from 1974 until 1991.
douga	One of the three major agro-climatic zones in Ethiopia with altitudes over 2300 m.a.s.l. annual average temperature less than 16 degree Celsius
endod	A perennial plant with small berries which, when dried, powdered and mixed with water, field a foaming detergent solution that has been traditionally used in Ethiopia for washing clothes
enjera	An Ethiopian traditional staple food item produced from a local grain called teff (*Eragrostis tef)*
equb	A rotating credit association in which each of its members contributes money periodically and the amount collected at each period is provided to one of the members often on a lottery system
esir	A bundle or package of something
gotera	Traditional crop storage device commonly produced from wood products
hanfets	A mixture of barely and wheat grown in the same crop field. It is a common crop variety grown in the study area
horoye	Rain-water harvesting device (small pond) introduced recently in Tigray and managed at individual household level
kenber	A farm tool (yoke) used to harness oxen in pairs with an average length of 140 cm in a traditional animal traction agricultural technology in Ethiopia.

kolla	One of the three major agro-climatic zones in Ethiopia with altitudes less than 1500 m.a.s.l. and temperature over 29 degree Celsius
kushet	A local term in rural areas of Tigray used to refer a rural village
meher	The main crop season in Ethiopia that covers the period from the month of June to September. In normal years rainfall is high in this period
mekoster	A local term in Tigray used to refer a sweeping material made up of commonly from forest products
mofer	A farm tool used to till land in a traditional animal traction agricultural technology in Ethiopia
selen	Locally produced mat weaved from plant fibres or leafs, mainly from palm trees (*Phoenix reclinata*) in Ethiopia
serit	Local by-laws that regulate local people in use and management of common pool resources
shekim	A certain amount of load (i.e., head-load) that an adult person carry and transport to a certain distance
tabia	The lowest administrative unit in Tigray
Tigrigna	An official language in Tigray regional state
woina douga	One of the three major agro-climatic zones in Ethiopia between altitudes 1500-2300 m.a.s.l. and temperature between 16-29 degree Celsius
woreda	The local term in Ethiopia equivalent to the English word 'district'

List of acronyms/abbreviations

a.e.u	adult equivalent unit
AHP	analytical hierarchy process
ANoVA	analysis of variance
B/C	benefit cost ratio
BoPED	bureau of planning and economic development
C&I	criteria and indicators
CBA	cost benefit analysis
CBFM	community based forest management
CIFOR	centre for international forestry research

CPR	common pool resources
CSA	central statistical authority
DECSI	dedebit saving and credit institute
df	degree of freedom
DIFD	department of international development of UK
EFAP	Ethiopian forestry action programme
EHRS	Ethiopian highland reclamation study
ETB	Ethiopian birr (the legal currency in Ethiopia); 1US$ = 8.68 ETB and 1EURO =10.62 during the survey time (March, 2005)
FAO	food and agriculture organization of the United Nations
FDRE	federal democratic republic of Ethiopia
FEI	forest environmental income
FFW	food-for-work
FGT	Foster, Greer and Thorebecke (the three persons whose poverty index is widely used in poverty analysis)
GDP	gross domestic product
ha	hectare
IDS	institute of development research
IIED	international institute of environment and development
IRR	internal rate of return
ITTO	international timber trade organization
km2	square kilometre
LS	livelihood strategy
m.a.s.l	meter above sea level
MAI	meal annual increment
MCA	multicriteria analysis
MHL	middle highland
MNL	multinomial logit
MoA	ministry of agriculture
MU-IUC	Mekelle University-Institutional University Cooperation
NB	net benefit
NGO	non-governmental organization
NPV	net present value
NWFPs	non-wood forest products

OCL=0	opportunity cost of waste land (zero opportunity cost of land)
OCLP	opportunity cost of productive land
OCLS	opportunity cost semi-prodcutive land
pci	per capita income
PVB	present value of benefits
PVC	present value of costs
PWC	pair-wise comparison
REST	relief society of Tigray
RM	ranking method
RME	relative marginal effect
RMSSTD	root mean squared standard deviation
RUM	random utility model
SFM	sustainable forest management
SLA	sustainable livelihood approach
SLF	sustainable livelihood framework
sq.km.	square kilometre
STD	standard deviation
SWC	soil and water conservation
t	ton
TEV	total economic value
TFAP	Tigray forestry action programme
UHL	upper highland
VLIR	Vlaamse Interuniversitaire Raad - Flemish Interuniversity Council
WFP	world food programme
WWII	World War II (Second World War)
yr	year

List of figures

List of tables

Dedicated

to

My beloved wife
Tsega Gebre-egziabher

and

My lovely sons
Nathan and Anania

Summary

Environmental degradation and the deterioration of the natural resource base have become serious problems in Ethiopia. The existing biophysical, environmental and socio-economic indicators provide sufficient testimonies for the severity of the problem of natural resources deterioration in Ethiopia. Most forms of the nation's environmental problems are directly or indirectly attributable to the rapid dwindling of the country's vegetation cover and the consequent degradation of its land resource. To combat this problem national level environmental conservation and rehabilitation efforts were started in the 1970s, with particular focus on the fast deteriorating highland areas of the country. Closing degraded land areas from human and livestock intervention to promote natural regeneration of plants, commonly termed as exclosures, is among the major conservation efforts practiced in the highland areas of Tigray, northern Ethiopia. The introduction of this policy has brought major changes in land use in Tigray. Land areas formerly used as grazing land, bush lands, wood lands, and even some crop lands were converted to forestry. These were areas where local people generate lots of economic benefits (such as source of grazing; fodder collection; fuelwood; and other wood and non-wood products). This land use conversion limits the harvest of environmental products by local people due to the adoption of restrictive use rules. As a result, local people have encountered losses of economic benefits and welfare. These have led many local residents to view such a land use policy change as a less favoured land use option. On the other hand, local government and non-government agencies in favour of exclosures strongly argue for the desirability of exclosures in terms of the ecological functions and long-run economic benefits.

With respect to exclosures, several knowledge gaps arise: (1) the local costs of establishing exclosures and economic welfare loss emanating from access restriction have not been quantified and as a result little has been known about the economic contribution of environmental resource use in the welfare of rural people, (2) the factors that condition rural households' heavy dependence on 'natural extraction' have not been systematically identified, (3) the ecological services provided by the vegetation restoration in exclosures and the tradeoffs of alternative land use options have not been quantified and valued in order to give economic justification for such land use conversion, and (4) sustainable management of the closed areas has become a serious practical problem. Sustainability criteria and indicators, their relative importance, and areas that need special attention for efficient and effective interventions have not been critically identified.

Therefore, this study aimed at contributing to the existing stock of knowledge on the economic importance of environmental resource use to rural livelihoods; the trade-offs in terms of economic values (costs and benefits) associated with converting existing land use types to forestry; and the sustainable management of community owned natural resource systems. This may foster economic rationality among decision makers and the general public in land allocation for various uses and for sustainable management of closed areas. It would also provide important inputs to policy makers and insights into resource management options and livelihood strategies.

The thesis has four core chapters (chapters 2, 3, 4, and 5). With the help of empirical data from 360 randomly sampled rural households from 12 villages in Tigray, chapter 2 examines the role of forest environmental products in the wellbeing of rural households and compares the value of environmental goods with other household economic activities. We found that income from environmental sources occupies the second largest share in average total household income next to crop income. The poverty and inequality analyses show that incorporating environmental incomes in household accounts contribute significantly to the reduction in measured rural poverty and income inequality. Using the ‘livelihood approach’ as an analytical framework and multinomial logit (MNL) regression method, the determinants of households’ livelihood activity choice and their reliance on environmental extraction were identified in chapter 3. The MNL regression analyses indicate that heterogeneity in access to livelihood assets determines the choice of a household's livelihood strategy. Thus, targeted interventions in enhancing the positions of asset-poor households need to be introduced in order to mitigate local pressure on natural environment and improve the economic wellbeing of local people without hampering the resource base.

By integrating the available data on on-site and off-site effects of exclosures (i.e. the effects on soil erosion, biomass production, sedimentation, crop yield, and opportunity cost of land and labour) chapter 4 undertakes an economic analysis of the soil and water conservation effects of exclosures using the model of cost-benefit analysis. Key benefit and cost items were identified, quantified, and valued. Direct market prices and variants of indirect techniques (i.e. replacement cost method, productivity change method, and damage cost avoided) of environmental valuation were used to value the various benefit and cost items. Our alternative scenario analyses indicate that establishing exclosures in degraded land has a positive net present value (NPV). However, converting productive agricultural land to forestry yields a negative NPV even under some hypothetical scenarios of overestimated values of forest products and a low social discount rate. Thus, land conversion to forestry or other land use changes should be carefully analyzed and justified in economic terms before introducing the proposed land use change.

Using the general procedure of multi-criteria analysis (MCA), chapter 5 analyzes the sustainable management of community owned natural resources (with particular focus on community forestry). Three variants of MCA methods (ranking, pair-wise comparisons, and scoring) were used. Our analyses indicate that the performance of the prevailing resource management system is poor. Thus, the application of ‘traditional environmental management packages’ in Ethiopia which commonly pays due attention to the ecological aspects alone has to be substituted by research-based holistic management prescriptions. In order to harmonize both developmental and environmental objectives, locally relevant sets of criteria and indicators of sustainability should be carefully identified and evaluated from the local perspectives.

Chapter 1

General Introduction

1.1Background of the study

A number of studies indicate that environmental degradation and the deterioration of the natural resource base have become serious problems in Ethiopia, mainly in the Ethiopian highlands (Hurni, 1985, 1988; FAO, 1986; Newcombe, 1987; Chadhokar and Abate, 1988; Suctcliffe, 1993; Bojo and Cassels, 1995; Hoben, 1995; Fitsum Hagos et al., 1999; Kibrom, 1999; Demel Teketay, 2001; Girma Taddese, 2001; Sahlu Haile, 2004; Nyssen et al., 2004). The existing biophysical, environmental and socio-economic indicators provide sufficient testimonies for the severity of natural resources deterioration in Ethiopia. For instance, on the basis of the Ethiopian Highland Reclamation Study (EHRS) (FAO, 1986), by the mid-1980s, about half of the highland area (27 million hectares) was "significantly eroded". Fourteen million hectares (over one-fourth) was "seriously eroded" and over 2 million hectares are described as "beyond the point of no return". The Ethiopian highlands, defined as areas above 1500 m.a.s.l., cover about 44% of the total territory of the country. More than 83% of these highland areas are classified under eroded land category. Estimates indicate that the physical gross annual soil loss ranges from 42 –103 t/ha/yr (FAO, 1986; Sutcliffe, 1993; Bojo and Cassels, 1995). Based on field measurements of 202 plots in 12 sites of Tigray highlands, Desta Gebremichael et al. (2005) have found that the rate of mean annual soil loss from crop land in the absence of soil and water conservation measure is 57 t/ha/yr. It is also documented that at the end of 1980s the total land area covered by forests was less than 2.7% of the country and an estimated 150,000 – 200,000 ha of high forest is lost annually (Demel Teketay, 2001). It was estimated that in 1990 alone, 57,000 to 128,000 tons of grain production was lost due to reduced top soil depth caused by soil erosion (Demel Teketay, 2001).

The interactions of numerous economic, demographic, social, natural, and policy factors constitute the underlying causes of environmental problems in Ethiopia.

Factors such as high degree of dependence on natural resources, backward agricultural technology, lack of alternative employment opportunities, tenure insecurity, persistent poverty, rapid population growth, poor resource management, and meagre or no investments on resource development activities have led the country to severe environmental crisis.

Most forms of the nation's environmental problems are directly or indirectly attributable to the rapid dwindling of its forest resources. The clearing of forest land for agricultural use, the cutting of trees for fuel, timber, construction materials and agricultural implements, the burning of bushes and woodlands, and overgrazing have led to the loss of the nation's forest cover at an alarming rate. Severe shortages of fuel wood have rendered rural communities increasingly dependent on animal dung for fuel, contributing to the problem of declining soil fertility (Newcombe, 1987; Bojo and Cassels, 1995; TFAP, 1996; Fitsum Hagos et al., 1999; Gebremedhin et al., 2000; Girma Taddese, 2001). Forest and soil degradation is particularly severe in the Ethiopian highland areas such as the Tigray province.

To combat these severe resource degradation problems national level environmental conservation and rehabilitation efforts were started in the1970s, with particular focus on the fast deteriorating highland areas of the country (Campbell, 1991; Hoben, 1995). In this regard, Tigray is a noticeable province for its concerted efforts in combating environmental degradation problems. As part of these efforts, exclosures[1] and community woodlot establishments are among the major strategies of environmental rehabilitation adopted in Tigray (Gebremedhin et al., 2000). Since 1991, exclosures and community woodlots have been practiced at large scales.

The primary aim of exclosures and community woodlots was ecological regeneration rather than economic benefits. However, local community's expectations about economic benefits from these areas are increasing which in turn presents a major management challenge (Berhanu et al., 2000). The adoption of restrictive use rules and the limitation in allowable harvests have led many local residents to view exclosures as a less favoured land use option. On the other hand, interventionists

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[1] Exclosures are areas closed from human and animal interference to promote natural regeneration of vegetation. In this thesis we use 'exclosures' and 'closed areas' interchangeably.

(local government agencies and NGOs) strongly argue for the desirability of exclosures in terms of ecological functions and long-run economic benefits.

However, the arguments from both sides have been based essentially on qualitative narratives of the pros and cons of exclosure establishment and have not been backed up by quantitative reasoning and indicators. Little has been known in quantitative terms about the economic contribution of forest environmental resource use in rural poverty and income inequality. The local costs of establishing exclosures and economic welfare loss emanating from access restriction have not been quantified. The factors that condition rural households' heavy dependence on 'natural extraction' have not been systematically identified. The ecological services provided by the vegetation restoration in exclosures and the tradeoffs of alternative land use options have not been quantified and valued in order to give economic justification for land use conversion to forestry from its current use. On top of that, sustainable management of exclosure has become a serious practical problem in Tigray. Sustainability criteria and indicators, their relative importance, and areas that need special attention or systematic and informed interventions have not been critically identified. The existing management scheme is of a 'fragile' type, not of a self-sustaining kind. These are the key issues around which the themes of this thesis revolve.

1.2 Research questions

This research seeks to explore the economic contribution of environmental resource use to rural livelihoods; the determinants of households' dependence on extractive activities; the tradeoffs and gains of land reallocation to forestry; and sustainable management schemes for exclosures. Specifically, the study addresses the following key questions:

1) What is the contribution of forest environmental resources to the rural economy?
2) What is the share of forest environmental income in total household income and its contribution in alleviating rural poverty?

3) Do forest environmental products promote or mitigate rural income inequality?
4) What factors determine household's livelihood activity choice and why are some households more dependent on forest environmental products than others?
5) Is land reallocation from its current use to exclosure land use type justifiable economically? Or in other words, is it economically efficient to convert or reallocate land unit to forestry activity in the study area?
6) Is the existing management scheme of exclosure sustainable? What are the sustainability criteria and indicators in the context of the study area? What are the incentive compatibility conditions for the sustainable management of closed areas?

1.3 Aims and objectives of the study

The general aim of this research is to contribute to the existing stock of knowledge on the economic importance of environmental resource use to rural livelihoods; the trade-offs in terms of economic values (costs and benefits) associated with converting existing land use type to forest land use type; and the sustainable management of community owned natural resource system. This may foster economic rationality among decision makers and the general public in land allocation for various uses and for sustainable management of closed areas. It would also provide important inputs to policy makers and insights into resource management options and livelihood strategies.

The study has the following general objectives:

- to identify, value, and integrate the role of forest environmental products with other conventional set of rural households' activities and analyse the economic contribution of environmental income to rural livelihoods.
- to investigate the determinants of rural livelihood activity choice with particular emphasis on determinants of households' choice on extractive activity.
- to analyse whether reallocation of land to forestry activity is an economically efficient decision or not in the study area.

- to assess the existing management schemes of exclosure and identify criteria and indicators of sustainable forest management from the local perspectives.

Specifically the objectives of the study are summarized as follows.

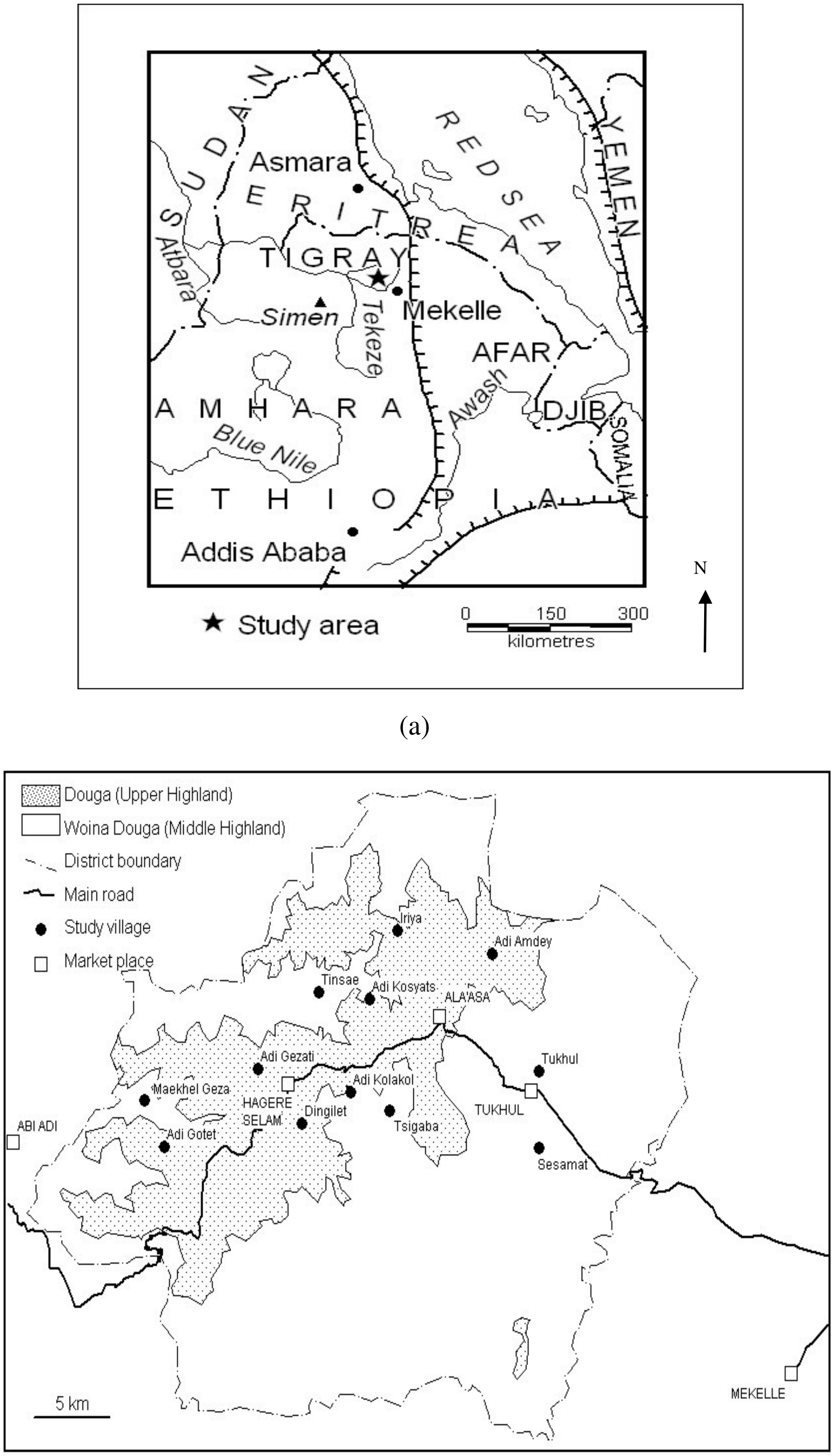
- to examine the significance of forest environmental income in total household income of the rural economy.
- to examine the extent of change in measured rural poverty with and without incorporating forest environmental income.
- to analyze the extent to which forest environmental products contribute in reducing or promoting rural income inequality.
- to specify the factors that condition households' decision on livelihood activity choice.
- to identify the major specific determinants of households' decision on forest product extraction and dependence.
- to undertake the economic analysis of the soil and water conservation effects of exclsoures.
- to examine the performance of the existing management system of exclsoures from the sustainability point of view.
- to identify the relevant set of criteria and indicators of sustainability for exclosure management.
- to assess the relative importance of the criteria and indicators relative to the objective of sustainability of exclosures.
- to generate some policy implications and recommendations.

1.4 Study area description

1.4.1 Tigray Regional State

Location and natural conditions

The Regional State of Tigray is located in northernmost part of Ethiopia between 12° 15′ N and 14° 50′ N and 36° 27′ E and 39° 59′ E (Figure 1.1). The region has a total area of approximately about 80,000 square km. Tigray shares common borders with



(a)

(b)

Figure 1.1 (a) Location of the study area in Ethiopia, (b) the study district with selected sample villages (Source: both maps are produced by Jan Nyssen)

Note: Douga (upper highland) is land area from 1500-2300 m.a.s.l. and woina douga (middle highland) is land area from 2300-3200 m.a.s.l.

Eritrea in the north, the Afar Region in the east, the Amhara Region in the south, and Sudan in the west (Figure 1.1).

The topography of Tigray varies from about 500 meters above sea level (m.a.s.l.) in the northeast to almost 4000 m.a.s.l. in the southwest. The eastern escarpment falls steeply from the plateau of 2900 m.a.s.l. lowering to the Afar depression of -150 m.a.s.l. As we move west of the escarpment the area is largely made of mountainous plateaus. The altitude of this area ranges from 1500–3000 m.a.s.l, which again drops in elevation, as we move further west (close to the Sudanese border), to about 500 m.a.s.l. According to the traditional agro-climatic classification of Ethiopia, the region is classified into three agro-ecological zones: lowland (*kolla*) (less than 1500 m.a.s.l.) 39%, medium highland (*woina dega*) (1500 to 2300 m.a.s.l.) 49%, and upper highland (*douga*) (2300 to 3200 m.a.s.l.) 12%.

The geology or lithology of the study area is composed of Mesozoic sedimentary rocks (Adigrat sandstone, Antalo limestone and Amba Aradam sandstone), covered by tertiary basalt flows with interbedded silicified limestone. These subhorizontal layering of rock formations have resulted in a stepped landscape (Virgo and Munro, 1978; Nyssen et al. 2002). A Luvisol-Regosol-Cambisol-Vertisol catena is common on the basaltic parent material (Nyssen et al. 2000). Cumulicalcaric Regosols, Calcaric Regosols, Calcaric Cambisols and Calcisols occur in limestone areas (Nyssen 2001).

Tigray is a semi-arid zone characterized by a long dry period. The rainfall is characterised by high spatial and temporal variability, and by frequent occurrence of drought. The amount of rainfall increases with altitude. Average rainfall varies from about 200 mm in the northeast lowlands to over 1000 mm in the south-western highlands. The regional average annual rainfall falls between 450-980mm. Most of the rainfall falls during the '*meher*' season from June to September. In some parts of Tigray, there is short rainy season called '*belg*' which falls during the months of March, April and May. Average temperature in the region is estimated to be 18℃, but varies greatly with altitude. In the highlands of the region, during the months of November, December and January, the temperature drops to 5℃. In the lowlands of western Tigray, especially areas around Humera, the average temperature increases from 28℃ to 40℃ during the summer (Fitsum Hagos et al., 1999).

Poor soil quality and moisture stress are the two major constraints of agricultural productivity in Tigray. Studies indicate that the soils in highlands of Tigray are deficient in major soil macronutrients and organic carbon (Haile et al. 2003). Severe degradation of forest resources and the ensuing high level of soil erosion appear to be the underlying cause for the region's land degradation. Forest resources of the region were overexploited and today forests and woodlots cover less than 2 percent of the region's total area (TFAP, 1996). The evolution in the region's forest degradation has closely linked with the early human settlement, centuries of traditional agricultural practices, increasing fuel wood demand, and population pressure. Recently, rehabilitation and conservation activities are under way through exclosures, community woodlots and private plantations.

Administrative and socio-economic aspects

The Tigray region is divided into four administrative zones and 35 *woredas* (districts). Each district is subdivided into several tabias which is the lowest administrative unit in the region. A tabia is further divided into *kushets* (villages). In most cases, *kushets* own common woodland, pasture area and/or irrigation schemes. According to the 2006 projection of the Central Statistical Agency of Ethiopia, the region has a total population of 4, 335,000 (81.2% rural population and the remaining 18.8% in urban areas (CSA, 2006).

Agriculture is the single most important sector of the economy of Tigray. It consists of crop production, livestock rearing and crop-livestock mixed farming. According to the Bureau of Planning and Economic Development of the Tigray regional state, agriculture contributes about 57% of the regional GDP (36% of which is accounted by crop production, 17% by livestock and 4% by forestry) (BoPED, 2004). About 85% of the population of Tigray earns their living from agricultural activities, mainly as subsistence farmers (Girmay Tesfay, 2006). The mixed crop-livestock farming system dominates the agrarian economy of Tigray. The farming system is predominantly characterized by traditional technology based on animal traction, rain-fed and low productivity subsistence. As a result, average crop productivity is about 0.8 ton/ha

(BoPED, 2004) which is lower than the national average of 1.2 ton/ha recorded between 1980 and 1997, the period when Ethiopian agriculture was highly stagnant due to institutional constraints (Abrar et al., 2004). In the highland areas of the region, due to population pressure land fragmentation becomes so intense that average land holding is less than a hectare per household.

Generally, the incidence of poverty (proportion of people below the absolute poverty line) is high in Ethiopia. The situation in Tigray, however, is more stringent than the national average. During 1999/2000 the proportion of absolutely poor people in Ethiopia was 44% (with about 45% in rural areas and 37% in urban areas) (Assefa and Frehiwot, 2003). Reports from the Tigray Bureau of Planning and economic Development shows that about 75% the population of Tigray are living below the absolute poverty line and an average peasant household covers only 38% of the household's annual food demand from its own agricultural production (BoPED, 2004).

1.4.2 The Study district

The study area, Dogua Tembein *Woreda* (district), is situated in the upper watershed of Tekeze River (Northern Ethiopia). The capital of the district, Hagereselam, is situated at an altitude of 2650 m.a.s.l., at about 50 km west of Mekelle, the capital of Tigray regional state. The district has an estimated total area of about 1110 km^2 with 119,044 inhabitants implying an average population density of 107 persons per sq. km. In comparing against the average population density of 61 persons/km^2 for the Ethiopian highlands (Holden & Shiferaw, 2002) and 87 persons per sq. km. of the Tigray region (CSA, 2006), this figure is high. The population density varies according to the different agro-ecological zones of the Tembein highlands. In the upper parts of the highlands it is estimated that up to 250 inhabitants are living per km^2 and in the lower parts of the highlands there are many areas with less than 100 inhabitants per sq. km (Naudts, 2003)$^.$ The majority of the population of the district are living in the different villages surrounding the town of Hagereselam. Typically, between 100 and 250 households are in the one village. About 7,000 of the total population are living in Hagereselam town, the district's capital.

The average annual rainfall in the district ranges between 712 and 794 mm. The temperature profile of the Tembein highlands shows little variations throughout the year, monthly maximum temperature for Hagereselam is between 22 and 20 °C, monthly minimum temperature between 6 and 4 °C. According to the traditional agro-climatic classification, the Tembein highland area is situated in the zones of *woina dega* (1500-2300m) and *dega* (2300-3200m).

Administratively, the district is divided into 18 *tabias*[2] each of which includes some villages (locally known as *kushets*). The numbers of villages (*kushets*) in the tabias vary from 2 to 12 with a mean of 4.3 and mode of 3. As part of the environmental rehabilitation and forest regeneration programme, in the past 2 to 3 decades, about 11,924 hectares[3] (i.e., nearly 10% of the total area of the district) were closed from the intervention of man and livestock. The closed areas (exclosures) area is distributed through out the district. Mostly, exclosures are located on steep and degraded slopes (Descheemaeker et al., 2006). Each village possesses a certain number of exclosures. The closed areas vary in time of establishment and in size. In terms of age, closed areas are distributed with a mean age of 13 and standard deviation of 4.6 years. The size distribution has a mean of 55 ha and a standard deviation of 92 ha which implies high variability in terms of size. On average, each of the villages possesses five exclosures. Villages have their own local by-laws, locally known as '*serit*' to regulate access and management of exclosures. However, due to either economic reasons or rule failure, violation of the rules is a major threat to the sustainability of resource management.

Like that of the regional economy, agriculture is the main source of livelihood in the study district. The farming system can be classified as mixed crop and livestock subsistence farming. A mixed wheat and barley variety (locally called '*hanfets*'), wheat *(Triticum aestivum)*, teff (*Eragrostis tef),* barley (*Hordeum vulgare)*, and horse bean *(Vicia faba)* are the main crops grown in the area, respectively accounted for 35%, 20%, 19%, 10%, and 4% of the cultivated land in the 2004/05 main cropping season. Sales of livestock (mainly small ruminants) and livestock products are

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[2] '*Tabia'* is the lowest administrative unit in Tigray, usually comprising of 4-5 villages.

[3] This information is obtained from the Relief Society of Tigray (REST), a local NGO branch office operating in the study district.

important sources household's cash income. Sale of firewood is also commonly practiced in the study area.

1.5 Evolution of exclosures

Most environmental reclamation initiatives in Ethiopia, including exclosures, are generally attributed towards responding to the continual deterioration of the nation's natural resource base, mainly since the second half of the 20th century. Most forms of these environmental problems are related to the rapid degradation of the nation's forest resources. The Tigray region of Northern Ethiopia is known for the severity of natural resource degradation. For instance, according to the TFAP (1996) estimate, the current forested land in Tigray region is less than 2% of the region's total area.

Therefore, environmental rehabilitation becomes a necessary intervention to combat the fast deterioration of the natural resource base in Tigray. Establishment of exclosures is one of the major environmental rehabilitation and protection measures adopted in Tigray (Gebremedhin et al., 2003). An exclsoure is basically a 'set-aside' land use policy in which a land area is closed from human and animal interference to promote natural regeneration of vegetation cover in a degraded land. In some instances it may be complemented with enrichment plantation.

The information obtained from elders of the community, local leaders, and key informants unanimously confirm that it was during the feudal monarchy reign of Emperor Haileselassie (before 1974) that establishment of exclosures in Tigary could be traced. However it is since the 1991 that exclosures have been practiced at large scales as an effective means of restoring the vegetation cover and rehabilitation of the environment in Tigray. Today, exclosures cover about 10-15% of the total area of Tigray.

1.6 Methodology

1.6.1 The data

Chapters 2 and 3 of the thesis are based on household survey data. To estimate the economic value of forest environmental resources to rural livelihoods and how forest environmental incomes interact with the standard household income components and household welfare, primary data were collected via questionnaire survey. The sampling units were rural households selected from the district.

To ensure representation of the district's two agro-ecological zones and population density, first we stratified villages on the basis of agro-ecology and population density. As indicated earlier, the classification of the agro-ecological zones is based on altitude; altitude ranges from 1500-2300 m.a.s.l. are locally termed as *woina douga* i.e middle highland areas and above 2300 m.a.s.l. locally known as *douga* i.e upper highland areas. On the basis of population, the *woreda* can be divided into high and low population density areas. The *douga* areas are highly (densely) populated and the *woina douga* areas are with low population density. Therefore, *douga* & sparse population density and *woina douga* & high population density cells do not exist in our stratum. As a result, for our stratification purpose, we consider only two stratum-*douga* areas with high population density (stratum-1) and *woina douga* areas with low population density (stratum-2). Since the proportion of low-land areas *(kolla)* is only about 1% of the total area of the district and no villages exist in these areas, we did not consider *kolla* for the study.

Twelve villages were randomly selected from the two strata (six villages from each stratum). In each village 30 households were selected randomly, yielding a total sample of 360 households. A comprehensive dataset, on both forest resource uses and other standard economic activities, were collected through a household survey. The survey was administered from March – May, 2005. The survey has paid special attention to forest environmental products harvested from private sources, exclosures, woodlots, and other community commons.

The data used in cost benefit analysis of chapter 4 are obtained from various previous biophysical and socio-economic studies undertaken in the study district and in Tigray at large, expert guesses, and partly from own household survey of 2005 (described in chapter 2 & 3).

The data for the sustainability analysis of forest management in chapter 5 came from focus group discussion and stakeholder multi-criteria analysis (MCA) workshop. Qualitative information, views, and perceptions of the local community were elicited with the help of focus group discussions with 18 selected groups in the study area. A three-day MCA workshop of stakeholders with a team of 13 carefully selected stakeholders consisting of experts, practitioners and local resource users were convened to elicit ranking, pair-wise and scoring (see section 5.4.2 in chapter 5) data used in sustainability analysis. Key informants from the local people and some relevant experts were also interviewed to receive additional insights on issues related to the management of exclosures.

1.6.2 Analysis

Depending on the specific aims of each chapter, various analytical models were used in this thesis. To integrate the forest environmental income component with the more standard household economic activities, in chapter 2 we used an environmentally augmented household income accounting model (Cavendish, 1998, 1999). To investigate the contribution of forest environmental income on measured rural poverty and income inequality, chapter 2 also uses of Foster, Greer and Thorebecke (1984) poverty indices (commonly known as FGT indices) and Lerman and Yitzhak (1985) model of decomposition of aggregate Gini by income sources. Whereas the FGT indices enable us to investigate the changes in poverty measures (head count poverty, poverty gap, severity of poverty), the decomposition of aggregate Gini to component income sources shows allows us to analyze the contribution of each income component to total income and the marginal effect of each income source. Applying these analyses for 'with and without' forest environmental income scenario, we were able to measure the contribution of forest income in rural poverty and income inequality.

In chapter 3 initially cluster analysis was used to group sample households into some distinct clusters on the basis of their dominant livelihood strategy. Then a multinomial logit (MNL) regression model of strategy choice (discrete choice variable) on 'asset-based' explanatory variables was used to determine the key predictors that differentiate household's strategy choice in general and 'extractive' activity and forest dependence in particular.

Chapter 4 utilizes the standard cost benefit analysis (CBA) model. Aiming at weighing the economic trade-offs of land reallocation to forestry programmes, the major soil and water conservation effects of exclosures and the opportunity costs of 'closing' land areas were identified, valued, and analysed using the method of CBA.

The method of multi-criteria analysis (MCA) was used in chapter 5. Adopting this general decision-making tool, the criteria and indicators of forest sustainability were identified, their relative importances were assessed, and their performances were evaluated in chapter 5.

1.7 Outline of the thesis

This dissertation is about the economic valuation of the goods and services flowing from 'local commons' (community owned forest resources) from the perspectives of local communities and management of problems of the same. Accordingly, the dissertation's outline is presented as follows.

Chapter 2 analyzes the role and significance of forest environmental products in rural economies, poverty and inequality. As most standard household hold surveys do not incorporate incomes from environmental sources, this chapter fills the gap in our understanding of the actual functioning of rural economies and the extent of rural poverty and inequality by explicitly incorporating environmental products in household income accounting. Chapter 3 examines the determinants of households' livelihood strategy choice and their reliance on forest extraction. In chapter 4 the economic efficiency of land reallocation to forestry activities and soil and water conservation effects of exclosures were analyzed. Chapter 5 is about the sustainable management of forests. Taking the multiple dimensions of forest functions and various stakeholders into account, chapter 5 identified sustainability criteria and indicators, assesses their relative importance and current performance relative to the desired sustainable level. Concluding remarks and recommendations are provided in the last chapter.

Figure 1.2 shows the interrelationships and feedbacks of each chapter to the overall understanding of the economic value of forest environmental resource use to local people, its environmental functions and the sustainable management of common-pool resources.

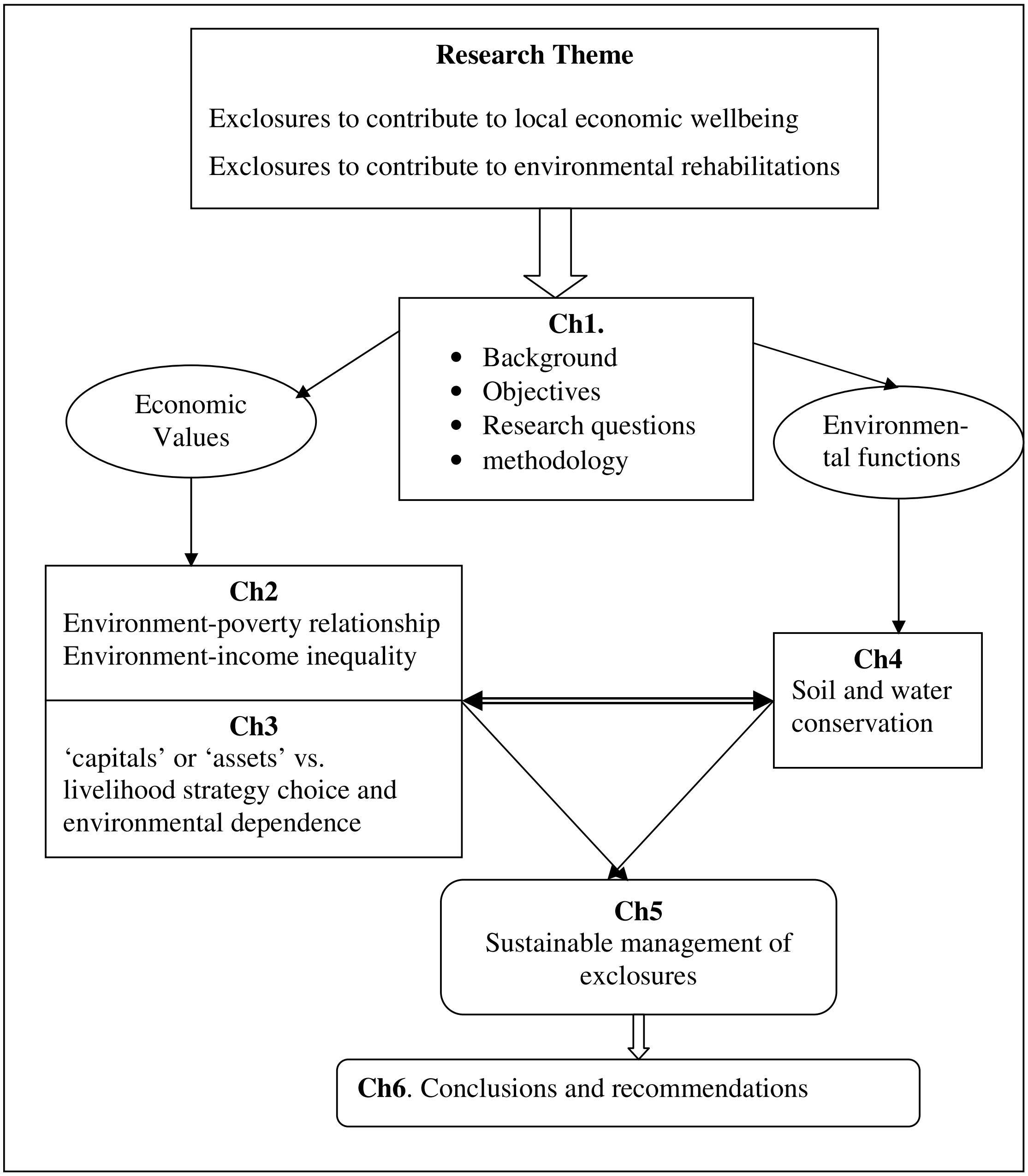

Figure 1.2 Schematic presentation of thesis outline

Chapter 2

The economic contribution of forest resource use to rural livelihoods

2.1 Introduction

Incomes from environmental sources play an important role in rural livelihoods of the developing world. In particular, products from forest environmental sources contribute significantly to rural households' economic wellbeing (Reardon and Vosti, 1995; Reddy and Chakravarty, 1999; Cavendish, 1999, 2000; Vedeld et al., 2004; Fisher, 2004; Getachew Mamo et al., 2007). Most rural household surveys, however capture the conventional rural activities, such as crop production and livestock rearing and rarely incorporate incomes from environmental resources. The goods and services freely provided by environmental resources, such as forest environmental income, are often omitted. Thus, there is a substantial gap in our understanding of the actual economic contribution of environmental resources, the functioning of rural economies and the extent of rural poverty and inequality.

However, recently there is a growing awareness of the importance and value of the use of natural resources in the lives of rural communities (Campbell and Luckert, 2002; Cavendish, 2000; Vedeld et al., 2004; Reardon and Vosti, 1995; Fisher, 2004). For instance, Cavendish (1999) estimated that 35% of the total income of rural households in communal areas of Zimbabwe originates from the use of environmental resources. Fisher (2004) asserts that rural households in southern Malawi earn 30% of their income from forest environmental resources. Godoy et al. (2002) have estimated that, on average, 17-45% of household earnings across four Amerindian villages in the Bolivian lowlands and eastern Honduras is generated from forest activities. The 2000 Global Forest Resource Assessment (FRA) report of FAO reveals that:

"More than 1.6 billion people depend to varying degrees on forests for their livelihoods. About 60 million indigenous people are almost wholly dependent on forests. Some 350 million people who live within or adjacent to dense forests depend on them to a high degree for subsistence and income. In developing countries, about

1.2 billion people rely on agro-forestry farming systems that help to sustain agricultural productivity and generate income. Worldwide, forest industries provide employment for 60 million people. Some 1 billion people worldwide depend on drugs derived from forest plants for their medicinal needs". (FAO, 2000 cited in World Bank, 2004: 16).

In the agrarian economy of Ethiopia, the economic contribution of trees and forests is significant but not yet well documented. Due to lack of data and valuation methods of the forest resources, the existing figures underestimate the total contribution of forestry sector to the country's economy and even do not reflect the 'formal' economic contribution of forests let alone the 'informal' ones[4]. Through 1982-1992 periods, for instance, the agricultural sector accounted for 45% of the total GDP, and over the same period, forestry accounted for about 5.5% of the agriculture sector and 2.5% of the total GDP[5]. These figures, however, do not reflect the non-marketed or informal forest products and environmental and social services of trees and forests. The socio-economic contribution of Ethiopia's forests is diversified and valuable. It ranges from direct supply of domestic cooking energy and food items, to provision of jobs and revenues. Many households, both in rural and urban areas, depend on fuel-wood for domestic energy supply, wild medicinal plants for health care, and various food-plants for food security. However, these contributions were not accounted and reflected in household's livelihood system.

In Tigray, though forest resources are degraded, its contribution to the regional economy is still significant. The Tigray Forestry Action Program (TFAP, 1996) indicated that the gum and incense products alone accounts 1% of the region's agricultural out put. If the multiple forest products (both marketed and non-marketed) had been accounted, the true contribution of forests to the local economy would have been significantly high. So far, the local economic effects of the multiple forest products have not been studied and well documented.

Therefore, the aim of this chapter is to systematically integrate the value of forest resources within the more conventional set of household economic activities

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[4] 'Formal' refers to marketed forest products and/or included in income accounts and the 'informal' ones are forest products with no formal markets or not included in income accounts.

[5] These figures are derived from various statistical documents of the Central Statistical Agency (CSA) of Ethiopia.

(environmentally augmented household income accounts) and to analyze the role and significance of forest environmental products in household total income of the rural economy using data from 360 randomly sampled households from 12 villages in *Douga* Tembien district in Tigray (Northern Ethiopia). This chapter further aims to examine how the incorporation of forest environmental income affects the estimates of the extents of poverty and inequality in rural economies. By doing so, we will try to answer the following questions: a) to what extent does measured poverty change, if income from natural resources is considered when calculating total household income? b) to what degree do forest environmental products promote or mitigate inequality? These questions will be analyzed by applying various poverty indices and calculating Gini coefficients (decomposition of Gini coefficients by income sources).

2.2 The economic functions and values of forests and the importance of valuation of forest resource use

2.2.1 Multiple functions of forests to rural livelihoods

Despite the possibility of involving in various activities, the livelihood strategies of rural households are directly or indirectly linked with the natural resource base. This is mainly due to the fact that a significant proportion of the population of the developing world is engaged in agricultural and other primary sector[6] economic activities for their very survival. Comparing with secondary and tertiary economic activities, it is the agricultural activity that involves extensive use of natural resources for its production.

Besides as inputs in agricultural production, natural (environmental) resources also directly offer a wide variety of products and services to rural households: consumption goods, consumer durables, production inputs, inputs into productive capital, assets, and a range of indirect values (Cavendish, 1998). For instance, forests provide a wide range of products and services catering to a variety of man's socio-economic needs, ecological functions and cultural heritage. Subsistence and cash incomes from non-cultivated forest-related resources complement other sources with a

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[6] Primary sector activities are economic activities which involve agriculture, forestry, mining, and other related activities.

continuum running from households that depend almost entirely on these incomes to those that basically do not depend on them at all (Vedeld et al., 2004). This implies that environmental resources play a very crucial role in the rural economy. Despite the multifarious utilizations of environmental resources, conventional rural household surveys neglect goods and services that environmental resources offer to the local communities. Consequently, little is known about their values in terms of overall rural household welfare (Cavendish, 1999; Campbell and Luckert, 2002).

In the literature, three different major functions[7] or roles of forest income in rural livelihoods are identified (Cavendish, 2003; Vedeld et al., 2004; Angelsen and Wunder, 2003):

- *By supporting the current consumption/meeting households subsistence needs*: Forest products are important to maintain the current level of consumption and prevent the household from falling into deeper poverty. This function of forest income in rural livelihoods is its support of current consumption with no or limited scope of lifting people out of poverty. This may be in the form of seasonal gap-filling and complements other incomes; regular subsistence uses; and/or low-return cash activities.
- *By providing valuable safety nets in times of emergency*: Forest products are used to overcome unexpected income shortfalls or cash needs. This function refers to the role forests can play during periods of hardships (during the period of unpredictable irregular events that cause a temporary need for extra income).
- *By providing a possible pathway out of poverty*: Forest products provide a way to increase household income in a sustainable manner either via accumulation of capital to move into other activities (a "stepping out" strategy) or intensification and specialization in existing activities (a "stepping up strategy").

Despite the wide range of forest functions, economic decisions do not often take into account these functions and their respective values. One of the main reasons for

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[7] The three functions may not necessarily be mutually exclusive; a particular forest product can serve the three functions simultaneously.

overlooking forest functions in economic decisions is that the values of many forest products and services are either underestimated or not valued at all because of absence of well-functioning markets, information asymmetry, and the non-marketed nature of various forest products and services. The International Institute for Environment and Development coined the term *"hidden harvest"* to draw attention to the importance of indigenous plant species in influencing the livelihoods of rural households and our limited knowledge of such functions (IIED, 1995).

The multitude of products and services provided by forests can be classified into three broad categories: *Wood products, Non-wood Forest Products (NWFPs), and services.* According to the working definition of FAO (1995):

- *Wood products* are timber, chips, charcoal and fuel wood, as well as small woods such as tools, household equipment and carvings.
- *NWFPs* consist of goods of biological origin other than wood, as well as services, derived from forests and allied land uses. The term NWFP excludes all woody raw materials. Consequently, timber, chips, charcoal and fuel wood, as well as small woods such as tools, household equipment and carvings are excluded. Herbs, wild foodstuffs, fibres, gums and latex are examples of NWFPs.
- *Services* include forest services such as ecotourism, grazing, bioprospecting and forest benefits such as soil conservation, soil fertility and watershed protection.

2.2.2 Economic value of forests

The worth of the various functions of a particular forest or nature area to its stakeholders constitutes an economic value. Hence, in assessing the total economic value of forests we consider all the possible functions of forests and the relevant stakeholders' preferences. Therefore, economic values are inherently anthropocentric by nature (Lette and Boo, 2002; Kengen, 1997), i.e., they are human-oriented and human given. Economic values associated with the various functions of forests can be classified into two main categories: *use* and *non-use values*, each having some sub-categories (Kengen, 1997; Campbell and Luckert, 2002; Bishop, 1999; Lette and Boo, 2000). The use values are divided into *direct use, indirect use, and option values*. Under non-use value category we have the *existence* and *bequest values*.

The total economic value (TEV) is an aggregate[8] of the use values and non-use values:

i.e. TEV = UV + NUV = [DUV + IUV + OV] + [EV + BV]

A short description of each component is given below.

- *Direct use value (DUV)*: these are values of forest functions/benefits that accrue directly to the consumers. These values may be associated with either consumptive uses or non-consumptive uses. Consumptive uses could be commercial and industrial forest products, such as timber, fuel wood for sale, fruits, medicine, charcoal, rattan, animals and so on. Consumptive uses could also be non-market domestic products e.g. fire wood for subsistence use. Non-consumptive use values include values of functions such as ecotourism, recreation, science, education and the like.
- *Indirect use values (IUV)*: benefits that accrue indirectly either to forest users or non-users. Examples include ecological or environmental services, protection of biodiversity, aesthetic, cultural and spiritual values
- *Option Values (0V)*: values of a potential use in the future.
- *Existence values (EV)*: intrinsic values placed by non-users on environmental assets purely for its existence without any intention of using it directly in the future.
- *Bequest values (BV)*: the value that people derive from knowing that the forest is passed on to the future generations.

2.2.3 The importance of valuing forest resource use

Valuing forest resource use by rural households enables us to assess its quantitative contribution to rural livelihoods and the extent of dependency of rural people on forest

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[8] However, this simple additive expression of total economic value oversimplifies the problem. The various value components may not be mutually exclusive among each other. Hence, due attention must be paid as the overall economic value estimate obtained in this way may underestimate or overestimate the true value of nature.

products. Similarly, estimating the economic value of environmental resource use in rural livelihood systems is important in order to correctly diagnose rural poverty. The traditional concept of poverty focuses on monetary income and wealth. This materialistic definition of poverty from classical economists dominated until the post WWII period (Angelsen and Wunder, 2003). Accordingly, until the 1960s the policy focus was essentially on expanding monetary income. However, a number of recent empirical studies on rural economies in developing countries show that the non-monetary income and consumption may be even more important for market-remote rural households than cash income (Cavendish, 2000; Fisher, 2004). The Sustainable Livelihoods Approach (SLA) of the British Institute for Development Studies (IDS) has also paid due attention on '*natural capital'* in the analysis of poverty.

Based on rigorous fieldwork in Zimbabwe, Cavendish (2000) makes a compelling case that environmental income can play a crucial role in the livelihoods of rural households, especially in the poorest. In his study, the lowest income quintile derived about 40% of total income from the use of environmental resources. Even when the percentage contribution from natural resources is relatively small, income from these sources may be of vital importance to people living close to the survival line. In particular, environmental income may fill the gap in times of income shortages from other standard sources and act as a safety net or insurance during unpredictable economic shocks. If such a significant source of income is neglected, our understanding of rural poverty will be partial and distorted. Including environmental income while studying rural households can, therefore, be helpful in enhancing our poverty diagnosis by focusing on neglected sources of livelihoods.

Besides its importance in rural poverty diagnosis and understanding the role of environmental resources in rural economies, Cavendish (2002) identified two other reasons for valuing environmental resource use. First, many forms of rural environmental degradation or enhancement are driven by the households' extraction and management choices of the environmental resources. Households may choose to degrade the environment or invest in environmental protection. Exploring the role of environmental resources in rural livelihoods enables us to understand the economic constraints and incentives that may lead to conservation or destruction of the rural environment. Second, understanding environmental values will have key policy implications on issues such as land use policy, agricultural intensification, privatizing the commons, and designing resource management schemes. A clear understanding of how poor people are dependent on their environmental resources is fundamental in shaping policies that safeguard and develop environmental assets for the poor in a targeted manner (Sjaastad et al., 2005; Cavendish, 2000).

2.3 Data and methodology

To make direct comparisons between the values of environmental resources use and those of agricultural, off-farm activities and other rural activities, monetary estimates of the various livelihood portfolios of local communities are sought. Thus, a key step in understanding the role of environmental resource use in rural livelihoods is estimating household incomes from environmental sources and examining carefully the share of these resources in the overall livelihood strategies. These involve monetary accounting of the products and services of environmental resources using relevant valuation techniques (Campbell and Luckert, 2002). To this end, in this section, we discuss our methodological approach in augmenting the conventional household income accounts with incomes from forest environmental sources and how these incomes are attributable in influencing measured rural poverty and inequality.

2.3.1. Income accounting

Since our focus is primarily on forest environmental resources (rather than the entire set of environmental resources), we attempt to account the products and services that households generate from forest plant resources. In our attempt of measuring the value of households' uses of plant resources (environmental goods) and setting this in the context of the overall household livelihood portfolio, an appropriate measure of the household's economic status[9] has to be chosen. Following Cavendish (2002), we use the *total net income*[10] (*monetary or cash income* and *income in kind*) approach as

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[9] In measuring household's overall economic status, the consumption of leisure has not been given monetary values, because, on the one hand, the consumption of leisure is hard to quantify and value in rural economies of poor nations; and on the other hand there are very meager opportunities available for labour time in the context of African rural settings in general and in the study area in particular.

[10] The concept of net total income, as employed here, is a standard measure of welfare, used in most rural income and expenditure surveys. While consumption is often preferred to income as a welfare measure in household studies, in this and other rural African studies the distinction between net income and consumption is insignificant.

a broad measure of household's economic status. Household total income can be broken down into various components. In this study, we define five major categories[11] of household total income:

- Crop income: crop sales income and the value of the consumption of own produced goods (subsistence use).
- Livestock income: livestock or livestock product sales income and the value of own consumption (subsistence) of livestock products.
- Off-farm income.
- Net remittances (transfers).
- Forest environmental income.

In accounting household income categories empirically, we have made some simplifying assumptions following similar approaches used in other 'poverty-environment' relationships studies (Cavendish, 2002; Twine et al., 2003; Fisher, 2004; Narain et al., 2005):

- *Own labour value was not deducted from net income*: The contribution or use of household labour in own production is not deducted from the value of output in net income computation. For poor rural households working in areas where labour markets are absent or thin and alternative opportunities are less, imputing the opportunity cost of labour time (shadow wage rate) is difficult. Therefore, the net income is inclusive of own-labour costs. The exclusion of the value of own labour time is the usual approach in rural household studies (Ellis, 1998).
- *Gross value of environmental income is used*: Most forest products do not require high skill levels for its extraction; many of them can be extracted with minimum capital investment; and the opportunity cost of unskilled rural labour is very low. In such a scenario, the costs of capital consumption and the costs of labour will be trivial. Hence, in valuing environmental income, the costs of capital (depreciation), costs of intermediate inputs, and labour costs are not deducted from value of forest products i.e. we used gross value of environmental income which is a good approximate of natural rent.

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[11] The various categories of income are measured in terms of *net income* (the value of income gained from an income generating activity net of the costs of all the inputs used in that activity except the value of the use of own labour).

- *Only actual harvest of forest environmental products are estimated at current market prices or household's own reported values*: Previous studies on value estimates of the harvest from environmental sources (forest products) were criticized due to the assumptions of potential harvest or potential market on which their value estimates were based (Peters et al., 1989; Grimes et al., 1994 cited in Wollenberg, 2000). Recent studies focus on actual harvest of goods and use either market prices or own reported values to estimate the actual contribution of forest products (wood or non-wood products) in rural livelihoods (Cavendish, 2002; Fisher, 2004; Narain et al., 2005). In this study we follow the latter approach.

On the basis of these assumptions, the calculation of each income item will be given as follows:

1) Net crop income: In calculating net crop income, gross crop income is derived by measuring the value of different end-period crop products over the year for each household using January-February 2005 local market prices. Next, the values of crop inputs (fertilizers; ploughing services; seeds and any payment to hired labour) are summed to obtain a measure of total crop input costs. Then, we deduct these values from the values of gross crop income for each household to obtain the net crop income.

2) Net livestock income: Livestock produces a myriad of goods and services for household livelihoods in terms of self consumption and sales income. Besides products such as meat, milk products and egg, they also provide draft, transport and manure. Annual gross income from livestock products and services are obtained for each household. Livestock income consists of three main sub-components: livestock sales, livestock products, and services. For the first two sub-components local markets prices are used to value. Imputed values are used for livestock services in the form of, for example, ploughing and transport services. Summing the three sub-components yields gross livestock income. Next, annual expenditures[12] on cost items such as purchased fodder or straw, veterinary services, and hired-in labour are aggregated to

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[12] Note that the value of own labour services and that of free browsing and grazing from environmental resources are not included in the computation of annual expenditures.

obtain the total costs on livestock production. Then a simple deduction of aggregate annual costs from gross livestock income results in a figure for net income from livestock.

3) Off-farm income: Although the dominant economic activities of peasant households are crop cultivation and animal rearing, they may also engage partially in a variety of off-farm employments. Such activities may comprise wage employment, petty trade, small-scale non-farm market production, and other cash generating own business activities. A substantial number of households in the study area participates in food-for-work (FFW) activities which involve labour contribution to public works such as road construction or maintenance, soil and water conservation activities, and forest rehabilitation and receiving food in return for their labour services (Gebremedhin and Swinton, 2001; Holden at al., 2006). Consequently, it is quite logical to give a separate category (income title) for such an income source in household income accounts. Off-farm income is defined in net terms, that is, *net of any costs* incurred related to a person's engagement in an activity. Accordingly, the total value of a household's annual off-farm income is obtained by a simple summation of all the incomes earned from various off-farm activities by all adult household members.

4) Net remittances (gifts): It is a common practice that rural households in Ethiopia receive transfers in kind or cash from family members, relatives, and sometimes governmental units or NGOs. They may also remit out to other households or individuals. In most of the cases, however, rural households are net receivers. The accounting of this income category is quite simple. We add up all the remittances, gifts or transfers received during the year by the household and subtract the amount remitted out if any.

5) Forest environmental income[13]**:** To measure environmental resource use with a monetary yardstick, we relied on household's *own-reported values* for environmental goods as the basis for valuation. Respondents reported the weekly, monthly or yearly amount of each product harvested/gathered by the household, the amount consumed/used, the amount exchanged, the amount given to other households (gift), the amount sold, and the cash amount received from sales of these products. In case the forest products were bartered rather than sold, the retail sale price of the exchanged commodity was recorded as the cash income. An important advantage of this approach is that the resulting value estimates are derived from actual household choices (not on potential resource use). In the case study area, some forest environmental products such as fuel woods, construction woods for houses, farm implements, household furniture, inputs for basket making, sweeping material, and wild food items (for example, cactus) are widely traded locally and hence have local markets. For such environmental products the household's own value estimates can be used in our valuation exercise. There is also large number of environmental goods such as wild food items (e.g. wild fruits and vegetables) for which the local markets are absent or thin, but whose value estimates are commonly known by the local people. For such products most households are able to report the amount of the products used and the corresponding value estimates. Therefore, households' stated values could be used to value these products. However, for some environmental products such as traditional medicine, wild washing soda (for instance, products from *Phytolecca dodecandra* species, locally called '*endod'*[14]); and leaf litter as fertilizer, households find it difficult to estimate the value. In such cases we use either the value of a closely substitute marketed product as an estimate of the value of the environmental product under question or adjust their estimates or some other different value estimation methods. For instance, the value of a certain quantity of wild

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[13] Indirect use values of forest environmental services such as watershed protection, windbreak uses, spiritual and cultural values, recreation, and soil fertility maintenance are not included here. Such indirect uses require specialized valuation techniques. Also, in some studies forest animal products such as game and edible insects and birds are considered as forest products (Cavendish, 2002; Sunderlin et al., 2004). However, we did not attempt to solicit information about edible animals and game products due to two reasons. First, because of the sparse forest occurrence and the predominance of bush lands in the study area, game products are very scarce and not easily harvestable. Second, due to cultural reasons consumption of wild animals such as wild insects is strictly prohibited in most of the cases.

[14] 'Endod' is a perennial plant and has small berries which, when dried, powdered and mixed with water, yield a foaming detergent solution that has been traditionally used in Ethiopia for washing clothes.

washing soda can be estimated from the market price of a unit of soap used for similar purposes.

The data have some limitations. First, the villagers may not recall part of the forest products they harvested, used, or sold as the survey is based on recall. Second, some households may fail to tell the truth due to various reasons. Third, respondents may neglect to report some smaller scales or minor products sold or used for home consumption. Fourth, environmental products collected may vary from year to year but the survey comprises data only for one year. Despite these limitations, the values obtained reflect robust estimates of forest products use for the reasons that maximum precautions were taken from the inception of questionnaire design to data cleaning and analysis.

6) Miscellaneous income: In addition to the five major income components described above, some households also earn income from various other sources such as honey income, interest income and rent income from land rented out. The income earned from such sources is aggregated and classified as 'miscellaneous income' in household income accounting.

A final issue concerns the sources and tenure structure of the natural resource system where forest products are being harvested. Concerning land tenure and property rights to natural resources in Ethiopia, article 40 (sub-article 3) of the Constitution of the Federal Democratic Republic of Ethiopia (FDRE) states: *"The right to ownership of rural and urban land, as well as of all natural resources, is exclusively vested in the State and in the peoples of Ethiopia. Land is a common property of the Nations, Nationalities and peoples of Ethiopia and shall not be subject to sale or to other means of exchange"* (FDRE, 1994). Accordingly, land is not a private property in Ethiopia. Individuals have only usufruct rights on land. In spite of the provisions for possession right to land and rights to land improvements in sub-articles 4 and 7 under article 40 of the Constitution ("*Ethiopian peasants have the right to obtain land without payment and the protection against eviction from their possession"* (sub-article 4) and *"Every Ethiopian shall have the full right to the immovable property he builds and to the permanent improvements he brings about on the land by his labour or capital. This right shall include the right to alienate, to bequeath, and, where the* *right of use expires, to remove his property, transfer his title, or claim compensation for it"* (sub-article 7)), the exclusive ownership right vested in the state has created disincentives in land and natural resources development related investments. This constitutional constraint, fuelled by land fragmentation, population growth, poverty and small holdings do not leave enough room for private forest investments among Ethiopian peasants in general and in the study area in particular. As a result, we do not see economically meaningful private forest developments. However, this does not mean that peasants do not have small patches of forested land at their homestead or around their farm land.

As indicated in preceding discussions the main interest of this chapter is to account quantitatively the economic importance of forest products freely provided by the environmental sources. Accordingly, for instance, we do not consider forest income from commercial forestry as 'forest environmental income', because commercial forestry is an investment activity and the return from such an investment is a profit, not an 'environmental income'. Therefore, for the purpose of this study, we elicited data on forest environmental products from two main sources where the household actually harvested forest environmental products.

1) Exclosures: These are areas possessed by the community and closed from the intervention of man and livestock for natural forest regeneration. Harvesting of forest products from exclosures is regulated by the community. Harvest restriction for NWFPs is not stringent. For instance, in a cut-and-carry system all the community members have regulated access to the periodic harvest of grass for animal fodder and for thatching. In principle, access to wood products is restricted. However, there are many instances where the community regulatory rules are violated by individuals. This may be partly due to the 'need'[15] of local people to harvest products and partly due to 'greed'[16]. While administering the questionnaire sufficient efforts have been made to elicit the type and quantity of products harvested from exclosures by individual households without the consent of the community (commonly referred as 'illegal harvest'). We did not approach respondents directly to tell us what products

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[15] This relates to poverty and lack of alternative energy sources to substitute essential forest products such as firewood.

[16] This relates to the free-riding problem in which even some better-off farmers violate the rules to optimize private benefits.

and how much of each they harvested illegally. Our approach was indirect in the sense that, for instance, if a household did not indicate the use of firewood in any of the other category of forest product sources, we posed him/her a question “where does the household obtain firewood”. Then he/she discloses “we obtain deadwood or branches of trees fallen in the ground from exclosures”. Thus, exclosures are one of the essential sources of forest environmental products (mainly non-wood forest products) either in community regulated harvest or tacitly.

2) Other communally owned forest resources and grazing fields: These are community-level managed or semi-open access land use types such as community grazing fields. They are different from exclosures in that access to these areas is not restricted. Most sample households claim that their major source of grazing is either community owned or even beyond the community in other villages. They also claim the same land use type as an important source of some important forest products such as firewood for home use and sale, farm implements, construction materials, and household furniture.

3) Forest products from homesteads or crop lands: In addition to the two major sources of ‘forest environmental products’ indicated above, households may also obtain some environmental products from their homestead or farm field. These include forest products for which the household does not allocate labour and other economic resources in planting or cultivating or managing. For example, a farm household may harvest grass or wood product grown spontaneously in/near its crop field or homestead. Such environmental products are freely available for the household. No effort or investment is made in the cultivation of such products. No external body regulates the harvest of products from these sources. Therefore, a forest product from such privately owned areas is also considered as ‘forest environmental product’.

2.3.2. Measuring poverty

One faces two distinct problems while attempting to measure poverty viz. choosing a criterion of poverty (e.g., the determination or specification of a ‘poverty line’ in terms of per head income or consumption level) and constructing an index of poverty

(Sen, 1976). The concern of this section is of the latter one, i.e. to construct an index of poverty with and without forest income in order to assess the contribution of forest income to total rural poverty level in the study area. In constructing the poverty index, we use the poverty line determined by the MU-IUC socio-economic research team[17] from the 'Geba Catchment[18] Rural Household Survey-2005' data for the catchment's rural population (see appendix 2C for the procedures in constructing the poverty line).

Several indices of poverty have been suggested for the measurement of poverty (Sen, 1976; Thon, 1979; Kawkani, 1980; Foster, Greer and Thorebecke, 1984 (FGT hereafter)). In our analysis, we employ three variants of the FGT index. The FGT poverty index P is calculated as follows:

$$P(\alpha) = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z - y_i}{z}\right]^{\alpha} \tag{2.1}$$

where α = is a parameter that can take 0, 1 or 2 for the three variants of FGT index to be applied in our study.

n = the total population size for which the poverty measure is sought

q = the number of poor households below the poverty line

z = the poverty line level income

y_i = the per capita income[19] of the household (the sum is taken only on those y values not greater that z)

When $\alpha = 0$ the formula represents the head count poverty, i.e. the percentage of poor in a population. The poverty gap is calculated by putting α =1 in the equation. When α = 2, we measure the severity of poverty. Putting α =2 in the equation means squaring the poverty gap (the distance that separates the poor from the poverty line). The use of squared poverty gap implies that the poverty gap is weighted by itself in

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[17] MU-IUC program is a ten year (2004-2013) multidisciplinary Research and Development collaboration programme between the Flemish Universities (Belgium) and Mekelle University (Ethiopia) with the financial aid of VLIR. The Socio-economic Research project is one of the six research projects under the MU-IUC programme.

[18] All the sites from which the forestry and other standard household income data collected and used in this research are located within the Geba catchment.

[19] This is the per capita household income adjusted to adult equivalent scale. It is not simply the quotient of household total income and household size. The household size is adjusted to a.e.u to reflect the variations in households' demographic structure.

order to give more weight to the very poor (relative deprivation concept of poverty) (Foster et al., 1984).

The subgroup additive property of FGT index embodies an interesting economic interpretation. Suppose that the population is divided into '*k*' distinct groups of households (indexed by *i = 1, 2, …, k)* with a population sizes of 'n_k' in each group. The decomposability property of FGT index allows us to re-write equation (5) as follows:

$$p(\alpha)=\sum_{j=1}^{q^{(1)}}\frac{n_1}{n}\left[\frac{y_{1j}^{(1)}-z}{z}\right]^{\alpha}+\sum_{j=2}^{q^{(2)}}\frac{n_2}{n}\left[\frac{y_{2j}^{(2)}-z}{z}\right]^{\alpha}+\ldots+\sum_{j=k}^{q^{(k)}}\frac{n_k}{n}\left[\frac{y_{kj}^{(k)}-z}{z}\right]^{\alpha} \tag{2.2}$$

where $q^{(k)}$ (indexed i=1, 2, …, k) represents the number of people below the poverty line in sub-group *k* and $y_{kj}^{(k)}$ is the income vector of poor people in sub-group *k*.

Each of the right hand additive terms in equation (2.2) represents the sub-group measure poverty. This equation can be expressed in shortened form as:

$$p(\alpha)=\sum_{i=1}^{k}\sum_{j=1}^{q_j^{(k)}}\frac{n_k}{n}\left[\frac{y_{ij}^{(k)}-z}{z}\right]^{\alpha} \tag{2.3}$$

The decomposition enables us to quantitatively assess the effect of changes in sub group poverty on total poverty. The expression:

$$\sum_{j=1}^{q_j^{(k)}}\frac{n_k}{n}\left[\frac{y_{ij}^{(k)}-z}{z}\right]^{\alpha} \qquad 2.4)$$

may be interpreted as the absolute contribution of sub-group *k* to the total poverty index and equation (2.5) is the percentage contribution of sub-group *k*.

$$100\sum_{j=1}^{q_j^{(k)}}\frac{n_k}{n}\left[\frac{y_{ij}^{(k)}-z}{z}\right]^{\alpha} \Big/ \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z-y_i}{z}\right]^{\alpha} \tag{2.5}$$

Essentially, the FGT (α=2) measure of poverty satisfies the following important conditions proposed for a good poverty index.

First, it is decomposable in the sense that the poverty measure for the whole population can be additively decomposed with population-share weights. This means that the poverty level index for the population as a whole is equal to the weighted sum of the poverty measures for the population subgroups. This additive property is essential in the sense that it enables us to analyze the contribution of various population subgroups to the changes in overall poverty. Many other poverty measures do not satisfy this additive property (Kakwani, 1980; Blackorbey and Donaldson, 1980).

Second, the FGT (α=2) poverty index satisfies the two basic axioms proposed by Sen (1976). In order to account the distribution of income among the poor rather than the mere head count of the number of poor in a population and to reflect the depth of poverty, and the inequality among the poor (the severity of poverty), Sen (1976) has put forward the following two conditions (axioms) to be satisfied if a poverty index is taken to be good:

- MONOTONOCITY AXIOM: Given other things, a reduction in income of a given person below the poverty line must increase the poverty measure.
- TRANSFER AXIOM: Given other things, a pure transfer of income from a person below the poverty line to anyone who is richer must increase the poverty measure.

Third, the FGT (α=2) is justified by a relative deprivation concept of poverty. If we measure poverty as the weighted sum the income shortfalls of the poor, the choice of weight does matter in the final index we develop. FGT (α=2) takes the income shortfalls themselves as weights. Since deprivation depends on the difference between the poor person's actual income and the poverty line, taking income shortfalls as weights in FGT (α=2) is closely related to the aspect of relative deprivation.

The t-statistic is computed to test whether the difference between the two poverty indices (with forest incomes and those without forest incomes) at a given α is statistically significant. To compute the t-statistic, we must first obtain the standard error of the difference between two poverty indices. Given the sample standard error of an index for a given α, the standard error of the difference between two estimates can be computed.

Suppose that $\hat{p}^{1}{}_{(\alpha)}$ and $\hat{p}^{2}{}_{(\alpha)}$ are two sample estimates of a poverty measure for a given α based on two independent samples with standard errors $s.e.(\hat{p}^{1}{}_{(\alpha)})$ and $s.e.(\hat{p}^{2}{}_{(\alpha)})$ respectively. Kakwani (1993) showed that the standard error of the difference between these two estimates is:

$$s.e.[\hat{p}^{1}{}_{(\alpha)} - \hat{p}^{2}{}_{(\alpha)}] = \sqrt{(s.e.(\hat{p}^{1}{}_{(\alpha)})^{2} + (s.e.(\hat{p}^{2}{}_{(\alpha)})} \tag{2.6}$$

Kakwani (1993) shows further that the standard error of the asymptotic distribution of each of the poverty measures of the $p_{(\alpha)}$ equals:

$$s.e(\hat{p}_{(\alpha)}) = \sqrt{(\hat{p}_{(2\alpha)} - \hat{p}_{(\alpha)}^{2})/n} \tag{2.6a}$$

Then, the sampling distribution of the standardized difference ($\hat{\theta}$) (i.e., the test-statistic for testing the equality of the measures is given by:

$$\hat{\theta} = \frac{(\hat{p}^{1}{}_{(\alpha)} - \hat{p}^{2}{}_{(\alpha)})}{\sqrt{(s.e.(\hat{p}^{1}{}_{(\alpha)})^{2} + (s.e.(\hat{p}^{2}{}_{(\alpha)})}^{2}} \tag{2.7}$$

and follows an asymptotic normal distribution with zero mean and unit variance.

2.3.3. Measuring inequality

The literature on the derivation and decomposition of Gini coefficients is quite rich (Pyatt et al., 1980; Shorrocks, 1980; Shorrocks, 1982; Shorrocks, 1983; Lerman and

Yitzhaki, 1985; Podder, 1993; Adams, 1994; Yao, 1997; Yao, 1999; Reddy and Chakravarty, 1999). When total income consists of a number of income sources, the Gini coefficient measuring total income inequality can be decomposed into factor components. The decomposition enables us to examine the contribution of each component to the total Gini and to find out which component is more responsible than others to the total income inequality. Among the various decomposition methods suggested in literature we will adapt the method proposed by Lerman and Yitzhaki (1985). This method possesses a number of noteworthy features compared to many other methods. For instance, it enables us to determine the marginal impact of each income component on overall income inequality. It is probably the most intuitive with its clear correspondence to the Lorenz curve[20]. It yields an intuitive economic interpretation of the parts making up each component income source's contribution to inequality ((Lerman and Yitzhaki, 1985); Lopez-Feldman et al., 2006).

We follow Lerman and Yitzhak (1985) in their approach to decomposing Gini coefficients by income sources. Suppose that the population consists of N income units[21] (household) indexed by n (n= 1, 2,… ,N) and that the total income of each income unit is a sum of incomes from K different sources.

Let: X_k = a specific income source or income component (k = 1, 2, …, K)

$X = \sum_{k=1}^{K} X_k$ = the total income of an income unit from all the k components

μ_{kn} = the per capita income of the n^th^ household from source k.

$\mu_n = \sum_{k=1}^{K} \mu_{kn}$ = the per capita total income of the n^th^ household from all sources

S_k = income component k's share in total income and measures the importance of income source k with respect to total income.

G_k = the Gini of source income k and measures the inequality of the distribution of source k.

R_k = the Gini correlation between income source k with the cumulative distribution of total income

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[20] The Lorenz curve plots cumulative percentage of total income (on the vertical axis) against cumulative percentage of population (on the horizontal axis) when the income vector is ordered from lowest to highest.

[21] An income unit can be a person or a household. Since our unit of analysis is the household, an income unit or a household refer the same thing. So, we may use both terms interchangeably.

As Shorrocks (1982) argues, there is exists no unique way to decompose inequality. In the literature we find many alternative formulae to derive the decomposition of Gini coefficient (Rao, 1969; Pyatt et al. 1980; Shorrocks, 1982; Yao, 1997; Yao, 1999). However, most authors derive the formula by calculating the area between the Lorenz curve and the diagonal line of a unit square (appendix 2B). Following Lerman and Yitzhaki (1985), the Gini coefficient for total income inequality (G) with k distinct sources of income can be decomposed as:

$$G = S_1 G_1 R_1 + S_2 G_2 R_2 + \ldots + S_k G_k R_K \qquad (2.8)$$

$$= \sum_{k=1}^{K} S_k G_k R_k$$

where S_k, G_k and R_k are as defined before.

In equation (2.8) the aggregate Gini coefficient (G) that measures total income inequality in a given population is expressed as the sum of the products of the kth income component share of total income, its own Gini, and its correlation with the rank of total income.

One of the essential economic inferences, from the decomposition of aggregate Gini coefficient in terms of the constituent income sources is to analyze the contribution of each income factor to total income inequality. The term $S_k G_k R_k$ is the contribution of the k-th income source to the overall income inequality. A more important rationale for decomposing the total Gini to component income sources is to learn how changes in particular income sources will affect the total income inequality. In the context of this particular study, we can estimate the effect of small changes in forest environmental income on inequality, holding income from all other sources constant, technically the effect of forest income on inequality. To do so, consider equation (2.8) and introduce a small change in income source k. Suppose that a change in each individual's income from source k is equal to ϕX_k where ϕ is close to 1, then it can be shown that the partial derivative of the overall Gini coefficient with respect to a percentage change (ϕ) in source income k is equal to:

$$\frac{\partial G}{\partial \phi} = S_k G_k R_k - S_k G = S_k (G_k R_k - G) \qquad (2.9)$$

Equation (2.9) indicates that the percentage change in overall inequality due to a small percentage change in k$^{\text{th}}$ income equals the initial share of that income in inequality ($S_k G_k R_k$) minus the share of it in total income.

The relative marginal effect (RME) of source income k to the overall Gini can be obtained by dividing equation (2.9) by G.

$$\frac{\partial G / \partial \phi}{G} = \frac{S_k G_k R_k - S_k G}{G} = \frac{S_k G_k R_k}{G} - S_k \qquad (2.10)$$

This equation can be interpreted as the impact that a 1% change in specific income source will have on total inequality.

2.3.4 Data collection

Data were collected from 12 villages of the study district (*Douga Tembien woreda*) in northern highland region of Tigray, Ethiopia. Research villages were chosen systematically to ensure representation of the district's two distinct agro-ecological zones. The classification of the agro-ecological zones is based on altitude. Altitude ranges from 1500-2300 m.a.s.l. are locally termed as *woina douga* i.e middle highland areas and above 2300 m.a.s.l. the area is locally known as *douga* i.e upper highland areas. Six villages from each zone were randomly selected. On average, each of the villages possesses five exclosures.

In each village 30 households were selected randomly, yielding a total sample of 360

households. A comprehensive dataset, on both forest resource uses and other standard economic activities, were collected through a household survey. The survey was administered from March – May, 2005. The survey has paid special attention to environmental forest products harvested freely from forest environmental sources specified in section 2.3.1. Instead of focusing on few forest products, quantity and value information was obtained on a range of forest resource uses. The various forest products included in the survey are presented in appendix 2D. Value calculation is based on the actual use of the forest products rather than the availability of the resource.

Though maximum care was taken from the inception of the survey to data entry and anlysis, as it is commonly observed in most rural household socio-economic survey in the developing world, our data set may encounter some limitations in terms of accuracy. As our survey is ‘income-survey’ as opposed to ‘expenditure survey’, we feel that household may hide some of their income sources and underreport their incomes. Despite such limitations, we believe that the data and the ensuing results indicate the real socio-economic conditions of the study area.

2.4 Results

Table 2.1 describes some key attributes/characteristics of the households in *douga* and *woina douga* villages. The average land holding is the same among households in both village categories. Except the average distance to the source of drinking water, households in *douga* villages encounter relatively higher magnitudes in the rest of the attributes. As distances to main road and market centers have potential influence on the household’s income from forest sources, *a priori* one may expect relatively lower forest income in *douga* villages than their counterparts in *woina douga* areas. The observed differences in most of the attributes in table 2.1 between the two village categories may provide us some explanations for the variations in empirical importance of forest products among the two village categories

Table 2.1* Household characteristics (by village categories)

Attributes	*douga* villages			*woina douga* villages		
	mean (sd.)[a]	min.	max.	mean (sd.)	min.	max.
Household size (head count)	6.13 (1.98)	2	10	5.60 (2.02)	1	10
household size (a.e.u)	5.00 (1.66)	1.58	9.34	4.50 (1.73)	0.82	8.34
land holding (ha/household)	1.00 (0.55)	0	2.5	1.10 (0.70)	0	4.75
Walking distance to main road [b]	63.00 (48)	5	240	48.00 (29)	5	180
Walking distance to market center [b]	86.00 (62)	6	270	64.00 (43)	5	210
Walking dist. to local primary school [b]	30.00 (40)	5	300	28.00 (18)	5	120
Walking dist. to drinking water source [b]	19.00 (24)	2	180	27.00 (28)	2	120

* All tables in this chapter are produced from my own survey, 2005.

[a] Numbers in parentheses are standard errors.

[b] All the walking distances are in minutes.

2.4.1 The contributions of forest products to total rural household income

In order to make the household income data welfare-comparable, the inter-household differences in household size and demographic structure are adjusted. Thus, in this and the remaining sections of the chapter, the 'household per capita income' refers to income per adult equivalent unit (a.e.u). For more discussions on a.e.u and the weights applied for various demographic structures of household members in this study, see appendix 2A.

Table 2.2 presents the environmentally augmented household income account, with income components classified under the five major headings identified earlier. Forest environmental income accounted for 27% of total household income on average, the second largest household income share next to crop income having a share of 43%. Comparing the share of forest environmental income with that of livestock share (16%) in average total household income, the former contributes nearly twice of the latter. This is a striking figure, because traditionally it is livestock income that was believed to be the major income share in rural Ethiopia. The empirical data challenges this belief. The pro-livestock argument put forward so far is a simple conjecture which may emanate from two major observations on Ethiopian agricultural system: the nature of peasant farming system and the total livestock population of the country. In terms of number, Ethiopia ranks first in total livestock population in Africa. However, it is often claimed that livestock productivity is among the least even in African standard (Gryseels, 1988). And the dominant farming system in Ethiopia is a mixed crop-livestock subsistence production. Hence, the existing belief of putting livestock in the fore front of Ethiopian peasants' livelihood strategies is a simple conjecture that does not take into account the productivity aspect. On top of these, most environmental products are not accounted in household income accounts. Fuel wood, for example, is an essential forest product used for cooking, but not explicitly accounted in most studies. We can find many rural households without livestock, but no one not using firewood. In countries like Ethiopia where the source of all animal feed is primarily from environmental sources, environmental products become an important input in the very livestock production system itself. Therefore, we can argue that our finding is not an exaggeration and overestimation of the importance of forest products. It is rather consistent with some similar research outputs in Ethiopia and elsewhere in Africa. For instance, Cavendish (1999) found that 35% of rural household income is derived from environmental products in Zimbabwe. Fisher (2004) showed that 30% of household income in rural Malawi is accounted by forest income. In the Dendi district of south western Ethiopia, Getachew Mamo et al., (2007) have found that 39% of the average household income is contributed by forest income; nearly equal to the combined contribution of crop and livestock incomes together (40%).

Table 2.2 Households' total income (in ETB*) and income shares by major income source (per a.e.u for all sample households in 12 villages)

Income component	total income By source	average per capita[1] hh. income by income source	income shares[2] (%)
Crop income	413,882	244 (161)♠	42.56
Livestock income	158,576	92 (143)	16.30
Off-farm income	104,496	62 (99)	10.75
Transfer income	12,670	7 (36)	1.26
Forest environmental income	262,989	155 (99)	27.04
Miscellaneous income	20,314	12 (35)	2.09
Total	972,525	574 (312)	100.00

* ETB = Ethiopian Birr which is the legal currency in Ethiopia. During the survey year, the exchange rate was US$1=8.68ETB; 1EURO=10.62ETB; ♠ Numbers in parentheses are standard errors.

Notes:

[1] The average per capita incomes for each income source is calculated by multiplying the population share of a household's a.e.u in total a.e.u population size and per capita of a source income for each household, then taking the sum over sample household (i.e. it is an expected income). Mathematically: average pci for income source k is: $ave.pci(k) = \sum p_i (ave_{ki})$ for i= 1, . . ., 360); where $p_i = aeu_i / \sum aeu_i$ (for i= 1, . . . , 360) (since n =360); $ave =$ average; and $ave_{k\,i} =$ the total earning of household (i) from income source (k) divided by the a.e.u of the i^{th} household. Or in language of Statistics, it is simply the expected value of each component of income.

[2] The shares of each income source is calculated as the mean of individual household's budget shares in stead of simply dividing the total of an income source to the overall total income.
Mathematically: *income share of source (k) =* $\sum p_i ave_{ki} / \sum p_i ave_{ti}$ where $ave_{t\,i}$ is average per capita total income, and the sum is taken over i for $i = 1, \ldots, 360$.

The inclusion of forest environmental products in household income accounting has raised the conventionally measured mean income (income source commonly captured in rural survey) by 37%. The implication is that the conventional approach of household income accounting invariably underestimates rural economies. The survey data reveal that the lion's share of forest income is accounted by the domestic use value of firewood. Firewood accounts for about 45% of total forest products' value. On average a typical household consumes about ETB 327 worth of firewood annually for domestic use. With almost nil alternative sources of rural energy (mainly for cooking) in rural Ethiopia, the dominance of firewood in rural forest income is not a surprising fact. Products from exclosures account for about 15% of the average forest environmental income. The actual share of exclosures is certainly much higher than the reported quantity because of the simple reason that households do not report all the products they harvested from exclosures and even do not disclose that they harvest from exclosures due to access restriction. Even if in reality some products are harvested from exclosures, during the interview, respondents say that it is from 'other communal sources'. So, taking the fact of underreporting and no reporting into consideration, the observed 15% share of exclosures products in overall forest environmental income is quite large.

Taking the scarcity of non-farm employment and rural labour imperfection into account, the observed 11% share of off-farm income should be appreciated. Income from this component is mainly derived from casual wage works in neighbouring urban centers and informal business undertakings. Transfer income is the lowest contributor to total average household income. It accounts for only about 1% in average household income. Remittances from household members working longer periods in urban centers dominate the transfer income component.

The distribution of the share of forest environmental income in average total household income is presented in figure 2.1. Though the distribution is slightly skewed positively (skewness = 0.856), we see that from 20% to 40% of the average income of nearly 60% of the households is accounted by forest environmental income. Figures 2.2 and 2.3 respectively indicate the distributions of household income per a.e.u without and with forest environmental income. As can be seen from the figures, both distributions are skewed positively, with the respective skewness of 1.64 and 1.48. The inclusion of forest income has pushed more households to the right tail of the distribution. For instance, when forest income was excluded from the household income measure, the proportion of households in the per capita a.e.u income range between ETB450-850 was 32%. Including forest income raises household proportion in the same income range to 47%. The relative skewness values of the two distributions also indicate a relative decline in skewness of the distribution when forest income is accounted.

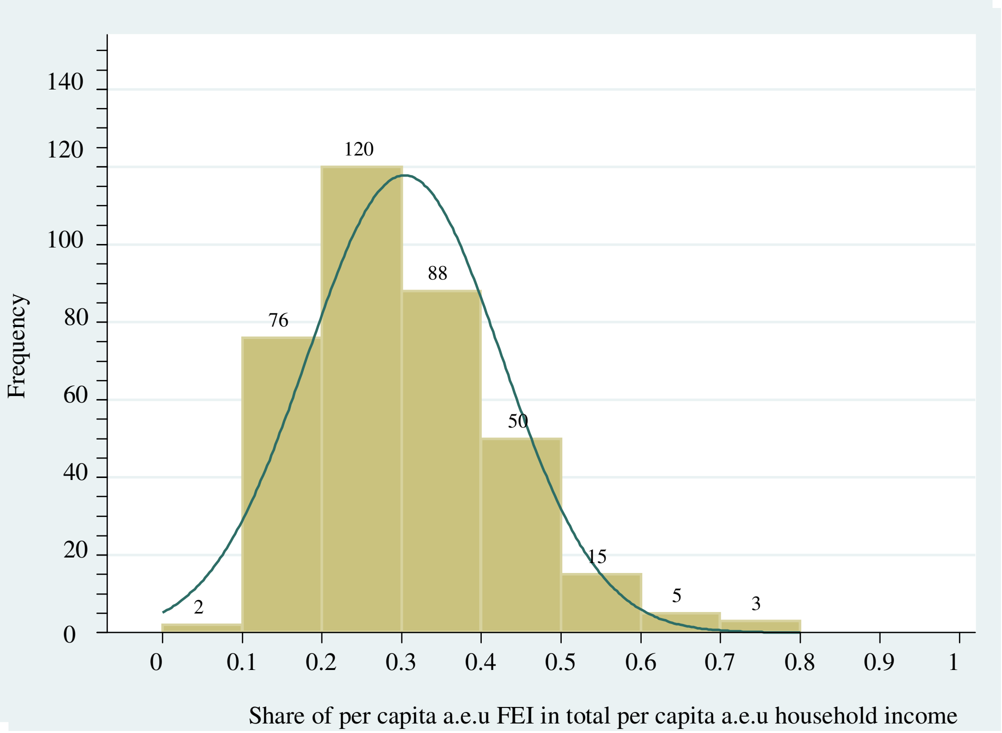

Figure 2.1 The distribution of the share of forest environmental income (FEI) in average household income

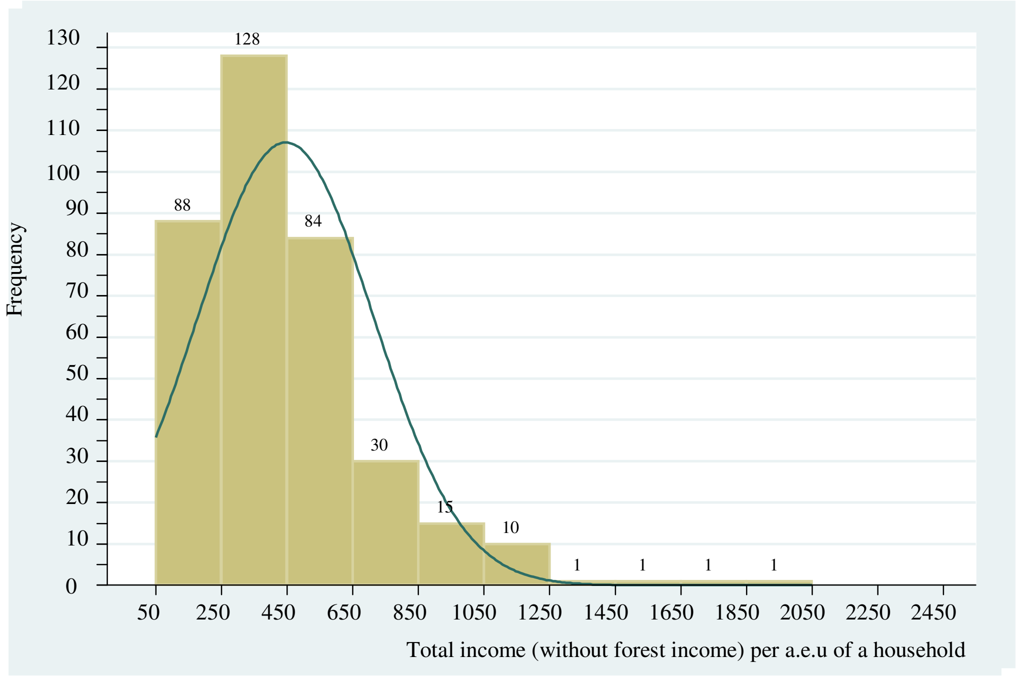

Figure 2.2 The distribution of household income per a.e.u (without forest income)

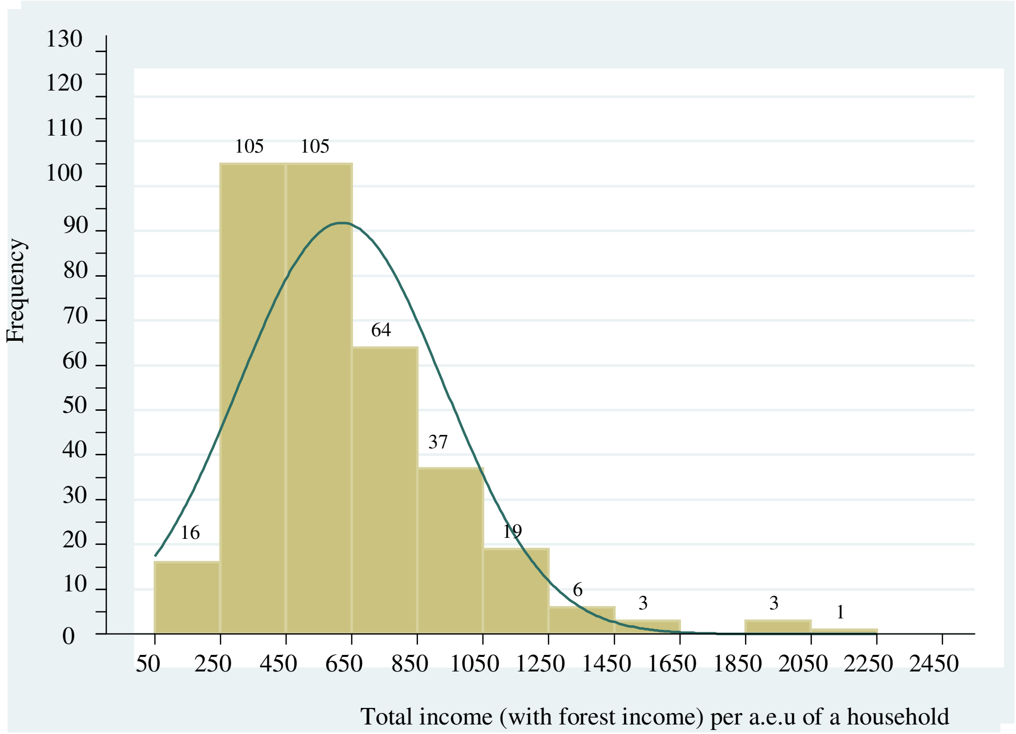

Figure 2.3 The distribution of household income per a.e.u (with forest income)

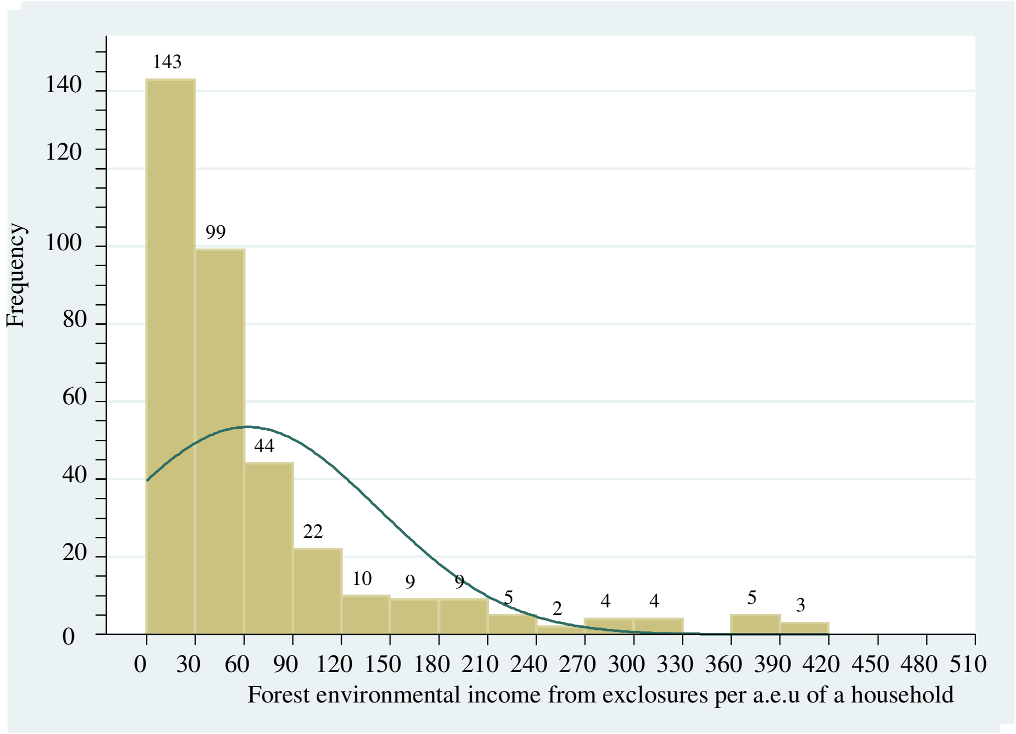

Figure 2.4 The distribution of forest income from exclosures across household

The distribution of exclosures income has shown highest skewness (Fig. 2.4). About 40% of the households interviewed have harvested, on average, forest products that worth only ETB 20 or less from exclosures. Among these households, 55% have reported that they did not harvest any product from exclosures during the year.

Table 2.3 presents the average per capita income per a.e.u of the various income components and their share of each in average household income. An important observation is that the share of forest environmental income decreases monotonically as average household income increases. Forest environmental income accounts for about 35% of average household income for the bottom 25% of the households surveyed whereas the top quartile derives about 23% of their average income form forests. The implication is that poor households depend more on forests than the rich. However, in absolute terms richer households consume more forest products than the poor.[22] Our finding is in agreement with other studies in tropical rural areas (Cavendish, 1999; Scherr, 2000; Fisher, 2003; Shackleton and Shackleton, 2005). However, in all income quartiles forest income holds the second largest share, the first being crop income.

The share of crop income does not show significant difference among the income quartiles. It falls between 42 to 44% of the total average household income. This may be an indication of two important features of crop production in the study area: (1) that crop is produced for subsistence use, and (2) that crop accounts the major share of subsistence for households at all income levels. Households at all income brackets produce crop mainly to satisfy their subsistence need. Hence, at all income levels crop production accounts the largest in their respective income. However, the absolute average crop income shows a monotonic rise when one moves from lower income quartile to the higher ones. Note that a very small share of income actually originates from cash sales.

For instance, only 4% of the average total crop income is accounted by cash sales. Hence, one may safely conclude that the study area represents a typical subsistence farming community. The trend is more or less the same for the other income components as well.

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[22] Some empirical studies find a U-shaped poverty-environment relationship (Narain et al., 2005).

Table 2.3 Household income per a.e.u and income shares (by quartile and income source)

	Household quartile							
	lowest 25%		25-50%		50-75%		top 25%	
Income component	income per a.e.u	income share (%)	Income per a.e.u	income share (%)	income Per a.e.u	income share (%)	income per a.e.u	income share (%)
crop income	126.21	41.99	213.89	44.71	275.12	42.15	430.21	41.79
livestock income	37.24	12.39	54.88	11.47	109.68	16.15	213.87	20.74
off-farm income	25.04	8.33	54.82	11.46	74.79	11.46	11.70	10.84
transfer income	0.74	0.24	4.70	0.98	13.19	2.02	13.37	1.30
Forest income	105.80	35.20	142.26	29.72	165.95	25.42	235.88	22.89
miscl. Income	5.57	1.86	5.56	1.63	13.95	2.14	25.18	2.45
Total	300.60	100.00	478.36	100.00	652.64	100.00	1030.76	100.00

Table 2.4 Household income per a.e.u and income shares (by village categories and income sources)

	upper highland villages		middle highland villages	
income component	income per a.e.u	income share (%)	Income per a.e.u	income share (%)
crop income	229.43	43.32	259.75	41.84
livestock income	90.15	17.02	97.15	15.65
off-farm income	59.15	11.37	63.84	10.28
transfer income	8.11	1.50	6.25	1.00
Forest income	133.42	25.19	178.72	27.78
micsl. Income	9.04	1.71	15.20	2.45
Total	529.66	100.00	620.91	100.00

Table 2.4 summarizes the contribution of forest environmental income and other income components in households' total and average income shares for the upper highlands (*douga*) and middle highlands (*woina douga*) households. Forest products contribute a slightly larger share (28%) in average household income for the middle highland villagers than that of the villagers in upper highlands (*25%*).

The explanations for this may be the existence of larger areas of exclosures and community commons with denser biomass population in villages surveyed in *woina douga* areas. The other possible explanation is that the majority of the sample *woina douga* villages are located either relatively near to Mekelle (the regional capital) or to

Hagereselam (the district capital) which may be outlets for the sale of firewood and some other non-wood forest products (NWFPs).

2.4.2 Forest income and poverty

Using the FGT poverty index formula (equation 2.1) and its decomposition method (equation 2.2), we can analyze the effect of forest incomes on rural household's poverty. On the one hand, we compute the total poverty index for the rural households with and without forest income to see the magnitude and direction of changes in poverty levels. This enables us to evaluate the change in poverty if the forest products are no longer available for various reasons (e.g. due to depletion). It also provides us with an estimate of the magnitude of poverty overestimation if income from natural resources is excluded in rural household income accounting.

Table 2.5 presents the results of the poverty calculations. We used the poverty line of ETB 700 per a.e.u per annum[23] (see appendix 2C). This magnitude is nearly equivalent to the 68th percentile of the total income distribution. This poverty line was derived by the MU-IUC socio-economic research team from the 'Geba Catchment Rural Household Survey-2005' using the cost of basic needs approach with allowance to the non-food consumption (see appendix 2C). Using this poverty line, three variants of FGT indices were calculated for income distribution that excludes forest and another distribution with forest income. The results are striking. In headcount measure of poverty (FGT(0)), nearly 86% of the households are classified as poor in conventional income measure, whereas the inclusion of forest income reduces the headcount poverty to 68%, a drop of 23.4% in the headcount measure. The poverty gap (FGT(1)) and poverty severity (FGT(2)) indices would even drop by larger percentages, a fall of 41.5% and 53.4% respectively.

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[23] Apparently, this figure seems low compared to the various estimates of poverty lines at national level or in Tigray. For instance, using the 1999/00 household income consumption and expenditure (HICE) survey conducted at the national level on 17,332 households, Assefa and Frehiwot (2003) estimated the poverty line at ETB 995 for rural and ETB 1057 for national poverty line. The official national poverty line is ETB 1075 in 1995/96 constant national average prices (Woldehanna, 2004). For Tigray region as a whole Fitsum and Holden (2003) have estimated poverty line of ETB 1033.45. As these estimates are either for the national level or for the combined urban and rural population with different consumption bundles and prices, they are not directly comparable to our poverty line. Ours is constructed for rural communities of a given catchment in Tigray who are generally poor. Therefore, though our poverty line estimate seems low, given the specificity of the catchment area and the level of rural poverty in the area, we believe that our estimate is fair.

Checking the statistical significance of the difference between poverty indices based on standard income as against those based on total income, the test reveals a statistically significant difference between the two. Using equation (2.7) we computed the t-values presented in the last column of table 2.5. The differences between the poverty indices with and without forest incomes are all statistically different from zero. As a result, we can conclude that excluding forest products from the income accounts of rural households in the study area not only generates exaggerated poverty indices, but they also differ in a statistically significant way.

In table 2.6, the poverty indices decomposed by village categories (*douga* and *woina douga* villages) are presented. The decomposition results in a very interesting finding. All the three poverty measures do not show much difference in the two village categories.

Table 2.5 FGT poverty index with and without forest incomes

	Without forest income		**With forest income**			
	Estimate	standard error	Estimate	standard error	Diff[1].	t-statistic of diff[2].
FGT(0)	0.8583	0.0184	0.6833	0.0246	0.1750	5.70**
FGT(1)	0.4127	0.0139	0.2416	0.0122	0.1710	9.25 **
FGT(2)	0.2405	0.0115	0.1116	0.0076	0.1289	9.35**

[1] Diff. = FGT(α) without forest income minus FGT(α) with forest income; for α = 0, 1, 2

[2] Sample t-statistic of the difference between the two indices.

** significant at 5% level.

However, including forest incomes in their income accounts yields significant differences between the two village categories in terms of headcount poverty, poverty gap and the severity of poverty. In all indices, the poverty burden in *douga* villages is less than that of *woina douga* villages. The sample villages in *woina douga* are relatively better endowed with exclosures and other communally owned natural environments such as grazing land and bush lands. This enables them to harvest more forest products which contribute in lessening the poverty burden.

Table 2.6 FGT poverty index with and without forest incomes by villages

	Without forest income		**With forest income**		
	Estimate	standard error	Estimate	standard error	Difference
UHL(*douga*)					(diff. with)[*]
FGT(0)	0.8500	0.0267	0.7389	0.0328	0.1111
FGT(1)	0.4335	0.0198	0.2821	0.0176	0.0809
FGT(2)	0.2583	0.0164	0.1350	0.0114	0.0470
MHL*(woina douga)*					(diff. without)[+]
FGT(0)	0.8667	0 .0254	0.6278	0.0361	0.0167
FGT(1)	0.3919	0.0197	0.2012	0.0163	0.0416
FGT(2)	0.2227	0.0160	0.0881	0.0097	0.0356

[*] the absolute difference between the three poverty indices of the two village categories with forest incomes included; [+] with forest income excluded.

To examine the effect of forest income on the poverty indices of the two village categories, consider FGT(2) with forest income in both villages and the contribution of each to the overall FGT(2) index. Using equations (2.4) and (2.5) we can decompose the overall FGT(2) (table 2.5) into two components: a part contributed by upper highland villages and the other part by middle highland villages (table 2.6). Using the decomposition formula (equation 2.4), we obtain that out of the overall FGT(2) value of 0.1116 (table 2.5), in absolute terms 0.0675 is contributed by subgroup upper highland (UHL) villages and the remaining 0.0441 is by middle highland (MHL) villages. In terms of percentage contribution (using equation 2.5), UHL villages contribute 60.5% of the overall poverty while the MHL villages contribute 39.5%. The interesting implication of this decomposition is that the better availability of forest products the less the contribution to overall poverty.

2.4.3 Forest income and inequality

On the basis of the classification of income components we adopted in this chapter, we decomposed the Gini coefficient by income source using the approach described in Lerman and Yitzhaki (1985) and adapted through equations (2.8) to (2.10). Our principal concern is to explore the place of forest income in total income inequality.

Table 2.7 Gini decomposition by income source

Source Income[♠] (1)	Sk (2)	Gk (3)	Rk (4)	Share[√] (5)	RME[+] (5)-(2)
Crop income	0.4188	0.3286	0.7811	0.4053	-0.0135
Livestock income	0.1559	0.6428	0.6089	0.2300	0.0741
Off-farm income	0.1103	0.6788	0.4645	0.1311	0.0208
Transfer income	0.0116	0.9641	0.3935	0.0166	0.0050
Forest envi. income	**0.2799**	**0.2681**	**0.6694**	**0.1894**	**-0.0905**
Miscellaneous income	0.0236	0.8452	0.3681	0.0277	0.0041
Total		**0.2652**			

Notes: Sk = the share of each income source in total income; Gk = the Gini coefficient of each of the income component; Rk = the Gini correlation of income from source k with the distribution of total income; Share = the share of each income source in total inequality; % change= the impact of a 1% change in the respective income source on inequality

[♠] All the income sources, including the total income, are in their a.e.u per capita forms.

[√] $(5) = [(2)\times(3)\times(4)]\div G$; where $G = 0.2652$.

[+] This is a relative marginal effect (RME) computed with help of equation (8). The values of RME reflect the impact of a 1% change in respective income source on overall inequality measure.

Table 2.8 Selected inequality measures with and without forest income

Inequality measures (1)	with forest income (2)	without forest income (3)
Relative mean deviation	0.189	0.221
Coefficient of variation	0.503	0.599
Gini coefficient	0.265	0.312
Mehran measure	0.369	0.432
Piesch measure	0.213	0.252
Kakwani measure	0.063	0.087

Table 2.7 presents the contributions of income components to per capita total income and income inequality in our empirical data. In columns (3) and (6) we find remarkable results for forest environmental income. Although forest income accounts the second largest share in total income, it is the lowest unequally distributed with least own Gini (0.2681) in column (3). Though the lower source Gini may not necessarily indicate that an income source has an equalizing effect on total income inequality, in the case of forest income in our data set it has an equalizing effect confirmed by other indicators of inequality.

As shown in table 2.7, the percentage contribution of forest environmental income to inequality (18%) is smaller than its percentage contribution to total income (28%). The low Gini value can also be explained by the fact that all households participate in the extraction of forest products, at least in firewood collection, implying that no zeros are included in the source Gini calculation. Looking at the relative effects of a marginal increase in each source in column (6), we observe that a 1% increase in forest income, other things being equal, results in a 0.1% decrease in overall income inequality. Thus, forest incomes have an equalizing effect on the distribution of total income in the rural economies of the study area. This sheds an interesting light on the policy dialogue with unambiguous policy implications. In terms of both the source Gini and relative marginal effect, forest income is pro-poor and has inequality reducing impact. Therefore, the policy implication is that in public undertakings that deal with equity in income distribution in the study area, utmost priority has to be given to forest sector development.

To supplement our generalizations concerning the inequality reducing role of forest income from Gini decomposition, in table 2.8 some selected inequality measures (besides Gini coefficient) are presented. These measures in column (3) are obtained from a simulation exercise of not considering income from forest environmental sources. This exercise elucidates the importance of forest income narrowing the income inequality gap among the villagers. Table 2.8 reveals that all the inequality measures indicate unanimously that inequality is lower with forest income than without. For instance, if forest income disappears for one reason or the other, inequality (as measured by the Gini coefficient) increases by about 18%. On the other hand, transformation of a rural economy operating without forestry sector to the one with forestry results in a 15% drop in the existing income inequality (see the Gini coefficients with and without forest income in table 2.8).

2.6 Conclusions and policy implications

We found that products from forest environmental sources represent an important component in rural livelihoods. Our findings highlight the relative importance of income from the extraction of forest environmental sources in overall household income. Contrary to the accepted belief that places livestock in the fore front of rural livelihoods in Ethiopia, we found that forest income occupies the second largest share in average total household income next to crop incomes. Our data indicate that livestock income occupies the third position. The results from the poverty and inequality analysis show that incorporating forest incomes in household accounts contribute significantly to the reduction in measured rural poverty and income inequality. On the basis of our findings, forests can be considered as pro-poor and play an inequality reducing role.

Two policy implications can be drawn from the findings. First, forest sector development should not only focus on long-term ecological effects but also pay due attention to the short-term economic benefits of the local people. At present, the establishment of exclosures and other forest development efforts mainly emphasizes on ecological restoration. The contribution of forest products to rural lives has to be acknowledged. Second, the existing excessive restriction on access to exclosures should be reconsidered. Use and access rules should be reformulated in a way that harmonizes both economic and environmental aspects, such that local people will generate economic benefits without damaging the resource base. This calls for revision of the existing rules and adoption of self-sustaining management schemes that promote local economic benefits and ensure the sustainability of the resource system.

Appendices 2

Appendix 2A. *Adult equivalence unit (a.e.u)*

If per capita household income is to be used as a measure of household welfare, it has to be adjusted for the inter-household variations in demographic structure (age and sex compositions). For instance, an annual total income of ETB12,000 to a house of a new couple (husband and wife) is not the same as ETB12,000 to a widowed woman with her three years old son, though the household size in both cases is two. Similarly, an annual total income ETB 12,000 to a household of a single adult person is quite different in comparison to the same amount for another household with several adults. Thus, the per capita household income has to be adjusted for differences of such demographic structure among households before we use it as a measure of household's welfare. The usual way of adjusting such inter-household variations is the conversion of the actual size and demographic composition of a household to a common scale, often known as the adult equivalent unit (a.e.u). This provides a more accurate reflection of inter-household welfare comparisons if we use household income as a measure of welfare.

Following Creedy and Sleeman (2004), the adult equivalence scale conversions can be undertaken as follows. Let Y_i be the total income of the i^{th} household (i = 1,…, N). The number of individuals in the i^{th} household is represented by n_i and the demographic composition by a vector d_i. Denoting the adult equivalent size of a household by m_i, it can be expressed as:

$$m_i = m(n_i, d_i)$$

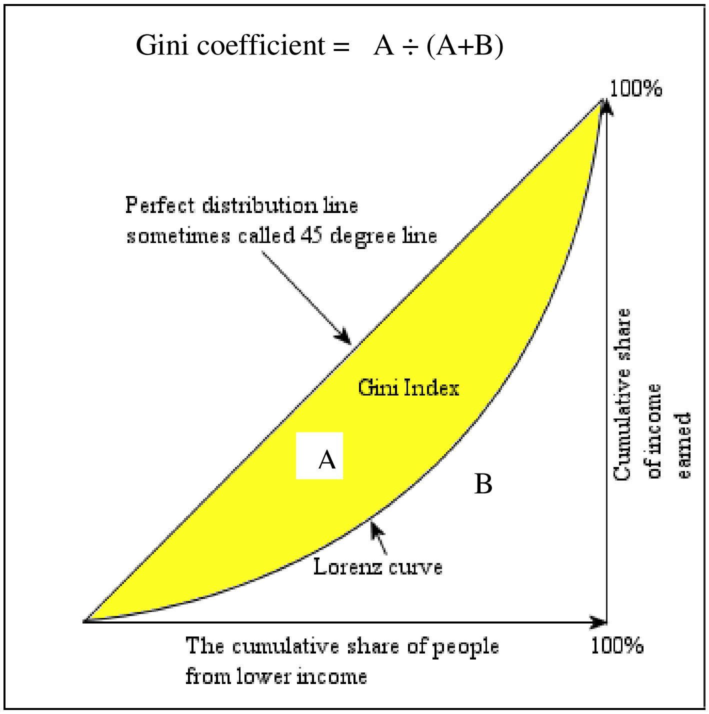
The household size m_i is normalized so that *m(n=1, male adult) = 1*. Specifying the age interval of male adult to use as a *numeraire* and the weights for various age brackets of male and female, the head count household size can be converted into equivalent adult unit. Using m_i as an adjusted household size, per capita household income can be obtained as: $y_i = \frac{Y_i}{m_i}$. It is this adjusted per capita household income that has been used in our poverty and inequality analysis. The weights assigned to various age intervals of male and female household members are indicated in table 2A below. Using these weights each member of the household is assigned a coefficient on the basis of his/her age and sex. In these coefficients male household members aged from 30 to 60 are treated as *numeraire.*

Table 2A. Coefficients for adult equivalent scale

	Adult equivalent scale	
Age	Male	Female
0-1	0.33	0.33
1-2	0.46	0.46
2-3	0.54	0.54
3-5	0.62	0.62
5-7	0.74	0.70
7-10	0.84	0.72
10-12	0.88	0.78
12-14	0.96	0.84
14-16	1.06	0.86
16-18	1.14	0.86
18-30	1.04	0.80
30-60	1.00	0.82
60+	0.84	0.74

Source: adapted from Dercon and Krishnan (1998). Changes in poverty in rural Ethiopia 1985-1995: measurements, robustness tests and decomposition. P.4. WPS/98-7. CSAE.

Appendix 2B. Lorenz curve



Source: http://en.wikipedia.org/wiki/Lorenz_curve

The **Lorenz curve** is a graphical representation of the cumulative distribution function of a probability distribution; it is a graph showing the proportion of the distribution assumed by the bottom *y%* of the values. It is often used to represent income distribution, where it shows for the bottom *x%* of households, what percentage *y%* of the total income they have. The percentage of households is plotted on the *x*-axis, the percentage of income on the *y*-axis (WIKIPEDIA.The Free Encyclopedia: http://en.wikipedia.org/wiki/Lorenz_curve). The basic derivation of Gini decomposition by source incomes is based on Gini mean difference formula related to the Lorenz curve.

Appendix 2C. Construction of the poverty line

Poverty line: what?

A poverty line is a threshold per capita income or consumption below which an individual is considered to be poor. Depending on the objectives of the inquiry, a poverty line can be constructed at different levels or different sections or sub-groups of the society; e.g., at a national level, a regional level, for a population at a certain geographical area, a rural population, and an urban population.

How to construct a poverty line?

The common method of constructing a poverty line is the Cost of Basic Needs (CBN) approach. With the help of this approach, establishing the poverty line starts with defining and selecting a "basket" of food items that are deemed to be adequate in meeting the nutritional requirements for good health and typically consumed by the poor (composition of local food diets). The quantity of the basket is determined in such a way that the given food basket meets a predetermined level of minimum calorie requirement, in the case of Ethiopia 2200 kcal per day per adult is taken for absolute poverty. This basket is valued at certain representative average prices. A food poverty line is usually defined based on the poorest 50% of the households deemed to be typical to the poor. Once the food component of the poverty line is determined, an allowance is made for the non-food component (Ravallion and Bidani, 1993; Assefa and Frehiwot, 2003; Fitsum and Holden, 2003).

Following Ravallion and Bidani (1993), the non-food component of the poverty line can be determined by examining the consumption behaviour of those households who can *just* afford the 'reference food basket'. This approach provides an answer to the question: *"what is the typical value of non-food spending by a household who is just capable of reaching food requirements? As long as non-food is a normal good, this will also equal the lowest level of non-food spending for households who are capable of acquiring the basic food bundle. It can thus be considered a minimal allowance for non-food goods."* (Ravallion and Bidani, 1993).

The non-food share of total expenditure for household i is estimated by regressing the food share of each household in total expenditure (S_i) on a constant and the log of the ratio of total consumption expenditure (Y_i) to the food poverty line $((Z^f)$ as follows (Ravallion and Bidani, 1994):

$$S_i = C_1 + C_2 \ln(\frac{Y_i}{Z^f}) + u_i \ ;$$

where C_1 & C_2 regression parameters and u_i is an error term.. Then the food share is given by the constant C_1. Amongst those households whose total expenditure is just equal to the food poverty line $(Y_i = Z^f)$, the food share is C_1, and the consequently the non-food share of the expenditure will be $1 - C_1$. Thus, the total poverty line (PL) is:

$$PL = Z^f (2 - C_1) \; ;$$

After the computations, a poverty line of ETB58.27 per adult equivalent scale per month is obtained. Multiplying by 12 months, we will get about ETB700/a.e.u/annum.

Appendix 2D. *Forest environmental products included in the household survey and the measurement units*

(Code)	**product types**
(01)	Fuel wood for home consumption
(02)	Fuel wood for sale
(03)	Timber
(04)	Construction woods for house (such as wood products for walls, roofs, and poles)
(05)	Construction wood (for livestock kraal)
(06)	Fencing materials
(07)	Farm implements (such as farm tool handles, '*mofer'* , *'kenber',* hoes)
(08)	Crop storage *(gotera)*
(09)	Household furniture (stools, plates, spoons, pestles, mortars, drums, decoratives)
(10)	Wild food items (such as fruits, vegetables, honey, mushrooms, roots, and cactus)
(11)	Traditional medicines
(12)	Tooth cleaning brush (twigs)
(13)	Wild washing soda (like '*endod*')
(14)	Leaf litter (as fertilizer or humus)
(15)	Livestock fodder or browse

(16)	Thatching grass
(17)	Fibres or ropes
(18)	Sweeping material *(mekoster)*
(19)	Inputs for basket making
(20)	Woven hats *(Barnetsa)*
(21)	Woven mats *(Selen)*
(22)	Gums, latexes, waxes, resins
(23)	Others, Specify__________

(Code)	**quantity units**
(01)	Head-load per person (‘*shekim*’)
(02)	Load per donkey or mule (*‘chinet’*)
(03)	Bundles (*‘esir’*)
(04)	Pieces (in number)
(05)	kg, or grams
(06)	Quintals
(07)	Tons
(08)	Bags
(09)	Meters
(10)	Yards
(11)	Others, Specify________

Chapter 3

Explaining environmental resource reliance and livelihood strategy choice: an econometric analysis

3.1 Introduction

In the developing world rural households may pursue a wide range of livelihood portfolio. Some households may diversify their livelihood strategies and others may essentially rely on one or few activities. It is not uncommon for a rural household to be involved in multiple activities: growing a variety of crops for subsistence consumption and/or for cash sale, livestock rearing, being involved in a variety of reciprocal transactions with fellow community members, having one family member in off-farm employment who remits money back to the household and another member involved in some small-scale industry, getting involved in a variety of informal activities, and collecting freely provided goods from environmental resources (Dercon and Krishnan, 1996; Barret et al., 2001; Campbell and Luckert, 2002).

Chapter 2 has shown that forest environmental resources provide a substantial contribution to the wellbeing of many rural dwellers. However, the level of forest use and the degree of reliance on forest environmental products differ across households. The factors that condition household's economic reliance in a particular economic activity in general and in forest environmental resource in particular may vary depending on the resource endowment of the household, household's demographic and economic characteristics, and some exogenous factors such as markets, prices and technologies. In this regard, understanding and explaining the factors that determine variations in households' activity choice and particularly reliance on forest products is essential for both conservation and development targeted policies.

Therefore, the aim of this chapter is to specify the factors that condition households' decision on livelihood strategy choice with particular focus on forest products extraction and dependence. For this we will adopt the livelihood approach as a framework of analysis. On the basis of the share of each major income source in total household income and with the help of cluster analysis, sample households are grouped into distinct clusters. Series of multinomial logit regressions are run on asset-based explanatory variables to identify the main factors that determine household strategy choice. Our analyses indicate that heterogeneity in access to or endowment of livelihood assets determines the choice of households' strategy.

3.2 Definition of terms

To facilitate our conception of the chapter's theme and remain consistent through out the chapter, definitions of some key terms (concepts) are given below.

- *Livelihood*: A livelihood is defined as comprising "the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is considered to be sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base" (Carney, 1998; DFID, 1999; Carney, 2002).

- *Livelihood assets (capital assets):* Livelihood assets refer to human and non-human resources (natural, physical, human, social and financial) upon which livelihoods are built and hence people need to access in the process of composing their livelihoods. The assets constitute a stock of capital that can be stored, accumulated, exchanged or allocated on activities to generate a flow of income or means of livelihoods or other benefits (Rakodi, 1999). In this chapter we use the terms 'capitals' and 'assets' interchangeably.

- *Livelihood strategy (activity):* This denotes the range and combination of activities and choices that people make/undertake – ways of combining and using assets – in order to achieve their livelihood goals (DFID, 1999). Throughout the chapter we interchangeably use 'strategies' and 'activities'.

- *Livelihood outcomes*: are the achievements or outputs of livelihood strategies. Livelihood outcomes may be expressed in terms of increased income, improved well-being, reduced vulnerability, or improved food security of the poor.

3.3 Livelihood approach

As a framework of analysis, the livelihood approach is an approach that aims at highlighting the different elements that shape poor people's livelihoods, the factors that influence them and the linkages between these various factors. The approach is centred on people and their livelihoods. The approach prioritises people's assets; their ability to withstand shocks (the vulnerability context); and policies and institutions that reflect poor people's priorities.

The engagement of a rural household in forest related activities as one of the sources of income can be considered as the household's economic choice in its pursuit to make a living given its resource endowments, household characteristics and exogenous factors. To have a wider conception of the rural household's activity choice and factors influencing the choice, we draw on the broader livelihoods strategies literature and apply a 'livelihood approach' in our empirical analysis. The central theme of the livelihood framework as a tool for the analysis of rural livelihoods is its conceptualization of people's livelihood choices and strategies in terms of access to five types of 'capitals' or 'assets'- natural, human, physical, social and financial (Scoones, 1998; DFID, 1999; Bebbington, 1999; Hussein and Nelson, 1998; Reardon and Vosti, 1995; Winters et al., 2002). This approach argues that the ability to pursue different strategies depends on the possession of or access to these assets from which different productive streams are derived and livelihoods are constructed. To create livelihoods, people should have to access to or control over 'capitals' (Scoones, 1998).

The basic tenet of the livelihoods approach is the belief that a range of assets are required to achieve people's livelihood outcomes. In other words, a single category of assets is not sufficient to yield the many livelihood outcomes that people seek (DFID, 1999). On the other hand a single category of assets can generate multiple influences that can affect other assets. For instance, secured access to natural capital (e.g., land) can affect one's access to financial assets via its role as collateral for credit. Similarly, in a community where livestock is used as a sign of social status, besides its economic functions, livestock ownership may generate social capital and at the same time being used as a productive physical asset (animal traction in traditional agriculture).

In line with the livelihoods approach, brief descriptions of the asset portfolios of rural households are given below. The major part of the descriptions is adopted on the basis of the DFID's 'Sustainable Livelihoods Guidance Sheets', a section dealing with the general framework of SLF (DFID, 1999):

- *Natural capital*: within the SLF, natural capital refers to the stock of natural assets such as land, forests, wildlife and water resources from which people derive resource flows and services useful for their livelihoods. In the context of the rural economies of the developing world where most people derive their livelihoods from natural resource-based activities, natural capital deems to be a very essential asset category. Variations in endowment of and access to natural capital among households generate perceptible differences in household's choice of livelihoods strategies and the associated outcomes.
- *Human capital*: encompasses the skills, knowledge and ability to exert physical and mental efforts on production processes and good health that enable an individual or household to pursue different livelihood strategies in order to achieve desirable livelihood outcomes. To make use the other four capitals effectively, it is necessary for the household to be endowed with human capital.
- *Physical capital*: comprises basic physical infrastructure such as transport and communication networks that help people meet their basic needs and produced means of production (producer goods) such as tools and equipments that enhance labour productivity. Most basic infrastructures are commonly public goods and hence accessed, with some exceptions (e.g., toll roads), without direct payments. Producer goods need to be acquired or owned if one wants to put them in the process of production. Lack of infrastructure and/or inadequate

access to the services of physical assets affect household's activities choice. For instance, poor transport infrastructure forces remote households to involve in harvesting low-valued forest products for domestic use and constrains a household's diversification strategy.

- *Social capital*: In the SLF, social capital refers to people's shared behaviour of networks, connectedness, relationships of trust, reciprocity, exchanges, community memberships and accepted social rules, common norms and sanctions.
- *Financial capital*: includes liquid assets in the form of cash or other easily cash-convertible items. Cash on hand, bank deposits, access to credit and insurance markets and regular inflow of money in the form of pension income or remittances constitute the financial capital of the household. Access to or possession of financial capital has a direct role in the achievement of livelihoods outcomes (e.g., purchased food reduces food insecurity) and determines livelihood options through its influence as a means to acquire other capitals (e.g., the application of purchased improved farm implements increase land and/or labour productivity which may, depending on the opportunity cost of labour, increase or shrink household labour supply to non-farm activities). Accesses to financial capital allow households to enter into more profitable lucrative business ventures without which households may be constrained from such undertakings.

With regard to the study of livelihood strategy choice, the asset-based approach is gaining popularity in recent years (Moser, 1998; Bebbington, 1999; Barret et al., 2001; Winters et al. 2002). Depending on specific capital endowments and the exogenous environment in which a household operates, people may pursue different livelihood options. Some households may engage primarily into direct natural resources based economic activities (e.g., harvesting of forest environmental products); others may focus mainly on crop production as their major means of living; and still others may earn substantial incomes from livestock rearing. Within the broad categories of livelihood assets, the specific factors that condition household's activities choice may vary from household to household.

3.4 Conceptual framework and hypothesis

3.4.1 Conceptual framework

Figure 3.1 presents the basic framework of the dependence of activity choice on 'assets'. At the heart of the framework in the figure (box 2) is our study object: a household's activities (strategies) choice. On the basis of the framework, a household's choice to pursue a particular activity or combinations of activities is conditioned by its asset holding (or access or endowment), see arrow (b) in figure 3.1. Many studies on income diversification and activity choice have pursued similar causality paths in both conceptual and empirical works (Reardon et al., 1992; Reardon and Vosti, 1995; Dercon and Krishnan, 1996; Dercon, 1998; Ellis, 1998; Bebbington; 1999; Coomes et al., 2004; Ellis and Freeman; 2004; Jansen et al, 2006a; Jansen et al, 2006b)[24]. Activity choice may also be influenced by exogenous factors such as shocks, policies, and technologies (arrows (g) and (f)). These factors can also affect livelihood assets (arrows (h) and (i)). For instance, natural disasters such as floods and bush-fire can change the local availability of environmental resources.

A specific activity chosen by the household generates livelihood outcomes such as food, cash income and sustainable natural management (box 3). The resulting livelihood outcomes in turn can affect the 'capitals', for example, through investment in households assets and natural resource conservation. Therefore, the 'capitals' themselves are endogenously revised by outcome effects (arrow (c)). Though the framework depicts the dynamics and endogenous interdependence conceptually, given data limitations, our empirical analysis will only examine the static role of household's asset holding (or access) on livelihood strategy choice with particular focus on extractive activity (household's draw and reliance on forest environmental resource). In investigating the determinants of households' livelihood strategy choices, such static models are often used (Dercon and Krishnan 1996; Jansen et al., 2006; Brown et al., 2006).

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[24] Following the Chayanovian tradition, some authors pay special attention to household demographics and treat it separately in modelling activity choice, for instance Coomes et al. (2004). In this study we included household demographics in the broadly defined 'human capital' and thus do not treat it separately.

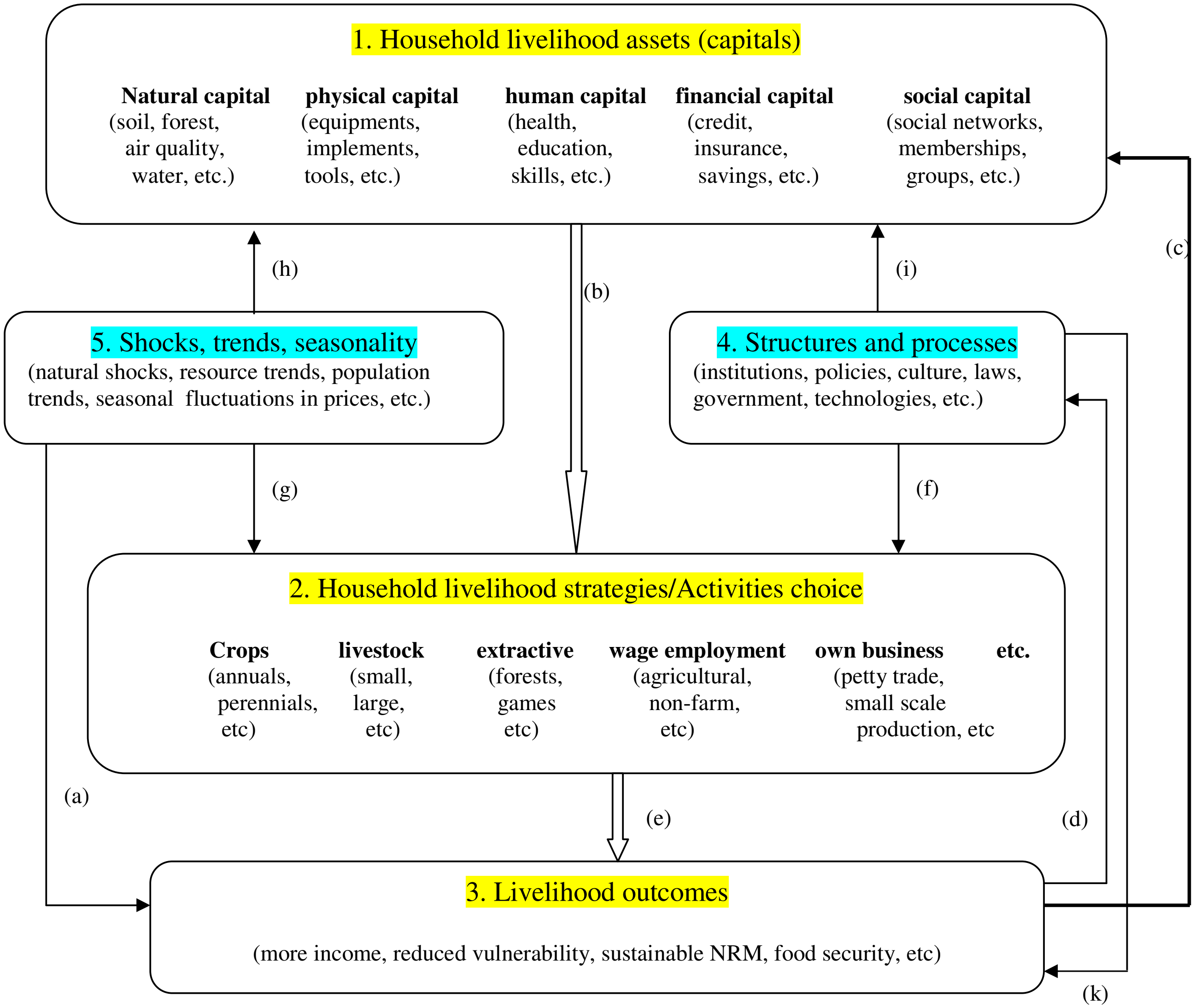

Figure 3.1. Conceptual framework of sustainable livelihoods. **Source**: adapted from DFID's sustainable livelihoods framework (Carney, 1998) and IDS's sustainable rural livelihoods framework (Scoones, 1998)

3.4.2 Hypothesis

Our guiding premise in exploring the determinants of household livelihood strategy choice is derived from the underlying utility maximizing behavioural responses of households and the fundamental proposition of the livelihood approach. The livelihood approach states that the type of activity undertaken and the amount of income earned by a household is a function of the assets under its disposal (Barret et al., 2005; Brown et al., 2006). Based on this proposition and the household's utility maximizing behaviour, we hypothesize that, *given the constraints imposed by differential access to assets, farmers choose an optimal livelihood strategy. The variation in observed (revealed) choices is due to the heterogeneity in asset constraints*. Following Brown et al. (2006), suppose that a farm household seeks to maximize utility defined over stochastic income by allocating its asset endowment across a set of feasible activities. Then, on the basis of revealed preference formulation, it can be argued that where different asset allocations yield different income distributions that can be ordered in welfare terms, any household that has failed to choose the more remunerative strategies must have faced a constraint that limited its choice set, as no one would freely choose to draw a dominated strategy when they had access to a better alternative. The implication of the hypothesis is that if livelihood strategies are ranked on welfare basis, some group of the sub-population select inferior strategies because they are unable (constrained) to choose strategies offering superior returns.

3.5 Empirical implementation

To test our hypothesis, we first group our sample households into some distinct clusters on the basis of the dominant livelihood strategies they pursue, and then test the statistical significance of the differences of the means of the distribution of total household income per adult equivalent associated with all identified groups (one-way ANOVA) and every paired-group mean differences (t-test). On the basis of the test results strategies will be welfare-ranked, which enables us to label some strategies as superior and others inferior.

Second, a multinomial logit (MNL) regression of observed clusters of strategy choices on asset-based explanatory variables will highlight key predictors that statistically differentiate households pursuing inferior or superior strategies. With the MNL regression we also identify the correlates of access to the most desirable set of livelihood strategies. If the effect of asset endowments on observed choices is statistically significant, we can conclude that asset constraints impede certain superior or high return activities beyond the reach of asset-poor households. In other words these households are forced to choose strategies with inferior welfare impact.

3.5.1 Cluster analysis

Cluster analysis is a data reduction statistical method used for grouping observations based on the predetermined characteristics of the observations (objects). It classifies objects into groups (clusters) in such a way that objects' within-cluster variance is minimized and between-cluster variance is maximized. We first run hierarchical clustering using the centroid and Ward's (see appendix 3.4) method to determine the number of clusters (Hair et al., 1995; Sharma, 1996). The resulting statistics such as R-squared (RS) and root mean squared standard deviation (RMSSTD) indicate a five cluster solution. Then we applied non-hierarchical (k-means[25]) cluster algorithm with Euclidean similarity (or dissimilarity) measure and k-random initial seed specification in STATA9.2/SE. The characteristics (variables) used in cluster analysis are the livelihood outcomes variables (household income from various distinct sources). Use of data on realized incomes to underpin the classification of households into livelihood strategies is commonly practiced among economists (Barrett et al., 2005; Dercon and Krishnan, 1996; Reardon et al, 1992). The following variables were used in cluster analysis: share of crop income in total household income; share of livestock income in total income; share of off-farm income in total income; share of forest environmental income in total income; share of transfer income in total income, and share of other incomes[26] in total income (hereafter we simply call it 'others').

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[25] K-means cluster analysis is a non-hierarchical method of partitioning data into a predetermined number of clusters.

[26] These are incomes from miscellaneous sources such as rent income from land rented out, income from honey, and interest income.

3.5.2 Econometric model specification

Following the random utility models (RUM) tradition (Train, 2003), the farm household's activity choice model assumes that households maximize their utility. Suppose that a farm household n $(n = 1, \ldots, N)$ faces a choice among J alternative activities. Let U_{nj}, $j = 1, \ldots, J$ denote the utility that n obtains from alternative j. The household chooses alternative i if and only if $U_{ni} > U_{nj}\ \forall j \neq i.$ On the basis of RUM, the utility (U_{nj}) that a household obtains from alternative j is decomposable into two components V_{nj} *and* ε_{nj} where V_{nj} is the portion of U_{nj} that can be represented from the observed attributes of the alternatives, labelled $X_{nj}\ \forall j$ and some household specific attributes, labelled H_n, and ε_{nj} captures factors that affect the utility (U_{nj}) but not captured in V_{nj}. Then the utility function can be represented as:

$$\left.\begin{aligned} U_{nj} &= V_{nj} + \varepsilon_{nj}\ \forall j \\ &= V(X_{nj}, H_n) + \varepsilon_{nj} \end{aligned}\right\} \qquad (3.1)$$

In equation (3.1), ε_{nj} is not known to the researcher and therefore can be treated as a random term. Denoting the joint density of the random vector $\varepsilon_n = \varepsilon_{n1}, \ldots, \varepsilon_{nJ}$ by $f(\varepsilon_n)$, the probability that the household n chooses activity i is given by:

$$\left.\begin{aligned} P_{ni} &= prob(U_{ni} > U_{nj} \quad \forall j \neq i \\ &= prob(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \quad \forall j \neq i \\ &= prob(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \quad \forall j \neq i \end{aligned}\right\} \qquad (3.2)$$

The expression in (3.2) is a cumulative distribution that measures the probability that each random term $\varepsilon_{nj} - \varepsilon_{ni}$ is below the observed quantity $V_{ni} - V_{nj}$ .Using the density $f(\varepsilon_n)$, this cumulative probability can be rewritten as:

$$\left.\begin{aligned} p_{ni} &= prob(\varepsilon_{nj} - \varepsilon_{ni} < \ V_{ni} - V_{nj} \quad \forall j \neq i \\ &= prob(\varepsilon_{nj} < \ \varepsilon_{ni} + V_{ni} - V_{nj} \quad \forall j \neq i \\ &= \int_{\varepsilon} I(\varepsilon_{nj} < \ \varepsilon_{ni} + V_{ni} - V_{nj} \quad \forall j \neq i) f(\varepsilon_n) d\varepsilon_n \end{aligned}\right\} \tag{3.3}$$

where $I(\cdot)$ is the indicator function. It takes the value 1 when the expression in parentheses is true and 0 otherwise. The multinomial logit (MNL) model to be used to analyze a farm household's choice between activities can be obtained from (3.3) by assuming that the unobserved portion of the utility (ε_n) is identically and independently distributed (iid) across alternatives[27] , an important assumption for logit models in general. The last expression under (3.3) is the cumulative distribution for each ε_{nj} evaluated at $\varepsilon_{ni} + V_{ni} - V_{nj}$ with the density function[28]:

$$f(\varepsilon_{nj}) = f(\varepsilon_{ni} + V_{ni} - V_{nj}) = \exp(-\exp) \ \exp(-\exp(-(\varepsilon_{ni} + V_{ni} - V_{nj})) \tag{3.4}$$

and cumulative distribution

$$F(\varepsilon_{nj}) = \exp(-\exp(-(\varepsilon_{ni} + V_{ni} - V_{nj})) \tag{3.5}$$

Given that $\varepsilon's$ are independent, the choice probability becomes

$$p_{ni} = \int \prod_{i \neq j} F(\varepsilon_{nj}) f(\varepsilon_{ni}) d\varepsilon_{ni} = \int \prod_{i \neq j} \left(e^{-e^{-(\varepsilon_{ni} + V_{ni} - V_{nj})}} \right) e^{-\varepsilon_{ni}} e^{-e^{-\varepsilon_{ni}}} d\varepsilon_{ni} \tag{3.6}$$

Some algebraic manipulation of the integral in (3.6) results

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[27] In probability theory, a sequence or other collection of random variables is independent and identically distributed (iid) if each has the same probability distribution as the others and all are mutually independent or unrelated.

[28] If a random variable x is identically and independently distributed (following extreme value), its density function is represented by $f(x) = e^{-x} e^{-e^{-x}}$ with cumulative distribution $F(x) = e^{-e^{(-x)}}$. This distribution is also called Gumbel distribution.

$$p_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} \qquad (3.7)$$

Equation (3.7) is a logit choice probability. Specifying V_{nj} as a linear function (linear in parameter) of X_{nj} and H_n as

$$V_{nj} = \beta' X_{nj} + \gamma' H_n \qquad (3.8)$$

Substituting (3.8) in (3.7), the logit probabilities can be expressed as[29]

$$p_{ni} = \frac{e^{(\beta' X_{ni} + \gamma' H_{nj})}}{\sum_j e^{(\beta' X_{nj} + \gamma' Hn_j)}} \qquad .(3.9)$$

Normalizing the $\beta' s$ and $\gamma' s$ to zero for one of the activities (say first activity), the MNL model for each activity ($i \neq activity\ 1$) can be rewritten as

$$p_{ni,\ i\neq 1} = \frac{e^{(\beta' X_{ni} + \gamma' H_{ni})}}{1 + \sum_{j=2}^{J} e^{(\beta' X_{nj} + \gamma' H_{nj})}} \quad \text{and} \quad p_{n1} = \frac{1}{1 + \sum_{j=1}^{J} e^{(\beta' X_{nj} + \gamma' H_{nj})}} \qquad (3.10)$$

Using the activity choices identified from cluster analysis for the study area (see section 3.6.1) the likelihood of the household's choice of a particular activity can be inferred from a given set of empirically observed variables that are supposed to condition the choice behaviour of the household and the parameters of the relationship can be estimated using the maximum likelihood estimation method. To be consistent with our conceptual framework and bounded by the availability of data, the predictors used in the regressions are carefully selected to capture the influence of various livelihood assets on household activity choice. We pooled both H_n *and* X_n together under broad 'asset-based' variables. The dependent variable is a polychotomous choice variable with five categories (Hamilton, 2004) i.e. the five livelihood strategies

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[29] The denominators in (3.7), (3.8), and (3.9) are the sum of the numerator over all alternatives. This assures that the probabilities sum to one.

identified in section 3.6.1. The names and descriptions of asset-based explanatory variables used in the regression analysis are given below. As the correlation matrix of these variables in appendix 2 indicates, multicollinearity problem is not observed.

Human capital & demographic variables

hhsize	total size of the household
dep_ratio	dependency ratio (0<age<14 + age>=65)/total household size))
hhage	age of the household head in years
hhsex	sex of the household head (dummy: hhsex = 1 if the head is male; and 0 otherwise)
hhedu	education (or literacy) of the household head (dummy: hhedu=1 if the head is literate; and 0 otherwise)
stud_ratio	the ratio of household members whose main activity is 'student (or schooling) to total household size

Natural capital[30] *and location variables*

plotsize	aggregate size of all the plots of land the house own (in ha)
UhMh	location dummy (whether a household is located in upper highland (UHL) villages or middle highland (MHL) villages). UhMh=1 if the household is in UHL; and 0 otherwise.
eucalyp	whether a household has some eucalyptus tree plantations or not (dummy: eucalyp = 1 if the household has eucalyptus; and 0 otherwise)
acc_graz	access of the household to community or other grazing land sources which is not owned by the household (dummy: acc_garz = 1 if the household has access to such sources; and 0 otherwise)
lndistsch*	log transformed walking distance (in minutes) to the nearest primary school
lndistraod*	log transformed walking distance (in minutes) to all weather roads. This variable is a proxy to access to markets.

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[30] As our data set is generated by household survey, we do not have plot level data such as soil fertility indices, soil moisture content and slope which may possibly affect household livelihood choice through their impact on agricultural potential of land.

irrigation	whether the household has some access to local small scale community irrigation sources or possesses its own irrigation facility or does not have access or possession of such sources at all (dummy: irrigation = 1 if the household has such access; and 0 otherwise).

Physical capital

lnassetagri*	log transformed current market value (in ETB) of all the agricultural implements that household possesses
lnassetdur*	log transformed current value (in ETB) of all the durable assets the household owns
donkey[31]	the number of donkeys owned by the household

Financial capital

equb_m[32]	whether any member of the household is a member of *equb* (dummy: equb_m = 1 if anyone from the household is equb member; and 0 otherwise).
baccount	whether anyone from the household member holds a bank account in local financial institutions (dummy: baccount = 1 if somebody holds bank account; and 0 otherwise)
dd_loan	this variable measures liquidity constraint or the demand for credit behaviour of households. Each surveyed household head is asked whether he/she demands for credit assuming that supply of funds are available (dummy: if yes=1; and 0 otherwise)

Note: The variables marked with '*' sign are expressed in their natural log form.

3.5.3 The data

The data used in this study were come from the environmentally augmented

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[31] Donkey is the major provider of carriage service in transporting goods in the study area. Other pack animals (mule, horse and camel) do also provide such transporting service. But no household has reported to own these pack animals except donkeys.

[32] '*equb*' is a rotating credit association in which each member makes periodic contribution to the association and the money collected at each period is provided to one of the members often on a lottery basis. But if any member comes across with certain shocks, then he/she is given a special privilege to get the money. It is a widely practiced *ex ante* coping system in rural Ethiopia.

household survey administered in the study area. Data were collected from 12 villages of the study district, northern highland region of Tigray, Ethiopia. Research villages were chosen systematically to ensure representation of the district's two distinct agro-ecological zones. The classification of the agro-ecological zones is based on altitude. Altitude ranges from 1500-2300 m.a.s.l. are locally termed as *woina douga* i.e middle highland areas and above 2300 m.a.s.l. the area is locally known as *douga* i.e upper highland areas. Six villages from each zone were randomly selected.

In each village 30 households were selected randomly, yielding a total sample of 360 households. A comprehensive dataset on household demographics, households' livelihood assets ownership and/or access, major sources of income from both forest resource use and other standard economic activities were collected through a household survey. The survey was administered from March – May, 2005.

To increase the accuracy and quality of the survey data, maximum cares were taken in questionnaire design, enumerator selection, field supervision and data entry. All the six enumerators have adequate knowledge about the study area (grown up in the area and with local mother tongue) and enormous field experience in data collection for numerous researchers (as enumerators, translators, interviewers, facilitators or moderators, and field workers) in the same district and other areas of Tigray. Field work was supervised by the researcher on a daily basis. Coding and data entry layout sheet on STATA software were prepared by the researcher and data were directly put on STATA (release 9.1/SE) by hired operators all with diploma in computer science. Supervision, on spot assistance and cleaning were made by the researcher through out the data entry. Thus, we believe that the data set reflect the real socio-economic situation of the study area.

3.6 Results

3.6.1 Household typology and description of livelihood strategies

With the help of cluster analysis the 360 sample households were categorized according to their dominant livelihood strategies. This helps us discover a robust typology of livelihood strategies that may describe the sample households (see figure 3.2 i.e. appendix 3.4). On the basis of the cluster solutions we arrived at the following five dominant livelihood strategies (LS):

LS # 1: crop production and forest collection (CF) (98 households)
LS # 2: forest collection (F) (38 households)
LS # 3: crop production (C) (69 households)
LS # 4: off-farm work and crop production and forest collection (OCF) (74 households)
LS # 5: livestock production & forest collection & crop production (LFC) (74 households)

Each of the five strategies are identified and labeled on the basis of the dominance of the share of an income source(s) in total household income. Since the shares of transfer income and 'other income' category in total household income are too small, we labeled the clusters on the basis of the four major income sources (see section 3.5.1). Depending on the distribution of each of the four cluster variables, we used different cut-off points for grouping the households. We employ median and third quartile values to set cut-off values to control the influence of outliers. For the crop income share the median value (40%); for the livestock income share the third quartile value (25%); for the off-farm income share the third quartile value (20%); and for the forest environmental income the median value (30%) are used as cut-off points.

As can be seen from table 3.1, in LS # 1 about 83% of the share of an average household's total income is accounted by incomes from crop and forest sources together, 47% from crop income and 36% from forest products. Consequently, this strategy is labelled as 'CF' i.e. crop-forest mix, though crop income is relatively more important.

LS # 2 and LS # 3 are mono-source dominated strategies where 62% of the former's and 64% of the latter's share in total income is dominated by forest source and crop income respectively. Though households under these strategies supplement their livings from other income sources, due to the dominance of single sources we labelled LS # 2 as 'forest collection' strategy and that of LS # 3 as 'crop production' strategy.

Table 3.1 Mean share of each income source [a] (by livelihood strategy)

			Livelihood Strategies									
cluster	full sample		LS # 1 (obs. 98)		LS # 2 (obs. 38)		LS # 3 (obs. 69)		LS # 4 (obs. 74)		LS # 5 (obs. 80)	
variables	mean[b]	SE[c]	Mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
cropshare	0.4200	0.1520	**0.4695**	0.0729	0.2039	0.0862	**0.6402**	0.0742	**0.5302**	0.1040	**0.2126**	0.0878
liveshare	0.1400	0.1491	0.0812	0.0788	0.0803	0.0867	0.0678	0.0716	0.0671	0.0701	**0.5702**	0.1069
offshare	0.1032	0.1246	0.0439	0.0581	0.0461	0.0741	0.0539	0.0623	**0.2056**	0.0872	0.0584	0.0699
envishare	0.3035	0.1214	**0.3598**	0.0688	**0.6197**	0.0975	0.2189	0.0582	**0.1641**	0.0829	**0.1366**	0.0808
TRshare	0.0103	0.0500	0.0251	0.0856	0.0029	0.0175	0.0038	0.0190	0.0040	0.0179	0.0072	0.0346
mislshare	0.0227	0.0502	0.0205	0.0488	0.0470	0.0711	0.0153	0.0329	0.0289	0.0584	0.0148	0.0400

[a] Each ‘mean column’ may not exactly add up to 1 due to rounding.

[b] There are slight differences in mean percentage shares of each income source in total household in this table and that of table 2.2 (chapter 2). The reason is that in table 2.2 the percentages are computed on the basis of household income per adult equivalent whereas in table 3.1 the calculations are based on the share of each income component in total household income (i.e. without taking the household size into account).

[c] SE= standard errors of the distributions of income shares of each source, by strategy.

cropshare = share of crop income in total household income

liveshare = share of livestock income in total household income

offshare = share of off-farm income in total household income

envishare = share of forest environmental income in total household income

TRshare =share of transfer income in total household income

mislshare = share of other incomes in total household income

Table 3.2 summary statistics* of explanatory variables (by household clusters)

Explanatory	LS #1 (crop+forest)				LS # 2 (forest)				LS # 3 (crop)				LS # 4 (OCF)				LS # 5 (LCF)			
Variables	Mean	Std	Min	max	mean	Std	min	max	mean	Std	min	max	mean	std	min	max	mean	std	min	max
Hhsize	5.79	1.97	1	10	5.03	2.17	1	9	6.25	2.06	2	10	5.7	1.98	2	9	6.15	1.9	1	10
Hhage	48.3	12.8	25	78	51	14.7	25	85	48.6	13	23	75	42	11.3	24	72	46.7	10.75	28	76
Hhsex	0.89	0.3	0	1	0.63	0.48	0	1	0.99	0.12	0	1	0.86	0.34	0	1	0.98	0.16	0	1
Hhedu	0.31	0.46	0	1	0.18	0.39	0	1	0.42	0.5	0	1	0.43	0.50	0	1	0.38	0.49	0	1
Dep_ratio	0.51	0.19	0	0.83	0.56	0.22	0	1	0.47	0.19	0	0.75	0.52	0.18	0	1	0.53	0.15	0	1
stud_ratio	0.21	0.21	0	0.8	0.20	0.22	0	1	0.27	0.2	0	0.8	0.19	0.16	0	0.6	0.2	0.18	0	0.6
Plotsize	1.16	0.71	0.25	4.75	0.72	0.46	0.06	2	1.17	0.53	0.38	3.13	0.92	0.64	0	2.9	1.03	0.50	0.25	3
UhMh	0.39	0.49	0	1	0.36	0.49	0	1	0.59	0.49	0	1	0.54	0.5	0	1	0.59	0.50	0	1
Eucalyp	0.89	0.3	0	1	0.61	0.49	0	1	0.87	0.34	0	1	0.59	0.49	0	1	0.76	0.43	0	1
Acc_graz	0.78	0.42	0	1	0.74	0.45	0	1	0.60	0.5	0	1	0.68	0.47	0	1	0.66	0.48	0	1
Irrigation	0.02	0.14	0	1	0.03	0.16	0	1	0.16	0.37	0	1	0.02	0.16	0	1	0.07	0.24	0	1
Lndistsch	3.02	0.87	1	5.7	3.25	0.77	1.61	4.79	2.94	0.75	1.2	4.25	3.01	0.71	1	3.9	3.04	0.99	0.69	4.79
Lndistroad	3.81	0.81	1	5.2	4.01	0.85	2.3	5.48	3.47	0.61	1.61	4.79	3.56	0.75	1.6	5	3.94	0.74	2.3	5.19
Lnassetagr	4.62	0.74	1	5.9	3.75	1.2	1	5.27	4.64	0.74	1	6.25	4.26	0.95	1	6	4.59	0.66	1	5.86
Lnassetdur	4.55	1.17	1	7.1	3.83	1.31	0.22	6.23	4.74	1.25	0.41	6.97	4.79	1.12	1	7.1	4.71	1.16	0.69	7.6
Donkey	0.45	0.5	0	1	0.37	0.49	0	1	0.67	0.47	0	1	0.34	0.5	0	2	0.58	0.50	0	1
equb_m	0.05	0.22	0	1	0.03	0.16	0	1	0.03	0.17	0	1	0.09	0.29	0	1	0.06	0.24	0	1
Dd_loan	0.62	0.49	0	1	0.61	0.50	0	1	0.52	0.50	0	1	0.53	0.5	0	1	0.53	0.50	0	1
Baccount	0.24	0.24	0	1	0.13	0.34	0	1	0.42	0.50	0	1	0.46	0.5	0	1	0.31	0.47	0	1

* Note that the averages for dummy variables in all clusters serve as percentages; for instance in LS# 2, a mean of 0.63 for the variable 'hhsex' implies that in the second cluster, 63% of the households are male headed and the remaining 37% are female headed.

In terms of total income per adult equivalent unit, households under LS # 2 enjoy the least income (ETB 428) comparing with all other strategies (see table 3.5).

Both LS # 4 and LS # 5 are of diversified strategy types. Households under both of the strategies undertake three main activities: off-farm, crop production, and forest collection in LS # 4 and livestock production, crop production, and forest collection in LS # 5. Thus crop production and forest product collection are common activities in both strategies. Whereas 53% of the total income in LS # 4 is accounted by off-farm income, in LS # 4, 57% is by crop income. Thus, LS # 4 is named as 'off-farm-crop-forest' (OCF) mixed strategy and LS # 5 is given the name 'livestock-crop-forest' (LCF) strategy.

Table 3.2 presents the summary statistics of asset-based explanatory variables by livelihood strategy. As indicated in the table, we find very unique characteristics of the asset position of households under the strategy dominated by forest collection (LS # 2). Comparing the households under this with the rest of the clusters, on average, the number of female headed households is the highest (37% of the households are headed by females). Households under this cluster are the least-educated and with highest dependence ratio (56%). They are least endowed with agricultural land (with average land holding of 0.72 ha/household) and agricultural implements. Most households under this category are also constrained by financial capital as demonstrated by poor linkages with the local financial systems (i.e., their *'equb'* membership[33] is quite low, they are the least fortuned in terms of access to credit, and almost all of them do not transact with the local banks). In general, households whose dominant strategy is identified as 'forest product collection' are the most disfavoured category in terms of the endowment of most of the livelihood assets.

As can be expected *a priori*, the livelihood strategies in which crop production plays the dominant role (LS # 1 and LS # 3) are characterized by the highest endowment of natural capital (land) and physical capital (agricultural implements) on average. As can be seen from table 3.2, the most distinguishing features of the two mixed strategies – the one dominated by off-farm income (LS # 4) and the other by livestock

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[33] The concept of '*equb*' and its socio-economic importance in rural Ethiopia is indicated in foot note 32.

production (LS # 5) – is their best endowment with financial capital compared to the rest of the strategies. Households grouped under these two strategies have relatively good access to credit, many of them have accounts in local banks, and their participation rate in *‘equb’* is larger than that of households under the rest of the clusters.

3.6.2 Are some livelihood strategies superior to others?

Table 3.3 reports the pair-wise comparison (t-statistics) of the statistical significance of the differences between mean total incomes per adult equivalent in all possible pairs among the five clusters. On the basis of the t-test for the equality of means of two populations, we find that at 5% significance level the means of most pairs of strategies show a statistically significant difference except few of the pairs. Two most noticeable features are observed from the t-test results. First, the differences between means of LS # 4 and LS # 5 are statistically insignificant and secondly, comparing the means of all other strategies with that of ‘forest strategy’ (LS # 2), the difference is statistically significant (i.e., mean household income per adult equivalent in LS # 2 is statistically significantly lower than the mean income of the other four groups). Table 3.4 presents the one-way ANOVA and confirms that the variation in mean household income is statistically significantly different between several clusters.

The computed t-test statistics in table 3.3 indicate that the means in strategies 4 and 5 are significantly larger than the other groups. If income is taken as a measure of household welfare, then we can rank the different strategies on the basis of each cluster’s mean income. The sample means of income per adult equivalent of the five livelihood strategies and the corresponding ranks is presented in table 3.5. Since means of LS # 4 and LS # 5 are not different statistically, we can safely generalize that these two diversified strategies generate better livelihood outcomes (superior strategies).

Table 3.3 Two-cluster t-test for the equality of population means (for total household income per adult equivalent across clusters)

The null hypothesis for all paired-difference t test is: Ho: diff=0; with alternative: Ha: diff≠ 0 (two-tail t-test at $\alpha = 5\%$)

statistic	LS#1=LS#2	LS#1=LS#3	LS#1=LS#4	LS#1=LS#5	LS#2=LS#3	LS#2=LS#4	LS#2=LS#5	LS#3=LS#4	LS#3=LS#5	LS#4=LS#5
t	2.6086	-1.6132	-2.6138	-3.1056	-3.5005	-3.7209	-4.2008	-1.0986	-1.4382	-0.1945
p-value	0.0101**	0.1086	0.0140**	0.0028***	0.0007***	0.0003***	0.0001***	0.2739	0.1525	0.8461
df	134	165	170	180	105	110	116	141	147	152
Decision	Reject Ho	accept Ho	Reject Ho	Reject Ho	Reject Ho	Reject Ho	Reject Ho	accept Ho	accept Ho	accept Ho

** = significant at 5%; *** = significant at 1%; df = degree of freedom

Table 3.4 One-way ANOVA (for total household income per adult equivalent)

Source of variation	SS	Df	MS	F	Prob>F
Between groups	2538751.13	4	634687.783	6.96	0.0000
Within groups	32289548.6	354	91213.4141		
			97285.7534		
Total	34828299.7	359			

Bartlett's test for equal variances: chi2 (4) = 14.2844, Prob>chi2 = 0.006

Table 3.5 Ranking of livelihood strategies

Strategy	Dominant activities	mean p.c a.e.u. income (in ETB)[a]	Rank
LS # 1	Crop production & forest collection	567	4th
LS # 2	Forest collection	428	5th
LS # 3	Crop production	632	3rd
LS # 4	Off-farm, crop, & forest collection	689	2nd
LS # 5	Livestock, crop, & forest collection	700	1st

[a] p.c a.e.u total income = total household income per capita per adult equivalent.

3.6.3 Econometric analysis of determinants of livelihood strategies

The estimation results of MNL regressions are presented in tables 3.6 -3.9. We run MNL regression four times[34] (by varying the base category in each regression) in order to be able to compare the effects of each specific predictor on the likelihood of a particular livelihood strategy choice relative to the other strategies. Since the strategy dominated by forest environmental product collection is our main interest, we pay due attention to the regression results of table 3.6 in which this strategy is treated as the base category. Hence, in this section, we present the results of table 3.6. The other MNL regression results obtained by treating each of the rest of the strategies as a base category are presented in appendix 3.3 (tables 3.7-3.9)

Forest strategy (LS # 2) vs. other livelihood strategies (MNL Results of table 3.6)

a) General assessment of forest strategy:

The respective coefficients of each explanatory variable in table 3.6 measure the effect of the variable on the relative probability that the household chooses a particular respective strategy relative to choosing forest strategy. Comparing forest activity with the rest of the livelihood strategies, sex of the household head and credit constraint significantly and consistently explain the choice of forest activity. Female headed households are more likely to get engaged in the collection of forest environmental products than choosing other strategies. The estimated model shows

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[34] We do not need to run the fifth MNL for LS # 5 cluster as a base. Because comparison of its probability relative to each of the other four groups is already undertaken in the four regressions.

Table 3.6 Multinomial logit regression results (base category: LS # 2 (forest))

Explanatory variables	LS # 1 (crop + forest)		LS # 3 (crop)		LS # 4 (off-farm + crop + forest)		LS # 5 (livestock +crop +forest)	
	Coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value
Hhsize	-0.1046	0.399	-0.1056	0.442	-0.0237	0.859	-0.0415	0.742
Hhage	-0.0242	0.197	-0.0388*	0.067	-0.0588***	0.004	-0.0410**	0.034
Hhsex	1.0930*	0.097	3.0391**	0.017	1.2982*	0.078	2.7821***	0.004
Hhedu	0.0799	0.286	0.5867	0.316	0.6536	0.258	0.1122	0.840
Dep_ratio	-1.4956	0.103	-2.4550*	0.079	-1.5200	0.244	-1.0494	0.417
Stud_ratio	0.9891	0.151	2.5226*	0.095	0.5163	0.706	0.9440	0.496
Plotsize	1.3246**	0.018	1.3770**	0.019	0.8612	0.140	0.6455	0.259
UhMh	-0.0858	0.864	0.6470	0.237	0.6386	0.222	0.6260	0.221
Eucalyp	1.4342***	0.008	0.7741	0.189	-0.5709	0.261	0.1267	0.804
acc_graz	0.1286	0.821	-0.0032	0.996	0.5535	0.341	0.1037	0.153
Irrigation	-0.7623	0.588	1.4410	0.273	-0.5967	0.685	0.6828	0.603
Lndistsch	-0.4217*	0.089	-0.3163	0.304	-0.4367	0.135	-0.3915	0.165
Lndistroad	-0.2056	0.562	-0.8407**	0.026	-0.5128	0.161	0.1478	0.691
Lnassetagr	0.6014**	0.049	0.5852*	0.086	0.0480	0.872	0.4952	0.111
Lnassetdur	0.0704	0.748	-0.1363	0.567	0.2757	0.239	0.1200	0.597
Donkey	-0.7407	0.156	0.2072	0.716	-1.0477*	0.060	-0.1673	0.752
equb_m	-0.1938	0.875	-1.0247	0.455	0.4550	0.698	0.2929	0.810
dd_loan	-0.5951*	0.101	-1.1177**	0.034	-0.8943*	0.079	-0.9673*	0.053
Baccount	0.3355	0.574	0.6209	0.318	1.1391*	0.060	0.5013	0.403
_cons	-0.0531	0.979	1.2280	0.615	4.5031**	0.033	-1.4308	0.517

* = significant at 10% ; ** = significant at 5% ; *** = significant at 1%

Log likelihood = -460.63998; LR chi2(76) = 205.40; Prob > chi2 = 0.0000; Pseudo R2 = 0.1823 that liquidity constrained households due to credit market imperfections are more likely to choose forest products collection as their dominant strategy comparing with all other strategies. One can intuitively justify the model's prediction. If a household is cash constrained to start up other activities, for instance to participate in own business undertaking, then choosing a forest related activity which does not require cash to start up is a rational choice. The summary of all the inter-strategy comparison is provided in appendix 3.1. Concerning the overall significance of the model the computed log likelihoods, chi-square values and the corresponding probabilities show that the over model is significant and explains the observed behaviour. For instance, when the base category is 'forest' (LS#2), the results of the MNL regression with log likehood = -460.6; chi-square = 205 (df=76), and p-value=0, implies that this model is statistically significant (see table 3.3 and the statitics below the table).

b) Assessing forest strategy relative to each of the other specific strategy

Comparing *forest strategy* with *crop & forest strategy*, male headed households, households with more land, having eucalyptus trees, more agricultural implements, located nearly to primary schools and better access to credit are more likely to choose a mixed crop and forest strategy than extractive activity (forest collection) as a dominant strategy. As land is the main input in agriculture, it is *a priori* expected that the larger the land size the more the probability that a household pursues crop production as a major strategy. A similar argument applies to the possession of more agricultural implements. Concerning eucalyptus trees, households possessing eucalyptus can easily harvest wood products from their eucalyptus trees in stead of depending on products from forest environmental sources and use their time that would have been allocated for forest product collection to other more remunerative alternative activities. Hence, such households are less likely to choose forest collection as a main strategy compared to those with no eucalyptus plantation.

Comparing *forest strategy* with that of *crop strategy*, households located far away from primary schools, with large number of uneducated adults (less student ratio), and more dependency ratio are more likely to be engaged in forest related activities as a dominant strategy. The possible explanations for this observed pattern can be: (1) In rural Ethiopian settings children are involved in a number of family works, mainly cattle herding and fodder and firewood collection. Though children are conventionally classified as dependents, in African settings they contribute enormously to household income in a number of ways. It is uncommon to see children without a bundle of firewood or fodder on their head when they are back to home from their daily herding business. This may be the possible explanation why high dependency ratio households are more likely to engage in forest related activities. (2) Given the scarcity of farm land in the study district[35], illiterate adults are underemployed on agriculture. Besides, the rural labour market is largely imperfect. Urban centres do not have capacity to absorb migrant labourers from rural areas which makes rural-urban migration a less favoured strategy to earn a living and get out of poverty. Therefore, as the number of illiterate adult household members increases, forest related activities become an alternative strategy. This may be the reason why forest product mining becomes the dominant strategy for households characterized by less student ratio at household level.

Comparison of *forest strategy* with a diversified *off-farm & crop & forest (OCF) strategy* shows that ownership of donkey increases the probability of a household to choose forest activity as the dominant strategy. This may be explained by examining the linkage between the bulky nature of forest products and the key role donkey plays in transportation in rural areas. Besides its use as a source of household's domestic energy, revenue from the sale of firewood is also a good source of supplementary income. But the major market demand for firewood is either in Hagereselam (the district's capital) or Mekelle (the regional state capital), both of which are distantly located for many of the location of sample households. Given the poorly supplied road infrastructure in the area, it is unthinkable to transport bulky firewood to the urban centers in the absence of donkey. If one crosses the 55km distance between Mekelle and Hagereselam, one can observe tens or even hundreds of donkeys loaded with firewood, many towards Mekelle and some to Hagereselam. Therefore, given the observed fact in the study area, the positive relationship between donkey ownership and engaging in forest activities, is not surprising.

Comparison of *forest strategy* with diversified *livestock & crop and forest (LCF) strategy* reveals those households with younger or female heads and less access to

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[35] The average land holding of sample households is 1.05ha/household.

credit market are more likely to pursue forestry activity. This prediction seems sound because as younger heads may not have sufficient accumulation to invest they tend to engage in forest product collection. As they get older and older they accumulate and save to invest in other remunerative livelihood options and become less dependent on forest products.

3.7 Discussion

Largely, the results reveal two important patterns. A first pattern concerns the step out of dependence on forest products and into crop production. Our results show that this step is influenced by access to natural and physical capitals such as land and agricultural implements. A second pattern reveals that financial (investment) constraints impede households to enter the more profitable strategies involving livestock and off-farm activities. Both patterns highlight that mixed (diversified) strategies are more lucrative than other strategies. Taking diversification as one of the livelihood strategies and examining why households diversify, we find numerous conditioning factors in the literature (Reardon et al., 1992; Reardon, 1997; Ellis, 1998; Dercon, 1998; Woldehanna, 2001; Block and Webb, 2001; Barret et al., 2001; Smith et al., 2001; Abdulai and CroleRees, 2001; Fisher et al., 2005; Jansen et al., 2006). Our results are consistent with many of these previous works. For instance, we find that liquidity constraints limit households' potential investment in profitable off-farm income generating activities[36]. Households that do succeed in pursuing this strategy are more likely to have a bank account and are headed by household heads that are male and young. Given the male-biased Ethiopian culture, it is men who dominate major economic activities and hence have more chance to diversify strategies than the women. We further argue that two superior strategies identified are not only superior economically but also compatible with the limited natural resource base of the Tigray region. Environmentally, the Tigray region of Northern Ethiopia is one of the most degraded areas in the country. In most parts of the region, soil fertility and forest density are very low. With such natural environment endowment, the potential role of

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[36] Ellis (1998:15) argues that credit market failures motivate farm households to engage in wage employment in order to generate cash income to substitute for the absence of credit. But in Ethiopian rural settings where rural labour market imperfection is so eminent, rural wage employment is often unlikely.

crop production as a dominant livelihood strategy to get people out of poverty is very limited. Almost all peasants of the region are operating at the subsistence level. Given the natural asset endowment of the region, LS #5 has practical importance and plausible policy implications. It has a win-win potential in the sense that with prudent application of this strategy, both environmental and economic objectives can be met. Our finding is consistent with similar studies elsewhere in Africa. For example, Barrett et al. (2005) in their case studies in Cote d'Ivoire, Kenya, and Rwanda found that in drier agro-ecological zones, crop production is less likely to cover even the household's consumption requirements. They suggested that livestock production is an important livelihood strategy in dryland areas.

The existing livestock production system in the study area is very traditional. It is a kind of extensive livestock production where cattle are simply let to the communal grazing areas and what matters from the point of view of the peasant is the number of livestock he/she owns, not its productivity. It is this century old free-grazing practice that is supposed to be one of the major reasons for the current environmental degradation of the region. Production of animal feed at household level is almost non-existent. At this point, one may raise a question 'how a strategy dominated by livestock production can be compatible in such a fragile natural environment? The answer to this question depends on the choice of the production technology of livestock. If farmers are motivated[37] to produce fodder at farm level, focus on the productivity rather than livestock quantity, and intensify livestock production, the ultimate outcome will be environmentally friendly and economically sound. The existing dependence on free environmental sources for animal feed, which is detrimental to the very resource system, is substantially reduced and eventually substituted by own fodder production. Livestock production then will be a lucrative source of cash income. Practicing livestock production as the dominant activity with its high economic returns, peasants can supplement their living by mixing with crop production activity for domestic (subsistence) use. Given the low soil quality and small land holdings, crop production can only be a complementary activity, not the dominant one. Therefore, LCF is feasible both economically and environmentally, and

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[37] The motivation can take any form (various economic incentives mechanisms, focused extension services, tailor-made farmer trainings, provision of fast growing plant species for fodder production, improved livestock varieties, and/or any other feasible approach).

hence interventions targeting on both objectives should focus on diversified livestock + crop + forest strategy.

Concerning the arguments for the compatibility or desirability of a diversified off-farm + crop + forest strategy, in areas where there is intense environmental degradation and per capita land holding is diminishing over time due to population pressure, reliance on farm income may lead rural households to be vulnerable to even minor shocks. Given the low agricultural potential of most parts of Tigray, rural livelihood diversification strategy dominated by off-farm activities can be considered as one of the desirable paths in rural development endeavour. However, as our findings indicate this strategy is characterized by entry constraints in the form of financial capital to start up the activity. The implication is that though rural areas in Tigray are better endowed with rural financial services than most rural areas in other parts of Ethiopia[38], our evidence indicates that the existing rural financial channel supplies fewer funds than the demand.

3.8 Conclusions

Farming households earn their living from various sources. Using data on rural households from the Tigray region of northern Ethiopia, we identified five dominant livelihood strategies (ranked according to mean income): strategies dominated by forest collection, crop and forest dominated activities, strategies dominated by crop production, and two distinct mixed type strategies (one, with off-farm + crop + forest and the other, with livestock + crop + forest). The central questions that we seek answers in this chapter were: What factors explain the observed patterns of livelihood strategies? Why some people are more dependent in forest related activities? Are there activities (mainly high return activities) from which some households excluded by constraints? In line with these questions, we hypothesized that heterogeneity among households in 'assets' endowment explain households' choice of livelihood strategies and the same set of factors explain the exclusion of some households from high return activities.

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[38] The Dedebit Saving and Credit Institute (DECSI), the second largest microfinance institute in Ethiopia, is providing financial services in many parts of rural Tigray.

Through the MNL regressions we found that heterogeneous access to livelihood assets are the main explanations for observed variations in activity choice. Thus, in this regard the empirical evidence supports our hypothesis. We also found that activities dominated by livestock production and profitable off-farm undertakings are superior in terms of their return and the consequent effect on welfare. But these activities are mainly constrained by substantial investment requirements. Again constraints imposed on some households in the form access to some of the livelihood assets prevent asset-poor households from taking up better return economic opportunities. This finding is also in conformity with our hypothesis.

Based on our findings, we recommend that to break the constraints prudent interventions in enhancing the positions of asset-poor households should be exercised so that households may enjoy better economic benefits without impairing the natural environment. From our results, three policy recommendations can be formulated. First, entry constraints hinder some households from taking advantages of better return activities. Entry constraint in the form of financial capital is the major bottleneck in off-farm and livestock activities. Therefore, to boost these activities in rural Tigray with the concomitant economic and environmental benefits ways should be sought to channel more financial resources to the rural areas. Rural credit motivates local people to take advantage of new business opportunities for which they could not enter due to the prevailing financial constraint. Breaking such constraint via financial asset provision makes more local people (especially younger members) to divert their livelihood strategy to more profitable business undertakings in stead of tying themselves with forest harvesting. Second, though the livestock production dominated strategy is economically superior in terms income gain, sufficient care should be taken in expanding livestock production. Otherwise it will be detrimental to the already fragile environment. Therefore, targeted livestock extension programmes and quality and productivity based production technologies should be disseminated in order to make livestock production environmentally compatible. Third, family planning and gender related interventions relieve household dependency ratio and can minimize the population pressure on local resources. This is a feasible policy intervention area which may result in sustainable use and management of forest resources in the long-run.

Appendices 3

Appendix 3.1 Summary of the comparison of the likelihood of each strategy in relation to the other strategy (on the basis of asset-based variables which are statistically significant)

	compared with			
base strategy (↓)	LS #2	LS #3	LS # 4	LS #5
LS # 1 (more likely)	male headed households, more land, possession of eucalyptus, near to school, more agricultural. Implements, access to credit	middle highland households, have less access to irrigation, located far from the main road, possess no donkey	households with older heads, middle highland households, possessing eucalyptus, more agri. implements, no bank accounts in local banks	female headed households, more plots, middle highland households, possessing eucalyptus tree
LS # 2 (more likely)	NA	households with older heads, female headed households, more dependency ratio, less student ratio, less land, distantly located from roads, less agricultural implements, credit constrained households	households with older heads, female headed households, possessing donkey, credit constrained, no bank account in local financial institutions	households with older heads, female headed households, credit constrained households
LS # 3 (more likely)	X	NA	households possessing eucalyptus tree, good access to irrigation, more agricultural implements, less consumer durables, more donkey	possessing more land, better access to roads
LS # 4 (more likely)	X	X	NA	not possessing eucalyptus tree, possessing less donkey, having accounts in local banks

NA = not applicable, because we carryout the likelihood of inter-group comparisons, not intra-group comparisons.

X = comparisons are already made i.e. one can simply replace the cells marked with 'X' by the variables from corresponding cells where the two strategies intersect and use 'less likely' in stead of 'more likely' to get similar interpretations of the comparisons.

Appendix 3.2 Correlation matrix of the regressors

	V_{1}	V_{2}	V_{3}	V_{4}	V_{5}	V_{6}	V_{7}	V_{8}	V_{9}	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}	V_{19}
Hhsize	1.00																		
Hhage	0.10	1.00																	
Hhsex	0.30	0.12	1.00																
Hhedu	0.09	-0.16	0.21	1.00															
Dep_ratio	0.2	-0.11	-0.04	-0.03	1.00														
stud_ratio	0.33	0.24	-0.12	-0.06	0.03	1.00													
Plotsize	0.27	0.11	0.29	0.04	0.03	0.05	1.00												
UhMh	0.13	0.02	0.07	0.06	0.02	0.2	-0.05	1.00											
Eucalyp	0.10	0.004	0.14	0.01	-0.02	0.06	0.03	0.18	1.00										
Acc_graz	-0.09	0.07	-0.01	-0.11	0.04	-0.16	0.17	-0.26	-0.03	1.00									
Irrigation	0.05	0.06	0.05	0.04	-0.25	0.14	-0.10	0.06	0.08	-0.14	1.00								
Lndistsch	-0.07	0.02	0.004	-0.02	-0.02	-0.21	0.12	-0.07	-0.10	0.11	-0.12	1.00							
Lndistroad	-0.04	0.14	-0.04	0.04	0.02	-0.07	0.02	0.07	-0.02	0.27	-0.1	0.19	1.00						
Lnassetagr	0.33	0.02	0.38	0.18	-0.04	0.11	0.43	-0.01	0.15	0.12	0.03	0.02	0.05	1.00					
Lnassetdur	0.20	-0.1	0.16	0.19	-0.08	0.26	0.28	0.15	0.01	-0.11	0.08	-0.07	-0.14	0.42	1.00				
Donkey	0.23	0.11	0.25	0.05	-0.01	0.02	0.39	0.05	0.03	0.01	-0.03	0.11	0.03	0.23	0.24	1.00			
equb_m	0.06	-0.09	0.04	-0.01	0.003	-0.02	0.15	-0.07	-0.1	0.01	0.04	0.02	-0.15	0.13	0.2	0.03	1.00		
Dd_loan	0.07	-0.05	0.01	0.07	-0.11	0.02	0.14	-0.02	0.02	-0.02	0.10	0.04	0.03	0.16	0.01	-0.03	0.12	1.00	
Baccount	0.19	-0.06	0.16	0.09	-0.01	0.13	0.04	0.18	0.06	-0.17	0.11	-0.05	-0.21	0.05	0.18	0.01	0.01	-0.03	1.00

V_{1}-V_{19} = represent the 19 variables listed in the first column i.e., V_{1}= the first variable, V_{2}= the second variable, …, V_{19}= the nineteenth variable.

Appendix 3.3 MNL regression results with base category LS # 1, LS # 3, and LS # 4 (tables 3.7-3.9)

- LS # 1 as a base category (table 3.7)

Comparison between strategies # 1 and #3 indicates that households located in upper highland areas and with access to irrigation are more likely to engage in strategy # 3. Household head age, location dummy, ownership of eucalyptus tree, agricultural implements and bank account are statistically significant variables that differentiate strategy # 1 and # 4. Accordingly, households with older heads, possessing eucalyptus trees and more agricultural implements are more likely to choose LS # 1 than LS # 4.

- LS # 3 as a base category (table 3.8)

Crop production as the dominant strategy is more likely among households with more plots of land, better access to credit, households sending more children to school, male headed, or a younger head (see appendix 1). Though 'irrigation' variable is not significant statistically, it predicts positively to the likelihood of household's participation in crop production as a dominant activity. The limited explanatory power of irrigation is not surprising given the very low level of irrigation facility reported in the survey.

- LS # 4 as a base category (table 3.9)

Strategy # 4 and # 5 are both mixed (diversified) strategies. In section 3.6.2 we have shown that these two strategies are superior relative to the other strategies. Despite the relative strength of a specific variable in influencing their choices, both strategies are mainly conditioned by the variables measuring financial capital (see appendix 1). Relative to LS # 5, households having bank accounts are more likely to engage in LS # 4. As LS # 4 is dominated by off-farm activity, the intuitive explanation may be that people operating off-farm activities such as own business undertakings often use financial intermediaries either in depositing their profits or in borrowing for their business expansion or working capital.

Table 3.7 Multinomial logit regression results (base category: LS # 1 (crop+ forest))

Explanatory variables	LS # 2 (forest)		LS # 3 (crop)		LS # 4 (off-farm + crop + forest)		LS # 5 (livestock +crop +forest)	
	Coefficient	p-value	Coefficient	p-value	coefficient	p-value	coefficient	p-value
hhsize	0.1046	0.399	-0.0009	0.993	0.0808	0.462	0.0631	0.518
hhage	0.0242	0.197	-0.0146	0.361	-0.0345**	0.039	-0.0168	0.249
hhsex	-1.0930*	0.097	1.9460	0.107	0.2051	0.760	1.6890*	0.059
hhedu	-0.0799	0.286	0.5067	0.181	0.5736	0.138	0.0322	0.927
Dep_ratio	1.4956	0.103	-0.9594	0.378	-0.0244	0.982	0.4461	0.659
Stud_ratio	-0.9891	0.151	1.5334	0.197	-0.4728	0.677	-0.0451	0.967
plotsize	-1.3246**	0.018	0.0523	0.873	-0.4634	0.197	-0.6791**	0.046
UhMh	0.0858	0.864	0.7329*	0.059	0.7245*	0.062	0.7119***	0.047
eucalyp	-1.4342***	0.008	-0.6601	0.210	-2.0052***	0.000	-1.3075**	0.004
acc_graz	-0.1286	0.821	-0.1318	0.752	0.4248	0.328	-0.2324	0.554
irrigation	0.7623	0.588	2.2034**	0.014	0.1656	0.882	1.4451	0.121
lndistsch	0.4217**	0.089	0.1054	0.642	-0.0149	0.947	0.0302	0.880
lndistroad	0.2056	0.562	-0.6351**	0.013	-0.3072	0.232	0.3534	0.171
lnassetagr	-0.6014**	0.049	-0.0161	0.957	-0.5534**	0.050	-0.1061	0.700
lnassetdur	-0.0704	0.748	-0.2067	0.244	0.2053	0.278	0.0495	0.768
donkey	0.7407	0.156	0.9479**	0.017	-0.3070	0.431	0.5733	0.104
equb_m	0.1938	0.875	-0.8309	0.377	0.6489	0.379	0.4867	0.517
dd_loan	0.5951*	0.101	-0.5225	0.149	-0.2991	0.417	-0.3722	0.272
baccount	-0.3355	0.574	0.2853	0.464	0.8036**	0.040	0.1657	0.659
_cons	0.0531	0.979	1.2811	0.541	4.5562**	0.014	-1.3777	0.463

* = significant at 10% ;   ** = significant at 5% ;   *** = significant at 1%

Table 3.8 Multinomial logit regression results (base category: LS # 3 (crop))

Explanatory variables	LS # 1 (crop+forest)		LS # 2 (forest)		LS # 4 (off-farm + crop + forest)		LS # 5 (livestock +crop +forest)	
	Coefficient	p-value	Coefficient	p-value	coefficient	p-value	coefficient	p-value
hhsize	0.0009	0.993	0.1056	0.442	0.0818	0.496	0.0640	0.555
hhage	0.0146	0.361	0.0388*	0.067	-0.0199	0.284	-0.0021	0.896
hhsex	-1.9460	0.107	-3.0391**	0.017	-1.7409	0.159	-0.2570	0.851
hhedu	-0.5067	0.181	-0.5867	0.316	0.0669	0.871	-0.4745	0.212
Dep_ratio	0.9594	0.378	2.4550*	0.079	0.9350	0.438	1.4055	0.211
Stud_ratio	-1.5334	0.197	-2.5226*	0.095	-2.0062	0.123	-1.5786	0.197
plotsize	-0.0523	0.873	-1.3770**	0.019	-0.5158	0.182	-0.7314**	0.048
UhMh	-0.7329*	0.059	-0.6470	0.237	-0.0083	0.984	-0.0209	0.958
eucalyp	0.6601	0.210	-0.7741	0.189	-0.3450***	0.006	-0.6473	0.182
acc_graz	0.1318	0.752	0.0032	0.996	0.5567	0.221	-0.1005	0.809
irrigation	-2.2034**	0.014	-1.4410	0.273	-2.0378**	0.026	-0.7582	0.253
lndistsch	-0.1054	0.642	0.3163	0.304	-0.1204	0.635	-0.0751	0.742
lndistroad	0.6351**	0.013	0.8407**	0.026	0.3279	0.218	0.9885***	0.000
lnassetagr	0.0161	0.957	-0.5852*	0.086	-0.5372*	0.077	-0.0900	0.758
lnassetdur	0.2067	0.244	0.1363	0.567	0.4121**	0.043	0.2563	0.161
donkey	-0.9479**	0.017	-0.2072	0.716	-1.2549***	0.004	-0.3746	0.349
equb_m	0.8309	0.377	1.0247	0.455	1.4798	0.115	1.3177	0.159
dd_loan	0.5225	0.149	1.1177**	0.034	0.2234	0.578	0.1503	0.689
baccount	-0.2853	0.464	-0.6209	0.318	0.5182	0.215	-0.1196	0.762
_cons	-1.2811	0.541	-1.2280	0.615	3.2750	0.134	-2.6588	0.225

* = significant at 10% ;   ** = significant at 5% ;   *** = significant at 1%

Table 3.9 Multinomial logit regression results (base category: LS # 4 (off-farm + crop + forest))

Explanatory variables	LS # 1 (crop + forest)		LS # 2 (forest)		LS # 3 (off-farm + crop + forest)		LS # 5 (livestock +crop +forest)	
	Coefficient	p-value	Coefficient	p-value	coefficient	p-value	coefficient	p-value
hhsize	-0.0808	0.462	0.0237	0.859	-0.0818	0.496	-0.0177	0.872
hhage	0.0345**	0.039	0.0588***	0.004	0.0199	0.284	0.0177	0.297
hhsex	-0.2051	0.760	-1.2982*	0.078	1.7409	0.159	1.4838	0.109
hhedu	-0.5736	0.138	-0.6536	0.258	-0.0669	0.871	-0.5414	0.155
Dep_ratio	0.0244	0.982	1.5200	0.244	-0.9350	0.438	0.4705	0.674
Stud_ratio	0.4728	0.677	-0.5163	0.706	2.0062	0.123	0.4276	0.719
plotsize	0.4634	0.197	-0.8612	0.140	0.5158	0.182	-0.2156	0.569
UhMh	-0.7245*	0.062	-0.6386	0.222	0.0083	0.984	-0.0126	0.974
eucalyp	2.0052***	0.000	0.5709	0.261	0.3450***	0.006	0.6976*	0.083
acc_graz	-0.4248	0.328	-0.5535	0.341	-0.5567	0.221	-0.6573	0.121
irrigation	-0.1656	0.882	0.5967	0.685	2.0378**	0.026	1.2795	0.170
lndistsch	0.0149	0.947	0.4367	0.135	0.1204	0.635	0.0452	0.843
lndistroad	0.3072	0.232	0.5128	0.161	-0.3279	0.218	0.6606**	0.015
lnassetagr	0.5534**	0.050	-0.0480	0.872	0.5372*	0.077	0.4472	0.110
lnassetdur	-0.2053	0.278	-0.2757	0.239	-0.4121**	0.043	-0.1557	0.421
donkey	0.3070	0.431	1.0477*	0.060	1.2549***	0.004	0.8803**	0.023
equb_m	-0.6489	0.379	-0.4550	0.698	-1.4798	0.115	-0.1621	0.817
dd_loan	0.2991	0.417	0.8943*	0.079	-0.2234	0.578	-0.0730	0.845
Baccount	-0.8036**	0.040	-1.1391*	0.060	-0.5182	0.215	-0.6378*	0.098
_cons	-4.5562**	0.014	-4.5031**	0.033	-3.2750	0.134	-5.9339***	0.003

* = significant at 10% ;   ** = significant at 5% ;   *** = significant at 1%

Appendix 3.4 The dendogram

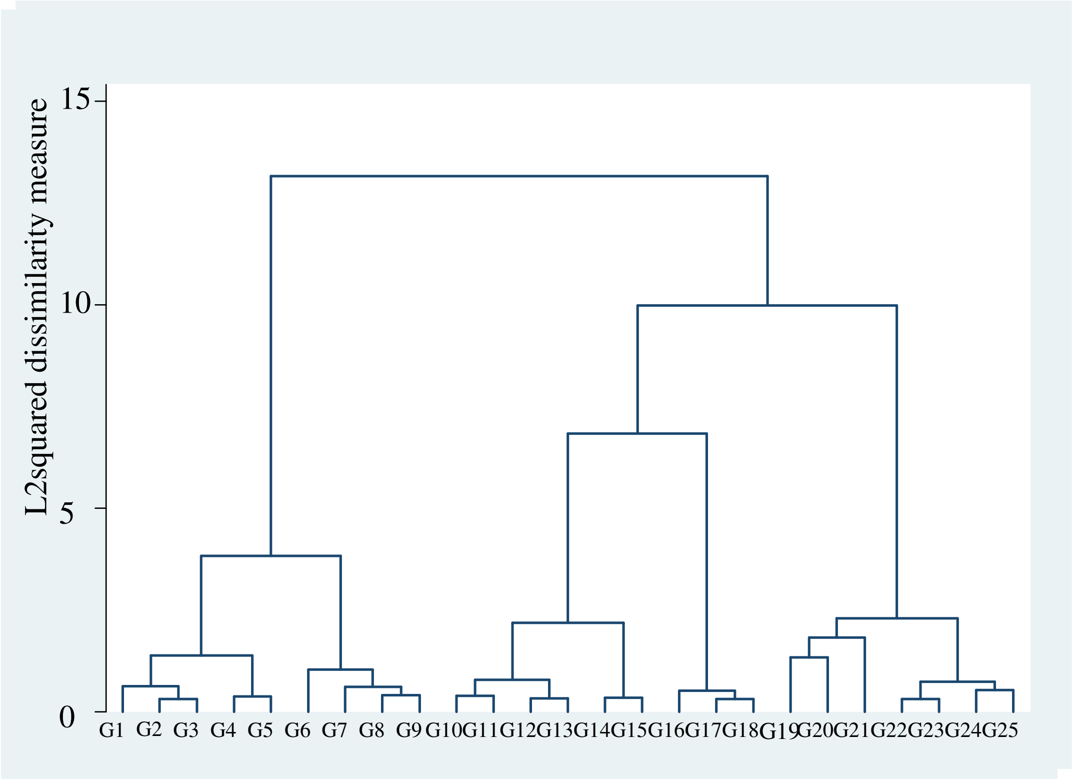

Figure 3.2 Dendrogram for wardslinakge hierarchical cluster analysis

Chapter 4

Valuing soil and water conservation effects of exclosures: an application of cost benefit analysis

4.1 Introduction

Land degradation and moisture stress are the major threats to agricultural productivity in Tigray. These problems are to a great extent directly or indirectly attributable to the rapid dwindling of forest resources in the region. According to the 1996 report of the Tigray Forestry Action Plan, forests and woodlots cover less than 2 percent of the region's total area (TFAP, 1996). Severe shortages of fuel wood have rendered rural communities increasingly dependent on animal dung for fuel, contributing to the problem of declining soil fertility (Fitsum Hagos et al., 1999). Among the various agents of soil degradation, water erosion is often considered to be the most serious form across Ethiopia mainly due to the mountainous and hilly topography, torrential rainfall, and low degree of vegetation cover, especially in the northern part of the country (Bojo and Cassels, 1995; Bojo, 1996; Esser et al., 2002; Nyssen et al., 2004).

To mitigate the problem, several soil and water conservation measures such as stone bunds, check dams, and terracing have been installed in Tigray. Protecting degraded areas from human and animal interventions for natural regeneration of plants (exclosures) is one of the widely applied conservation practices in the region. Besides their ecological services, exclosures are also expected to boost biomass production, mainly fuel wood and fodder, to satisfy the growing demand for these products. If harvested in a sustainable manner, biomass production can substitute the use of animal dung and crop residue for fuel without impairing the environmental functions of forests so that dung and crop residues could be applied in farm field to improve soil fertility and agricultural yield.

Water is seen as one of the most valuable and vital resources in Tigray. Water resource development schemes by harvesting seasonal runoff via earth dams and small ponds (*'horoye'*) are also practiced widely in Tigray. However, sediment deposition (rapid siltation) of reservoirs is among the serious problems that threaten the sustainability of the reservoirs (Haregeweyn et al., 2006). By trapping the incoming sediments exclosures reduce sediment inflow into the reservoirs. On the basis of their findings from field data, Descheemeaker et al. (2006) argue that exclosures bordering reservoirs should be considered as an effective means of trapping sediments entering into reservoirs. This is one of the important off-site functions of exclosures. The sediment trapping capacity of exclosures also minimize the negative effects of flooding damage on adjacent croplands in down slope locations.

In general, catchment protection functions such as preventing soil erosion and regulating water flows are the most cited environmental services provided by forests (Pattanayak, 2004; Kramer et al., 1997; Anderson, 1987). On the other hand establishing exclosures excludes the land unit from other alternative uses, which necessarily involves trade-offs. The trade-offs must be weighed for optimal allocation of a piece of land. This necessitates the economic analysis of alternative land uses. In principle, all the present and future flows of benefits and costs have to be valued and analysed in order to put a piece of land in its optimal use. However, such economic analyses in quantitative and monetary terms have not been addressed yet in Tigray and are rare in the developing countries at large (Kamer et al., 1997; Howarth and Farber, 2002). This is mainly due to methodological problems and difficulties in value calculation as most of the ecosystem functions are non-marketed and not readily exchanged in markets.

By integrating the available data on biomass production, soil erosion, sedimentation, crop yield, opportunity cost of land, and market prices from various sources, this chapter undertakes an economic analysis of the soil and water conservation effects of exclosures by adopting the method of cost benefit analysis (CBA). The chapter thus fills the gap of knowledge with respect to the economic justification of land allocation to alternative uses in the study area[39].

However, we would like to explicitly express the constraints and deficiencies in our economic analysis that mainly arise from the lack of knowledge (data) about the true nature of the economy-environment interactions. Particularly, quantification and economic analyses of the off-site effects of most environmental conservation measures are based on anecdotal information and assumptions that may affect the final estimate substantially (Enters, 1998; Barbier, 1997; Barbier & Burgess, 1997). In this regard it is recognized by many economists that despite some methodological advances in environmental valuation, the downstream impacts of upstream conservation measures could not be quantified accurately due to the problems of obtaining reliable data. Barbier (1987; p. 104 cited in Enters, 1998) argued that "given that many of the qualitative dimensions of various trade-offs cannot be quantitatively measured, precise analysis of all benefits and costs can not be assured". Therefore, as it is true with many other findings of similar studies, our finding is also indicative, not definitive.

4.2 Theoretical basis of CBA and its application in environmental analysis

Mainstream economics postulates that economic trade-offs will inevitably arise when a scarce resource is allocated to a particular use. Private agents, motivated by self interest, seek some guiding economic tools to put their resources optimally in order to achieve their objectives. The problem becomes more serious and complicated in public resource allocation. This is due to the fact that public economic decisions involve a series of externalities and trade-offs that necessitate careful accounting of the social impacts of the decision. Cost-benefit analysis (CBA) is an applied economic tool often used to guide economic agents in resource allocation or investment project decisions or policy

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[39] The quantities and values of each benefit and cost items are measured and expressed for a hectare of exclosure. Therefore, the ensuing economic returns from the CBA have to be interpreted in terms of per hectare area of exclosure.

alternatives. It is a technique that is used to estimate and sum up (in present terms) the future flows of benefits and costs of society's resource allocation decisions or policy alternatives to establish the worthiness of undertaking the stipulated activity or alternative and inform the economic efficiency to the decision makers. Traditionally, CBA is a widely used tool in public investment appraisal. However, there are many instances that CBA is also applied in natural resource conservation policies (Newcombe, 1987; Anderson, 1987; Grohs, 1993; Johansson, 1993; Jaggar & Pender, 2003; Mesfin Tilahun et al., 2007).

The basic rationale for CBA and its theoretical underpinning is rooted in the *principle of potential compensation* developed by Kaldor and Hicks (Kaldor, 1939; Hicks, 1939), commonly known as the Kaldor-Hicks criterion and widely applied in welfare economics. It states that an action is more efficient if those that are made better off could potentially compensate those that are made worse off and lead to a Pareto optimal outcome[40]. This implies that the Kaldor-Hicks criterion does not require compensation actually be paid, merely that the possibility for compensation exists and that it is potentially conceivable. In situations where benefits and costs are spread temporally, the economic analysis requires that the present value of benefits exceeds the present value of costs and an inter-temporal compensation should be conceivable. Therefore, the Kaldor-Hicks criterion forms an underlying rationale for cost-benefit analysis, i.e. in comparing the flow of benefits and costs by taking into account the time dimension of cost and benefit streams.

As such, CBA could be applied in decisions related to environmental conservation or environmental management. A particular conservation decision, for instance, is deemed to make differences in the stock and flow of the natural resource system under consideration. The role of CBA is to measure the benefits and costs of the differences and consequently enables us to compare two worlds: the world **with** the conservation measure

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[40] Unlike Kaldor-Hicks criterion, the Pareto-criterion for improvement does require actual payment and making at least one party better off without making anyone worse off.

and the world **without** it. However, application of CBA in environmental conservation or management faces a variety of challenges. One major challenge arises from the fact that many environmental goods and services are *not traded directly* in the market. Hence, attaching economic values to them becomes a difficult task to researchers. In spite of remarkable developments in non-market valuation methods the challenge still remains to attach accurate and true economic values to a large number of environmental goods and services. Another major controversy in applying CBA to environmental conservation or management is the *discount rate* used for discounting the future flow of benefits and costs. From an economic point of view the discount rate should reflect the social time preference. As ecosystem functions are complex and some environmental changes irreversible, the choice of the discount rate is not as simple as for private ordinary business investment decisions. Choosing a relevant *time horizon* from the perspective of local people is another important consideration in CBA application.

CBA models may be applied either as a financial CBA or as an economic CBA. The two models are closely related and their technical structures are very similar. The fundamental differences between the two are from the *perspective* in which the analysis is carried out and from the valuation of the goods and services. In financial CBA, the analysis is undertaken from a private point of view and market prices that individuals face are used to value goods and services. Market distortions or imperfections, externalities, and government interventions are not adjusted. On the other hand, economic CBA is always from the perspective of society and shadow prices are used in valuing goods and services. Any market distortions or imperfections and government interventions are adjusted to better reflect the worth of goods or services from the societal point of view. It is only when under perfect markets and no government intervention, which is hardly observed in real world economy (particularly in developing countries) that the two CBAs end up with the identical results.

In this study we are carrying out an economic CBA, as we take the perspective of the local people (society). Therefore, in the rest of the chapter, unless otherwise explicitly stated, CBA refers to economic CBA.

4.3 An overview of the on-site and off-site SWC effects of exclosures

Exclosures provide essential functions in terms of trapping incoming sediments and increasing water infiltration. They accelerate fertile soil build up and prevent important sediment loads leaving the catchment or silting downstream water reservoirs. Descheemaker et al. (2006) asserted that under the influence of vegetation and sediment deposition dark soils rich in organic matter develop on-site in the exclosures of the Tigray highlands. More generally, the soil and water conservation (SWC) effects of exclosures may be described by classifying the effects into three categories on the basis of the locations where the actual or potential effects may occur.

i) on-site effects: the exclosures itself

Exclosures improve the hydrology and soil inside the forested land in several ways: they prevent physical soil loss, maintain or increase soil water holding capacity, protect or increase top soil depth, prevent the loss of soil nutrient content and increase soil organic matter. These functions of exclosures improve soil quality (productivity) within the forested land itself. An increase in soil quality within exclosures has a number of biophysical and socioeconomic implications. As a result of improved soil quality and soil water content the total amount of biomass production will increase with its subsequent ecological and economic benefits. Biomass production within the forested area and its economic value is one of the important on-site economic benefits of exclosures dealt in CBA.

ii) off-site effects: nearby/adjacent land use types

By improving the hydrology of a catchment, besides the forested land, exclosures also have effects on land adjacent to them. The reduction in surface runoff may decrease in the smothering of crops by sediments or reduce washing of the crop field by floods. Some insects and wild bees residing in exclosures may increase the pollination of crops. Of course, there may be some possibilities that exclosures may contribute negatively to the nearby land use types, such as harbouring rodents and pests that can damage crops and increased pressure on the remaining pasture. But from the practical point of view exclosures can be considered as effective means of soil and water conservation measure (Descheemaeker, 2006) and some negative side effects are less important in the study area and hence we do not consider these effects in the CBA.

iii) off-site effects: downstream locations

By stabilizing the hydrological processes and regulating total water runoff and flooding, vegetation cover controls and/or reduces soil erosion and the problems of downstream sedimentation and siltation (Clark, 1996; Pattayanak and Mercer, 1996; Kramer et al., 1997; Pattanayak, 2001, 2004). Besides its negative effects to the source area, erosion also has downstream off-site effects. The eroded sediments can be deposited in reservoirs and reduce hydroelectricity generation and water supplies for irrigation. The sediment can also reduce the operational efficiency of irrigation systems and impair the quality of drinking water. Because of their sediment trapping capacity, exclosures can prevent sediment loads from leaving the catchment and silting up water reservoirs. Vegetation restoration in exclosures also acts as a ‘sink’ area where the incoming water infiltrates and/or deeply percolates beyond the root zones and contributes to the ground water recharge and induces new springs. The new water sources can be used, among other things, for irrigation. Reservoir sedimentation protection and new springs development are the major downstream benefits of exclosures in the study area.

Below, we list down the major possible environmental benefits (+) and damages (-) of exclosures in each of the three locations/sites.

1) On- site: on forested exclosure area itself

- increase in soil fertility (+)
- increase in soil nutrient content (+)
- increase in soil moisture content (+)
- increase in depth of top soil (+)
- increase in soil organic matter content (+)

- increase in rain water infiltration (decrease in run-off) (+)
- increase in soil fauna populations involved in nutrient recycling & soil aeration (+)
- increase in wild life (+)
- effect on biodiversity (+)

2) Off-site: in nearby/ adjacent land use types

- clear-water effect, clear water has more erosive power (-)
- soil nutrient deficiency if the upland exclosures traps the fertile sediment (-)
- increase soil moisture if infiltrated ground water flows to the crop land (+)
- pollination of crops increases
- harbour rodents, pests & other wild life that damage crops (-)
- decrease in flooding (+)
- decrease in the smothering of crops by sediments (+)
- loss of crop area (-)
- less grazing land (-)

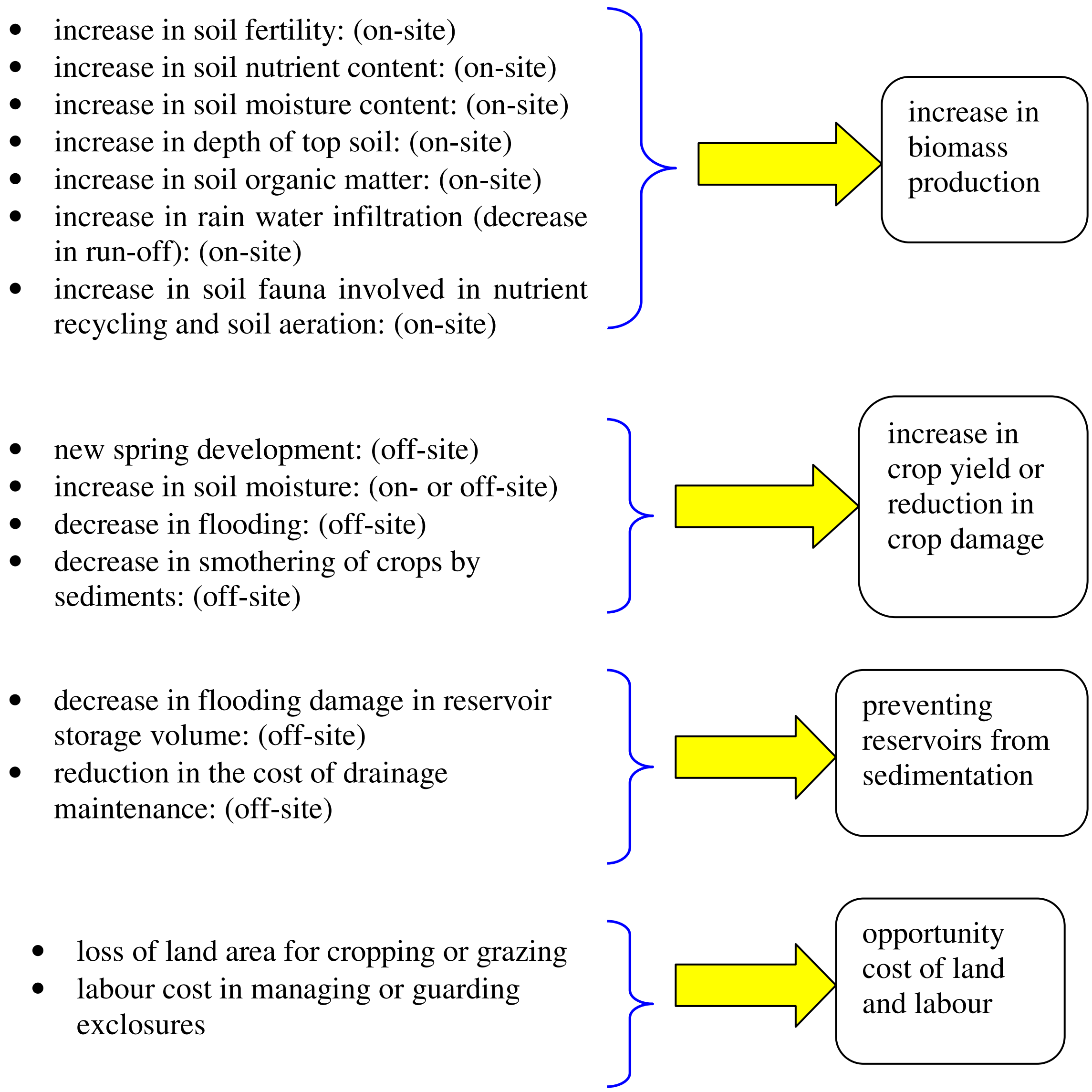
3) Off-site (downstream) effects

- decreased damage in reservoirs storage volume and more water supplies(+)
- increase in the probability of new spring up-coming (+)
- decrease in salinisation effect (+)
- decrease in provision of fertile sediments that increase yields downstream (-)
- decrease in provision of sand for use as a building material (-)
- reduction in the cost of drainage maintenance(+)
- decrease in run-off inflow into reservoirs (-)

In addition to the effects presented above the following general externalities of exclosures are also identified:

- dust trapping, positive effect on community health (+)
- carbon sequestration (+)
- climate regulation (+)
- drought mitigation effect (+)

- increasing pressure on the remaining pastures, which may lead to severe land degradation in other sites (-)



- increase in soil fertility: (on-site)
- increase in soil nutrient content: (on-site)
- increase in soil moisture content: (on-site)
- increase in depth of top soil: (on-site)
- increase in soil organic matter: (on-site)
- increase in rain water infiltration (decrease in run-off): (on-site)
- increase in soil fauna involved in nutrient recycling and soil aeration: (on-site)

- new spring development: (off-site)
- increase in soil moisture: (on- or off-site)
- decrease in flooding: (off-site)
- decrease in smothering of crops by sediments: (off-site)

- decrease in flooding damage in reservoir storage volume: (off-site)
- reduction in the cost of drainage maintenance: (off-site)

- loss of land area for cropping or grazing
- labour cost in managing or guarding exclosures

Figure 4.1 The soil and water conservation effects of exclosures

However, in the CBA we focus on on-site and off-site effects identified in the three locations, not on the general externalities as these are not as important as the former.

In order to facilitate the quantification and valuation and to show the results of combined effects, we grouped the important items listed above in figure 4.1.

4.4 Materials and methods

4.4.1 Methods of valuation

As discussed in section 4.3, exclosures regulate soil nutrients and soil hydrology both on-site and off-site. Depending on the problem at hand and the availability of data various valuation techniques can be applied. In this study we will use direct market prices for some cost and benefit items and the variants of indirect techniques (replacement cost approach, productivity change approach, and damage cost avoided approach) for some other cost and benefit items. The three indirect methods are briefly described below.

Replacement cost methods

The logic behind this method is to calculate the cost of a particular damage under consideration and to put the value on it using the equivalent cost of replacing. For instance, if we are estimating the on-site effect of soil erosion on farmland, we need to calculate the loss of soil nutrients due to erosion and put the value on it using the equivalent cost of commercial (artificial) fertilizer pursuing the following steps: a) estimating the mean soil loss per hectare (erosion rate) for sample areas; b) estimating the associated nutrients loss; c) valuing the nutrient loss per hectare (mainly loss of major nutrients i.e. nitrogen, phosphorus, and potassium) by taking the cost of commercial fertilizer replacement; and d) scaling up (extrapolating) to district/regional/national levels by estimating the area subject to erosion.

Productivity change methods

In this approach a particular damage is estimated by the value of the lost production valued in market prices. For instance, if our objective is to estimate the on-site economic value of crop output lost due to soil erosion we rely on estimates of the physical measurement of crop yields with and without soil erosion. The changes in crop yields are then multiplied by the unit price of the crops (Enters, 1998) to arrive at the effect of erosion on crop productivity.

Damage cost avoided approach

This is an approach which relies on the assumption that the costs of avoided damage are a measure of value resulting from the ecosystem services. The damage cost avoided method uses either the value of property protected, or the cost of actions taken to avoid damages, as a measure of the benefits provided by an ecosystem. For example, if a forest protects adjacent farmland from flooding, the flood protection benefits may be estimated by the damages avoided if the flooding does not occur or by the expenditures farm owners make to protect their field from flooding.

4.4.2 The data

The data used in this chapter are obtained mainly from various previous studies, expert estimates, and partly from the household survey of 2005 (described in chapter 2 & 3). Reservoir sedimentation and sediment yield data are mainly based on Haregeweyn et al. (2006). Data on construction costs of reservoirs are obtained from the project document of Sustainable Agriculture and Environmental Rehabilitation in Tigray (SAERT, 1994). Data on sediment trapping efficiency of exclosures are based on Descheemaeker et al. (2006). Estimation of potential new spring development is based on Descheemaeker (2006). Water productivity and incremental yield is based on Behailu et al. (2007). Biomass production data is adapted from various sources: Jaggar and Pender (2003), Mesfin Tilahun et al. (2007), Roebben (2004), Cleemput (2003), TFAP (1996), Newcombe (1987) and Wolde Mekuria et al. (2007). Expert estimates and personal communication with key resource persons on soil, hydrology, and forestry issues (Ermias Aynekulu, Emiru Birhane, Aklilu Nigussie, Mesfin Tilahun, Nigussie Haregeweyn, Wolde Mekuria, Katrien Descheemaeker, Bart Muys, Jean Poesen, and Jan Nyssen) complemented and enriched the data set. Local market prices for biomass products and crops are obtained from the 2005 household survey. Age and size distribution of exclosures is obtained from the district office of the Relief Society of Tigray (REST).

Some key quantitative estimates for selected variables adapted from various sources are presented in appendix 4.1.

4.4.3 Quantification and valuation of benefits and costs

The most essential tasks undertaken in any CBA are identification, quantification, and valuation of the streams of benefits and costs of the object of the study under consideration (be it investment project or policy alternative). It is also a common practice that analysts make some simplifying assumptions in order to make these tasks manageable. Particularly, valuing the benefits and costs of environmental projects becomes more complex and challenging than ordinary investment projects. In our case, we take the cost and benefit items identified in figure 4.1 (the items in the boxes at the right ends) and generally adopt an anthropocentric approach of value as practiced in mainstream economics. The cost and benefit items included in our analysis and the approaches used to quantify and value them are discussed below.

4.4.3.1 Benefit items

The four broad benefit items considered as the exclosures' SWC effects in the cost benefit analysis of this chapter are: biomass production, reservoir sedimentation protection, irrigation potential of new springs, and protecting crop field from flood damage.

1. Biomass production

As identified in fig. 4.1, changes in soil nutrients and hydrology induce the production of more biomass (both woody and herbaceous).

- **Woody biomass**: Based on review of available literature, observations and expert opinion (refer to section 4.4.2), the estimation of the potential level of sustainable woody biomass harvest from exclosures is based on the available biomass data from various previous works and expert estimates (EFAP, 1993; TFAP, 1996; Eshete, 1999; Jaggar and Pender, 2003; Wolde mekuria et al., 2007; and personal communication with Ermias, Emiru, Aklilu, Mesfin, Wolde, Descheemaeker, Muys. On the basis of this information the following set of rules or assumptions were made:

- Woody biomass harvest (production) is zero up to 5 years after establishment of the exclosures. The first five years are supposed to be a regeneration period and people have to wait for five consecutive years to start the first harvest.
- In the sixth year the mean annual increase (MAI) allows a sustainable harvest of 0.733 ton per hectare[41] (TFAP, 1996). In response to the accumulation of more nutrients and increasing water infiltration over time within exclosures, obviously the rate of plant growth increases each successive year till it reaches some maximum MAI. Based on available data we suppose that from year six onwards the MAI increases at a rate of 10% every year till it reaches the maximum possible annual sustainable harvest of 1.2 ton/ha in year 11 and thereafter the MAI will remain constant[42] at 1.2 ton/ha.
- To allow increase in the stock of the resource system in successive years, we need not harvest all the annual increment in which case the stock level remains constant. Thus, we assume that out of the annual incremental woody biomass, 2/3 is harvested for human use and 1/3 is left for ‘nature’ to allow the stock to increase. Accordingly, the volume of annual harvest of woody biomass will be 0.49, 0.54, 0.60, 0.66, and 0.72 tons per hectare in years 6, 7, 8, 9, and 10 respectively. In year 11 and onwards the volume of annual harvest will remain at 0.804 ton/ha.
- After year 10, exclosures are capable of regenerating the amount equal to or more than 1.2 ton/ha/year, so that the stock of the resource system increases and harvest becomes sustainable[43].

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[41] This figure is according to the estimate of Tigary Forestry Action Program (TFAP, 1996) for woodland.

[42] Ethiopian Forestry Action programme (EFAP, 1993; cited in Jaggar and Pender, 2003) has estimated an MAI of 1.2 ton/ha per annum for natural woodland in Ethiopia. See also TFAP (1996, p. 45). In this document the average mean annual incremental per hectare for natural forests, woodlands, bushlands, and shrublands is approximately estimated at 1.12 m^3/ha/year. Wolde Mekuria et al. (2007, p. 279) have estimated MAI for biomass in exclosures ranging from 0.70 – 1.05 ton/ha/yr.

[43] In principle forest harvesting is said to be sustainable if the volume of wood harvested in a given period is equal to or less than the increment yield that the forest system is capable of regenerating. In the case of

- The MAI woody biomass harvested is utilized as fuelwood (i.e., valuation is based on use of woody biomass as a fuelwood). This is a realistic assumption in the context of Ethiopia, particularly in Tigray where 95% of total demand for wood and woody biomass in rural areas is for fuelwood (Eshete, 1999; Jagger and Pender, 2003). Even higher estimates are documented in some studies. For instance, TFAP (1996, p.48) estimated that out of the total demand of 4,402,439 m^3 for wood products in Tigray, 4,313,700 m^3 (i.e., about 98%) is accounted by fuelwood demand.
- In practice, households face institutional barriers to harvest products from exclosures. However, in our analysis we assume that no exogenous factors hinder the sustainable level of harvest. Therefore, our estimate reflects the potential benefit, because the actual harvest may be constrained by institutional barriers.
- As woody biomass is a readily marketable product in the study area, we used the farm-gate price of fuelwood to value woody biomass products.

Therefore: $VW_{yha} = SWH_{yha} \times P_{mwt}$ (4.1)

where VW_{yha} = value of woody biomass per year per hectare of exclosure; SWH_{yha} = sustainable woody biomass harvest per year per hectare; and P_{mwt} = market price of woody biomass per ton.

- **Grass biomass**: On the basis of herbaceous biomass estimation study conducted in exclosures of various ages in the study area or elsewhere in Tigray (Mesfin Tilahun et al., 2007; Descheemaeker (pers. comm.); Cleemput, 2003), the estimates and trends of herbaceous biomass production are derived.

  - At the end of first year 1.11t/ha

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exclosures, since we need the stock of forests to increase over time (till it reaches some desired level of stock) all the incremental yields (MAI) should not be harvested.

- Up to the fifth year 40% annual increment is assumed till it reaches the highest value in year 5. Therefore, grass production becomes 1.54t/ha; 1.99t/ha; 2.44t/ha; and 2.85t/ha in the 2nd, 3rd, 4th, and 5th years respectively.
- After year five, as tree canopy increases herbaceous species are being dominated by woody species and hence grass production decreases in year six and after wards. It is supposed that a 20% annual reduction till it reaches a sustainable harvest level of 1.01 ton/ha/yr in year 10. From year 10 onwards the 1.01 ton/ha/yr amount of grass is constantly harvested (Descheemaker (pers. com.); Muys (pers.com.)).
- Some specific tree management schemes such as pruning or thinning are supposed to be practiced I order to allow a sustainable annual harvest such that grass production will not be zero as exclosures get older.
- The local market price is used to value herbaceous products harvested from exclosures.

2. *Prevention of reservoir sedimentation*

Seasonal runoff water harvesting via earth dams and ponds has been widely practiced in Tigray for the development of small and medium scale irrigated agriculture which is considered to be an important component of a long-term food security strategy. One of the major obstacles is sediment deposition in the reservoirs that reduces the water storage capacity of reservoirs and shortens their life span (Haregeweyn et al., 2006). By trapping the incoming sediments and stabilizing soil particles within the closed area itself, vegetation cover in exclosures counteracts the problem of reservoir sedimentation. This protective service has an important economic value in terms of avoiding the periodic maintenance cost or maintaining the life of the reservoirs for profitable economic activities. Therefore, preventing sedimentation of reservoirs is one of the important benefit items.

The maximum potential benefit occurs if exclosures of sufficient size and vegetation cover are assumed to exist in appropriate locations and distance (nearby to the reservoirs), such that all the incoming sediments can be trapped. In such a scenario the problem of sedimentation can be fully resolved. On the other hand, one can formulate an inverse relationship between distance and the effect of exclosures in protecting reservoir sedimentation i.e. the larger the distance between exclosures and reservoirs the less the effect of exclosures in protecting reservoir sedimentation.

Depending on the actual use of reservoirs in the study areas and the availability of data, we employed *the replacement cost (RC)* valuation approach. Since most of the reservoirs have either lost water storage capacity by risk of sedimentation or water shortages due to excessive seepage or insufficient inflow (Haregeweyn et al., 2006), they are mainly used for small scale irrigation, domestic water supply, and drinking water for animals. Data were not available on the economic effects of such small scale uses at household level. Besides lack of data it is also technically difficult to estimate the net indirect effect of exclosures on these uses. Therefore, we rely on the replacement cost approach i.e. how much does it cost had we removed all the silted sediments from reservoirs if the sediment flows have not been regulated by vegetation restoration in exclosures. Consequently, the cost of replacing the storage capacity of reservoirs that would have been incurred can be considered as the economic value of sediment reduction in reservoirs. This is actually a variant of the *replacement cost approach* in which we infer value from the annual cost that would have been spent on maintaining the storage capacity of reservoirs. In other words, we value the erosion protection services of a forest by measuring the cost of removing eroded sediment from downstream reservoirs.

To estimate the per hectare economic value of an exclosure's service in preventing reservoir sedimentation, we utilize the information provided in appendix 4.1 and pursue the following procedure. Assuming that all the sediments are trapped by exclosures:

- Divide the average digging cost of a typical reservoir (ETB 1.75 million) by the total storage volume of an average reservoir ($0.828\text{x}10^6$ m^3) (see appendix 4.1). This gives us about ETB 2.12 m^{-3} as the unit digging cost (CC_{unit}) for a cubic meter (m^3) volume of reservoir.

- Convert the weighted average mass of sediment deposited in a hectare of exclosure (48.6 ton $ha^{-1}yr^{-1}$) to volume using the average bulk density (1.24 ton m^{-3}) (Deschemaeker, 2006). This computation gives us 39 m^3 as the volume of sediments trapped in a hectare of exclosure in a year ($Sedd_{vol.}$)
- Multiplying the per cubic meter volume digging cost (assuming that removing or dredging the silted sediments would cost equivalent amount of money to the initial excavation cost) by the volume of sediments trapped in a hectare of exclosure, we would find about ETB 83 as estimate of the annual per hectare value of an exclosure with respect to reservoir protection. Therefore:

$$V_{\Pr ot.Sed} = CC_{unit} \times Sedd_{vol.} \tag{4.2}$$

where $V_{\Pr ot.Sed}$ is the reservoir sedimentation protection service of a hectare of exclosure per annum.

The above value estimate is based on the assumption that all the sediments that would enter the reservoirs were trapped by exclosures. However, in situations where exclosures are not located in appropriate sites, they can not trap all the incoming sediments. There are cases where some exclosures are located far away from the reservoirs and traps only part of the sediments. For an average situation, equation (4.2) may be used by deflating by a factor ranging from 0.3 to 0.5.

3) Reduction in flood damage of crop land

In this case, we would like to estimate the economic value of the probable damages to croplands if exclosures were not established in the hilly upland adjacent areas. To estimate the value of the function of exclosures in protecting flood damage via reducing the surface runoff, consider the following situation. Anecdotal evidence from the study area shows that out of the total area of exclosures in the *woreda* (11,924 ha), more than half of the exclosures are located above farm lands (own field observation and Descheemaeker, pers. comm.). Suppose that 60% of the total available exclosures (about

7,154 ha) are located above the farm field and protect crops from flooding. Taking a 50 ha average exclosure, we will have about 143 exclosures with a size of 50 ha (500,000 m^2) each subject to providing the flood protection function to crop land. Exclosures in the study district are usually following the contour lines over long distances with about 100 to 150m width. This implies that each exclosure has a length of 3.33 to 5 km. This would result in a total length from 477 to 715 km. Now, suppose further that in the absence of exclosures, the adjacent crop fields up to 100 m wide are damaged by flooding and smothering of crops by sediments. On the basis of this estimate the 7,154 ha exclosure areas would protect about 477 ha to 715 ha of farmland from flooding and crop smothering damage annually. This implies that provided the width condition is satisfied, a kilo meter length of vegetation cover in an exclosure protects one hectare of crop land in down slope area from flood damage. Taking the average of the two areas of protected crop field (596 ha), the per hectare flood protection value of exclosures can be estimated by multiplying the estimated crop value of ETB 689 ha^{-1} by the crop field protected (i.e. 596 ha), and then dividing the product by the total area of exclosures subject this service (i.e. 7,154 ha). However, all the farm fields are not equally susceptible to flood damage. We assume that in the first 50 m, all crops are exposed to flood damage and in the next 50 m about 50% of the crop is damaged. Then, it can be shown that had exclosures not been established crop output of ETB 43 $ha^{-1}yr^{-1}$ worth would have been lost by flood damage in the study area.

Note that some authors (e.g., Gibson, 1983) argue that increased runoff may benefit downstream farmers by transporting fertile sediments to the cropland. However, taking into account the torrential nature of rainfall and the hilly slope of the study area, we do not consider runoff as a beneficial hydrological process to local farmers.

4) New spring development and its irrigation potential

Another important function of vegetation restoration in exclosures is acting as a ‘sink’ area for incoming water inputs (both rain water and runoff coming from source areas and entering the sink area as run-on). Using the BUDGET soil water balance model developed by Raes et al. (2000), Descheemaeker (2006) investigated the hydrological processes in exclosures and the effect of vegetation restoration on the components of the soil water balance. Vegetation restoration in exclosures induces increased infiltration of incoming water. On the one hand, availability of more water increases biomass production in exclosures with consequently higher evapotranspiration. On the other hand, part of the infiltrated water that remains in excess supply (not utilized by plants) percolates deeply beyond the root zone and contributes to ground water recharge and induces new springs. Local communities use the newly originated water sources for productive economic activities, mainly irrigating high value cash crops which in turn contribute in improving local livelihoods. In this regard, a practical example in the study area is the May-zeg-zeg watershed project. Influenced by exclosures and other soil and water conservation structures at the May-zeg-zeg watershed project area, new springs originated and the surrounding community is irrigating local cash crops such as onion and garlic.Thus, the development of new springs induced by exclosures and their contribution to crop yield increment is considered as one component of the benefit item in the CBA of this study. To estimate the monetary value of this particular ecosystem service of exclosures we pursue the following steps.

i. Estimation of the amount of water production from a unit area of exclosure

This calculation is based on the field measurement and simulation analyses of Descheemaeker (2006). With the help of simulation analysis for different scenarios of land use types (with & without run-on) and rainfall situations, Descheemaeker (2006) has critically examined the effect of vegetation restoration on water balance components in the Tigray highlands. Some adjustments are introduced to estimate the volume of water produced from a hectare of exclosure and readily available for irrigation.

It is assumed that in an exclosure of 1 ha (say with length of 100m and width of 100m), the upper 20m (i.e. 0.2ha) receives extra water in the form of run-on and the remaining 0.8ha does not receive run-on. Taking the scenario of old exclosure with normal shrub cover and a year with average rainfall, Descheemaeker (2006) has found that 31% and 13% of the rain percolates out of the root zone in areas with and without run-on respectively. On the basis of this result and using the average annual rainfall of 700 mm, the volume of deeply percolated water per ha of exclosure can be computed as follows:

a) with run-on: DP (m^3) = 20m x 100m x 0.7m x 0.31 = 434 m^3

b) without run-on: DP (m^3) = 80m x 100m x 0.7m x 0.13 = 728 m^3

c) total: TDP (m^3) = 1162 m^3ha^{-1}

This means that 1162 m^3 of water percolates out of the root zone in a hectare of exclosure area. It is assumed that sooner or later all of this water will reappear as surface water somewhere downstream. However, it would be highly exaggerated to consider that all this water will be actually available for irrigation. By intuition it is only part of this water that would contribute to the development of new irrigation schemes, though we lack data on an actual amount of such water. Some water sources may be too small or in inaccessible areas or used for other purposes. As a rule of thumb, we assume that about 50% (581 m^3ha^{-1}) of the water may contribute to the development of new irrigation schemes. Call this adjusting factor F_1.

Another adjustment is related to transmission losses of water between the spring and the field due to evaporation and infiltration. Again, we do not have data on the amount of transmission loss. But, for traditional irrigation in Tigray experts suggest that the transmission loss is about 50 % (Jan Nyssen, pers. comm.). Call this adjusting factor F_2. By definition, the use factor will be $1 - F_2$.

Using the adjusting factors in equation (4.1) we estimate the volume of water ($vol.$) produced from a hectare of exclosure area (about 291m^3ha^{-1}).

$$vol. = TDP(m^3) \times F_1 \times (1 - F_2) = 291\, m^3 ha^{-1} \qquad (4.1)$$

ii. Estimation of water productivity (kg of crop yield per m^3 of water applied) and incremental yield

Water is an essential input in agriculture. In arid and semi-arid areas, such as Tigray, agricultural productivity is seriously hampered by moisture stress. In this regard, the new springs originated by the influence of vegetation restoration in exclosures could be utilized for productive agricultural activities. Based on previous studies on irrigation water productivity in Tigray, we estimate the incremental (potential) yield per unit of water applied. Our estimate of the incremental yield is based on the experimental study of irrigation productivity by Behailu et al. (2007) in Tigray. Using maize[44] as an indicator crop and data from two irrigation seasons, the average water productivity was estimated at 0.62 kg m^{-3}. According to the Agricultural Office of *Douga* Tembien district, in 2004/05 cropping season the average yield of maize in rain-fed agriculture was 2.25 ton ha^{-1}. From the traditional irrigation experimental sites on maize productivity in Tigray, Behailu et al (2007, p.38) obtained an average yield of 4.45 ton ha^{-1} (almost twice the yield in rain-fed agriculture). Thus, it can be considered that 50% of the yield in irrigated agriculture is due to the irrigation water. In other words the gross incremental yield (GIY) will be about 0.31 kg m^{-3}.

iii. estimation of the value of incremental crop output

The value of GIY is simply obtained by multiplying the GIY by the market price (P) of the product. To find the net value of IY we need information on the cost of production. For our purpose the relevant cost component is the variable cost (VC). Behailu et al. (2007) determined that about 28% of the gross product value is accounted by the variable production cost and $1-VC$ will be the percentage of net incremental product. Taking the market price of maize (ETB 200 per quintal or ETB 2 kg^{-1}) in the study area, the net incremental value (NIV) per m^3 of water is about ETB 0.45 and is obtained using equation 4.2.

$$NIV = GIY \times P \times (1-VC) \tag{4.2}$$

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[44] In many instances small scale irrigation is practiced for the production of high value cash crop, such as vegetables and fruits. However, water productivity data for such crops are not available. As maize is one of the common crops in the study area and also the productivity data are available, we used maize as an indicator crop.

iv. estimation of the incremental value for the adjusted total volume of water produced per ha of exclosure

This is simply the product of equation (4.1) and (4.2)

$$NV_{NS} = NIV \times vol. = [GIY \times P \times (1 - VC)] \times [TDP \times F_1 \times (1 - F_2)] \qquad (4.3)$$

where NV_{NS} = the net value of incremental output attributable to the new spring water, and the other notations are as defined for equation (4.1) and (4.2).

Using equation 4.3 the estimated value of net incremental output is: $NV_{NS} = ETB\,130 / yr$ from the irrigable volume of water produced from a hectare of exclosure in a year. Note that the effect of exclosures on deep percolation is not the same for young and old exclosures. The computation undertaken so far is for old exclosures with normal shrub cover. Following the steps (i) through (iv), we need to perform similar value estimates for young and medium-aged exclosures.

Table 4.1 Deep percolation of water in different ages of exclosures *

Exclosure category (land use type)	amount of deep percolation (ha^{-1}m^{-3}) With run-on	 without run-on	 total	NV_{NS} *(in ETB)*
Degraded grazing land$^{(a)}$	28	112	140	16
Young (<=5)$^{(b)}$	476	392	868	79
Medium-aged (5<age<=15)$^{(c)}$	504	728	1232	120
Old (age>15)$^{(d)}$	434	728	1162	114

* all the numbers in the table are calculated following steps (i) - (iv) and equations 4.1 - 4.3.

(a), (b), (c), (d): the deep percolation rates with and without run-on in the respective land use types are: (2%, 2%); (34%, 7%); (36%, 13%); and (31%, 13%) respectively and the mean annual rainfall of 700mm for a normal year is assumed in all the computations; (a) Descheemaeker (2006) has found that 2% of the rain water percolates in degraded grazing land in Tigray highlands.; (b), (c), and (d) are adjusted for the (2%, 2%) observed under (a). Note that in the original document old exclosures are further classified into two and different rates have been used. But, since there is no significant difference in final values for the two categories of old exclosures, we used the same rate for both.

Source: Calculated from the information in Descheemaeker (2006, p.275, figure 4.31)

4.4.3.2 Cost items

In general, the costs for a certain community forestry undertaking consists of the opportunity cost of land, material inputs cost (such as cost of seedlings and fencing), and labour costs. However, as forests in exclosures are supposed to regenerate naturally the costs related to material inputs are zero. As a result, two major cost items are considered in relation to the establishment of exclosures: the opportunity cost of land and labour cost[45].

1. *The opportunity cost of land*

If high potential land is taken out of their current use (say crop production) for forestry, land will be a significant cost for the forestry activity. Conversely, if non-productive marginal lands or wastelands with very few or no alternative uses are put aside for natural regeneration of trees society incur low or no opportunity costs for land. In our case, various available evidence indicate that the majority of exclosures in the study area are established in a hilly or steep degraded grazing land (TFAP, 1996; Descheemaeker et al., 2006; interview with local district office of Agriculture in Hagereselam and extension agents). Consequently, by treating those land units as waste lands one can reasonably assume zero value for the opportunity cost of land. But to be able to compare the costs and benefits of converting different land use types to forest land use type, we consider three cases concerning the opportunity cost of land:

- **Waste land**: Here we assume that land units converted to exclosures are waste lands (those lands with no alternative use), hence the opportunity cost of land is zero.
- **Semi-productive land**: In this case we assume that although the land is degraded it has still some potential to be utilized for some productive activities. We assume

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[45] Since exclosures are land areas left aside for natural regeneration of trees, labour cost for planting the seedling and labour inputs in the early years to take care of the transplanted seedlings are assumed to zero. We only conceive labour cost for regular guarding.

the opportunity cost of such land to be 1/3 of the estimated value of crop land in the district.

- **Productive crop land**: In this extreme case we want to see what would be the economic return if we were to convert productive crop land to exclosures. In this case the opportunity cost of a hectare of crop land will be the net crop revenue in the study area (as defined below (a) to (d)). This value is estimated to be ETB 698. From the 2005 household survey data administered in the area, we estimate the net value of crop from a hectare of crop land as follows[46]:
  a) Annual crop revenues per hectare = ETB 871 (including all the crop by-products)
  b) Average seed cost & fertilizer cost /ha/yr =ETB 144
  c) Oxen power /ha/yr = ETB 38
  d) Net crop income/ha/yr = ETB 689

In a CBA study for Eucalyptus plantation in the same study area, Jagger and Pender (2003) have used ETB 841/ha/yr as the opportunity cost of land for all land units with alternative uses. Their estimate was based on gross value of cropland per ha per year for all other alternative uses of land. They indicated that their value estimate may overestimate the true opportunity cost of land as it is a gross value, and not adjusted for less productive land. We believe that these problems are taken into account in our computations as our estimate is net crop value rather than gross value. We also provided alternative scenarios to capture the differences in productivity of land and the ensuing variation in opportunity costs.

2. *Labour cost*

The only labour cost we consider is the periodic payment for guards. We take the national minimum wage rate for unskilled labour as the opportunity cost of labour engaged in guarding activity. To determine the optimal number of guards to be deployed for effective guarding, we take into account the total size of land under exclosures in the

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[46] The value of labour input is not deducted in computing the net crop income (see chapter 2).

woreda. Recent land use data from the *Woreda* Bureau of Agriculture shows that the total size of exclosures in the *woreda* is about 11,924 ha. On average, an exclosure has a size of 50 ha. If we assume that one person can guard an average exclosure (50 ha), we need about 238 persons for guarding. Assuming that we pay ETB 200/month, the minimum monthly salary for unskilled labour in the Ethiopian public sector, the annual wage for labour guarding one exclosure will be ETB 2400. This means that for each hectare of an exclosure the social cost of labour will be ETB 48 per ha per year.

Harvesting and tree management (treatment) costs are not accounted in the opportunity cost of labour. This is because; on the one hand we can assume that some specific tree management, such as pruning and thinning to allow sustainable grass production, is undertaken in slack time where the opportunity cost of labour is zero. This is a common practice of rural labour time treatment for certain local undertakings in labour abundant countries of the developing world. On the other hand, we can argue that in the absence of exclosures search and collection costs of forest products are even higher than the case with exclosures. So, we do not value the labour time allotted for such activities.

Qualitative benefit or cost items

Quantifying and valuing some benefits or costs related to the establishment of exclosures have proved to be either difficult. Besides the soil and water conservation, forests in exclosures are beneficial in regulating microclimates, increasing biodiversity, carbon sequestration, hosting wildlife, and drought mitigation. Carbon sequestration, for instance, is an important environmental function of forests. But it is not included in the CBA analysis. Because: (1) the major concern of this chapter was on SWC effects rather than carbon issue, (2) due to low biomass production the volume carbon sequestrated seems to be low, and (3) exclosure as a project does not meet the '*additionality principle*' to qualify for world carbon market. They 'would have happened anyway' (i.e. government 'project' in Ethiopia). Regarding the local costs of establishing exclosures, they may harbour rodents, pests and other wild life that damage crops and livestock. Similarly increased pressure on the remaining pasture may cause severe land degradation in other sites. The exclusion of these items from the CBA may result in some variations in the estimated values of costs and benefits and their true values. However, we strongly believe that such omissions would not significantly affect our findings and the general conclusions.

4.4.4 Hypothesis and scenario setting

Standard economic logic tells us that, given the constraints, rational economic agents (be it an individual, household, firm, community, or a government unit) strive to put scarce economic resources in their best use to optimize their objective functions. In a society where agriculture plays the dominant role in securing livelihoods, land is the most important factor of production. Therefore, the decision to put a certain land unit to a particular use needs *ex ante* assessment of the benefits and opportunity costs forgone due to the stipulated land re-allocation. We consider some important economic parameters (mainly the opportunity cost of land and the discount rate) and how they influence the potential economic returns from exclosure land use type. We formulate the following hypothesis about the conditions for positive economic returns:

- *putting land with no or low opportunity costs into exclosures will yield positive and high economic returns.*
- *converting agricultural land to forested land in the form of exclosures will result in negative economic return for the local community*
- *a low discount rate and high biomass harvest will result in high return from exclosures even if the land converted to forested land has alternative uses.*

We distinguish three scenarios:

- **Scenario 1 (base scenario)**: This scenario assumes that the land converted to forested land use is waste land i.e. zero opportunity cost and 15% discount rate. Regarding the biomass production the estimates under section 4.4.3.1 for harvests of both woody and herbaceous products are used.

- **Scenario 2 (semi-productive land with positive opportunity cost is converted to exclosure)**: The base case scenario analysis assumes all exclosures are established on hilly degraded land not favourable for alternative productive uses (zero opportunity). But it may be the case that some of the land units converted to exclosures is cultivable (with certain productive potential) or good for grazing. Under scenario 2, we want to analyze the economic return of such semi-productive lands converted to forested land.

- **Scenario 3 (productive land is converted to exclosure but the biomass production is high)**: In this scenario we analyze whether converting crop land to forest land has positive economic returns or not. It is intuitive that a high level biomass production is expected if the forested land used to be crop land with good soil properties. Therefore, the basic question becomes whether more production of biomass could sufficiently compensate the opportunity cost of land so that conversion of crop land to exclosures be an economic choice. We assume the annual increment of woody biomass (MAI) increased from 1.2 ton/ha/yr to 2.0 ton/ha/yr, grass production remains at the base level because after a certain year of establishment of exclosures the influence of tree canopy on growth of herbaceous biomass is similar whether or not the land converted to forest cover was originally degraded or crop land.

4.4.5 Framework for decision-making

After the benefits and costs have been identified and valued, the analyst confronts choosing the decision criteria or rules to evaluate and compare the economic profitability of alternative projects. Various criteria exist to serve this purpose of which the common discounted measures are: net present value (NPV), internal rate of return (IRR), benefit-cost ration (B/C), and net benefit-investment ratio. For our analysis we choose NPV. Unlike other criteria such as B/C and IRR, NPV is a reliable criterion as it is not vulnerable to generate ambiguous results (Olschewski, 2006 cited in Mesfin Tilahun et al., 2007). NPV is defined as the difference between the sum total of the present value of discounted benefit streams and the discounted value of cost streams over the life of the project (equation 4.4).

$$NPV = \frac{\sum_{t=0}^{T} B_t}{(1+d)^t} - \frac{\sum_{t=0}^{T} C_t}{(1+d)^t} = \sum_{t=0}^{T}\left[(B_t - C_t)(1+d)^{-t}\right] \qquad 4.4)$$

where:

NPV = net present value (ETB/ha)
B_t =benefit at time ‘t’ (ETB/ha)
C_t = cost at time ‘t’ (ETB/ha)
d = the discount rate
t = time in years (t = 1, 2, …T)

Evaluating the worth of an investment project on the basis of NPV is straight forward. According to the NPV criterion projects with non-negative NPV are accepted and projects with negative NPV are rejected. It is also the preferred selection criterion to choose among mutually exclusive projects (Gittinger, 1982)

4.5 Empirical Implementation

Though establishing forestry projects such as exclosures could have wider regional and national economic and ecological impacts, in our empirical CBA we limit ourselves to analyze the local impacts of the project. Widening the boundary of inquiry requires an extensive and comprehensive data set that we are not endowed. We also restrict the scope of our empirical analysis to the local community whose day-to-day activities are highly linked to the direct utilization of forest and other environmental resources. The key economic parameters used in the empirical work are discussed below.

Discount rate

As described in section 4.2, in CBA all the future stream of benefits and costs are discounted to estimate the present worth of a project or policy alternative. The underlying logic behind discounting is that in the estimation of the worth of a project, future benefits and costs count for less than the present ones[47]. Therefore, one of the key economic parameters that need careful attention in CBA is the choice of a discount rate. As indicated in equation (4.4) decision criteria such as the NPV are highly susceptible to the chosen level of discount rate. In poor rural community settings with high degree of financial market imperfections the national level interest rate (for that matter the discount rate used in nationwide projects) usually does not reflect the true time preferences of local people. Local people's time preference may be conditioned by a number of factors. For example, poor people may prefer to have something today to having it some time in the future which implies poor household's high discount rate. Access to credit market is another example that influences people's discount rate. Credit constrained households' discount the future more than households with good access to credit. When the credit market functions reasonably well and is not constrained, people theoretically discount the future at the market interest rate. Fortunately, in the rural areas of Tigray (particularly in the study district) the local microfinance institute (DECSI) supplies credit at a rate much lower than the informal market rate (15% vs. 50% or more). So, for our CBA we apply a 15% discount rate and then we will examine the sensitivity of the results by allowing changes in this rate. Using the borrowing rate in the economic analysis of projects is commonly proposed in CBA (see Gittinger, 1982).

The period of analysis

The period of time that the economic analysis of the project is carried out is one of the parameters that the analyst chooses. There is no hard-and-fast rule in choosing the length of the project period. In capital investment projects the economic life of the project is often considered as a general rule to choose a time period. Unlike some commercial forestry projects for which the economic life can be determined from the estimated harvest periods, the economic life of our 'project' under investigation – closing a land area for natural regeneration of trees – is ambiguous. Consequently, the time period for the analysis is based on the influence of the discount rate on the economic significance of the future flow of benefits and costs. Due to discounting, future values become less and less important as the time period gets longer and longer. In practice the present worth of

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[47] The literature in rationale for discounting is rich (for example, see Gittinger, 1982; Jones et al., 2000)

future values beyond 30 years make no significant difference in the results of the analysis. For instance, at 15% discount rate, €1 thirty years from now has a present value of €0.015. At higher discount rates the present value will be much lower. Therefore, we chose 30 years for our CBA.

Value estimates

The value estimates of the cost and benefit items identified under section 4.4.3 and used in calculating the annual flow of benefits and costs for NPV analysis are presented in table 4.2. Later on some of the value estimates may be changed for sensitivity analysis.

Table 4.2 Value estimates of the benefit and cost items used in the calculations of NPV

Item	value estimate
Woody biomass (fuelwood)	ETB 300/ton
Herbaceous biomass (grass)	ETB 120/ton
Protection of reservoir sedimentation	ETB 83/ha/yr
Protection of crop field from flooding damage	ETB 43/ha/yr
New spring irrigation potential (young exclosure)	ETB 79/ha/yr
New spring irrigation potential (middle-aged exclosure)	ETB 120/ha/yr
New spring irrigation potential (old exclosure)	ETB 114/ha/yr
Opportunity cost of productive crop land	ETB 689/ha/yr
Opportunity cost of semi-productive land	ETB 230/ha/yr
Opportunity cost of wasteland	ETB 0/ha/yr
Cost of labour service in guarding	ETB 48/ha /yr

4.6 Results

4.6.1 Base case NPV estimates

The estimates of undiscounted net benefits (NB) and the net present values (NPV) for the base scenario, assuming different opportunity cost of land, are presented in table 4.3. Assuming a zero opportunity cost of land (i.e., highly degraded wasteland with meagre or no alternative uses), exclosures have positive annual net returns throughout the life of the project and the NPV is also positive (NPV=ETB 3,089/ha). As the opportunity cost of land is the major trade-off that society forgoes in establishing exclosures and other costs such as the payment for guards are insignificant, the positive NB and NPV are *a priori* expected and intuitive when the opportunity cost of land is assumed to be zero.

Table 4.3 NPV (ETB/ha) estimates for base case scenario (by annual benefit and cost flow, different opportunity costs of land, 15% discount rate)

$\text{Year}_{(t)}$	$\text{NB}^{(OCL=0)}_{(t)}$ (A)	$\text{NB}^{(OCLS)}_{(t}$ (B)	$\text{NB}^{(OCLP)}_{(t)}$ (C)	$\text{NPV}^{(A)}_{(t)}$ (D)	$\text{NPV}^{(B)}_{(t)}$ (E)	$\text{NPV}^{(C)}_{(t)}$ (F)
1	290.20	60.20	-398.80	252.47	52.37	-346.96
2	341.80	111.80	-347.20	258.40	84.52	-262.42
3	395.80	165.80	-293.20	260.44	109.10	-192.93
4	499.80	219.80	-239.20	258.29	125.73	-136.82
5	499.00	269.00	-190.00	248.00	133.69	-94.43
6	618.80	388.60	-70.40	267.24	167.88	-30.41
7	578.40	384.40	-110.69	217.48	130.10	-41.59
8	553.20	323.20	-135.80	180.90	105.69	-44.41
9	336.40	306.40	-152.60	152.34	87.02	-43.34
10	535.20	305.20	-153.80	132.19	75.38	-37.99
11-30[a]	*11,118*	*6,518*	*-2,662*	*862*	*506*	*-203*
Total[b]	**15,916**	**9,016**	**-4,754**	**3,089**	**1,579**	**-1,434**

'a': annual amount for years 11 through 30 inclusive. To reach column total, this amount must be included 20 times (the numbers in *'italic'* are the sums for the 20 years values); NPV= net present value; 'b': the sums are rounded to zero decimal place; 't'= the time period in years (t=1, 2,…30); OLC= opportunity cost of land; $\text{NB}^{(OCL=0)}_{(t)}$ = undiscounted net benefit when the opportunity cost of land is assumed to be zero (i.e. wasteland and the only cost item is the labour cost for guarding); $\text{NB}^{(OCLS)}_{(t)}$ =undiscounted net benefit when the opportunity cost of semi-productive land is considered; $\text{NB}^{(OCLP)}_{(t)}$ = undiscounted net benefit when the opportunity cost of a productive land is considered; $\text{NPV}^{(A)}_{(t)}$ =the NPV computed under (A); $\text{NPV}^{(B)}_{(t)}$ =the NPV computed under (B); $\text{NPV}^{(C)}_{(t)}$ = the NPV computed under (C)

An interesting issue that we seek to answer is the question whether benefits from exclosures compensate social costs when land units with positive opportunity cost are converted to forests so that the reallocation of land for forestry could be backed by economic justification. The results in table 4.3 (last two columns) throw light on this inquiry.

When partially degraded land (semi-productive land) is taken away from its current use for exclosures, though the net benefits are very low in the initial periods, the overall NPV is positive and large (NPV=ETB 1,579/ha). This result implies that society benefits more than it loses by reallocating semi-productive land to exclosures.

Table 4.4 NPV estimates [@] (ETB/ha) for base scenario (by benefit and cost items, 15% discount rate)

Benefit items	PVB
Woody biomass (on-site benefit: on forested area)	666
Grass (on-site benefit: on forested area)	1265
Crop field protection from flooding (off-site: adjacent areas)	282
Reservoir sedimentation protection (off-site: downstream effect)	545
New spring potential for irrigation (off-site: downstream effect)	646
Total	3404
Cost items	PVC
Labour cost	315
Opportunity cost of land	
Case 1: (OCL=0)	0
Case 2: (OCLS)	1510
Case 3: (OCLP)	4523
Total PVC (case: OCL=0)	315
Total PVC (case: OCLS)	1825
Total PVC (case: OCLP)	4838

NPV = sum of PVB – sum of PVC

Case 1: NPV = ETB 3,089

Case 2: NPV = ETB 1,579

Case 3: NPV = ETB -1,434

PVB= present value of benefits; PVC= present value of costs; NPV= net present value; OCL=0 means when the opportunity cost of land is considered as zero; OCLS = when a semi-productive land is converted to forest land use type; OCLP= when productive land is converted to forestry; [@] all values are rounded to the nearest ones.

Given the severity of shortages of forest products (especially high demand for fuelwood and grass for animal feed) in the study area, the result seems sound. But as the last column of table 4.3 indicates, putting productive crop land for forestry activity results in a negative net present value (NPV= ETB -1,434/ha). According to this finding, it is uneconomic to shift productive crop lands to forest land uses. Because, by doing so the trade-off is higher than the benefits stipulated.

Table 4.4 presents the discounted values of each benefit and cost item included in the analysis. The results give us some indication on the relative importance of the various items in the overall NPV. Comparing the relative share of on-site and off-site effects in total present value of benefits (PVB), 57% of the total PVB is accounted by on-site benefits and the remaining 43% by off-site benefits. Among the benefit items, the discounted value of grass products accounts for the largest share and woody biomass in the form of fuelwood occupies the second position. It is an observed fact, and studies also indicate, that fuelwood shortage is a serious problem in the study area (Newcombe, 1987; TFAP, 1996). Taking the fact of relative importance of fuelwood in the study area, one may cast doubt on the reliability of our result that gives more weight to grass products rather than woody biomass.

Two explanations could be provided for our findings. On the one hand, the existing local regulations do not readily allow the harvest of wood products from exclosures. Despite the existence of regulated access to exclosures for wood products in some communities (*kushets*) or by some section of the society or for some specific uses, in general there is a high degree of restriction on access to exclosures. Taking this access restriction and the slow natural regeneration of tree species into account, we formulated our problem by assuming zero woody biomass harvest at least in the initial periods i.e. till the trees get matured and access rules modified for sustainable wood harvest as more products are available in later stages. To allow the stock increment of the resource system over time, we further assumed that a certain proportion of the mean annual increment (MAI) of woody biomass is not harvested for human use (see section 4.4.3.1). For the harvest of grass products, however, there were no such restrictions. Periodic grass harvest is commonly practiced in the area. On the other hand, discounting makes distant future values less important in present terms. If we compare the undiscounted values, the total value of woody biomass per hectare of exclosure is larger than that of grass value. But in the discounted form the NPV of grass becomes larger than that of biomass from a hectare of exclosures. Our finding is consistent with some similar works in Tigray. For instance, in their CBA study of closing degraded *Boswellia Papyrifera* dryland forest in Tanqua Abergelle *woreda* of Tigray, Mesfin Tilahun et al. (2007) have found that in a closed site nearly 95% of the NPV is attributable to grass production whereas frankincense products accounted for only about 5% of the NPV. Their finding attaches much larger weight to the contribution of grass products in total NPV than ours (grass accounts about 37% of the total present value of benefits).

Besides the direct harvest of wood and grass products, vegetation restoration in exclosures exhibit important environmental services evidenced by the net present values estimated for new spring development and its potential for irrigation, reservoirs protection from sedimentation, and crop field protection from flooding damage. These ecological services respectively account for 18%, 16% and 8% of the total present value of SWC benefits of exclosures. As most studies focus on tangible benefits of forestry activities, our finding sheds an important light on the 'hidden' environmental values of vegetation in exclosures.

4.6.2 Sensitivity analysis

Usually the quantities and values of the benefit and/or cost items and the economic parameters used in the analysis may undergo changes over time. Such uncertainties of future circumstances affect the results of the CBA which were based under a certain set of assumptions. Therefore, it is not uncommon to rework the analysis to see what happens under the changed circumstances. Reworking the analysis to test the project's volatility to changes in one or more of the values or parameters of the project is known as sensitivity analysis.

Table 4.5 Effect of changes in various parameters on NPV (ETB/ha) of exclosures

Parameter	Change in parameter			
	+50%	+20%	-20%	-50%
	NPV_1	NPV_2	NPV_3	NPV_4
Waste land (OCL=0)				
(Base case & zero OCL, NPV=3089)				
Discount rate	2022	2534	3888	5620
Quantity of woody biomass	3422	3221	2955	2755
Price of woody biomass	3422	3221	2955	2755
Price of grass	3721	3342	2836	2456
Value estimates of all benefit items	4790	3770	2408	1386
Semi-productive land (OCL=ETB 230 ha^{-1}yr^{-1})				
(Base case & OCLS, NPV= 1579)				
Discount rate	979	1265	2035	3031
Quantity of woody biomass	1912	1712	1446	1246
Price of woody biomass	1912	11712	1446	1246
Price of grass	2211	1834	1326	946
Value estimates of all benefit items	3281	2260	898	-123
Productive land (OCL=ETB 689 ha^{-1}yr^{-1})				
(Base case & OCLP, NPV= -1,434)				
Discount rate	-1103	-1267	-1663	-2135
Quantity of woody biomass	-1102	-1301	-1566	-1767
Price of woody biomass	-1102	-1301	-1566	-1767
Price of grass	-802	-1181	-1687	-2067
Value estimates of all benefit items	267	-754	-2115	-3136

OCL= opportunity cost of land; OCLS= opportunity cost of semi-productive land; OCLP= opportunity cost of productive land; NPV_1,NPV_2, NPV_3, and NPV_4 are net present values when the parameter rises by 50%, rises by 20%, falls by 20%, and falls by 50% respectively.

In this study we consider three possible areas of change and investigate what happens to the results obtained in the base scenario when these changes were introduced to the analysis. Changes in the quantity or yield of the various benefit and cost items, changes in prices or values of the various cost and benefit items, and changes in discount rate were treated in the sensitivity analysis. Assuming high relative probability of change for some selected items, we introduced change in the following parameters: discount rate, quantity of woody biomass, price of woody biomass, price of grass and value estimates of all benefit items. Due to lack of historical records, we were not able to trace the empirical volatility of the parameters under consideration. Thus we assumed some possible changes, and the results are given in table 4.5.

Table 4.5 summarizes the impact of changes of some key parameters on NPV estimates with varying opportunity cost of land. As can be seen from table 4.5, changes in the opportunity cost of land and the social discount rate have strong influences on the NPV. Other things held constant and with zero opportunity cost for land, a 50% increase in social discount rate from the base case (i.e., from 15% to 22%) causes a 35% fall in NPV. On the other hand a decrease in discount rate by 50% (from 15% to 8%) increases the NPV by 82%, *ceteris paribus*. A shift from scenario 1 to scenario 2 (i.e., rather than highly degraded waste land if we assume that a semi-productive land is converted to forestry) results in a 49% fall in the NPV. The trade-off that society bears by converting productive cropland to forestry could not be compensated even with either high biomass production rates or high prices of biomass products or low social discount rates. The negative NPVs of the last five rows of table 4.5 demonstrate this fact. Irrespective of the possible changes introduced to the selected parameters the NPV remain negative throughout if the land reallocated for exclosures is productive cropland. Under this scenario an exceptional positive NPV is observed if we assume simultaneous raise in all benefit items by 50% and keeping everything else constant. However, such a scenario seems very rare and hence does not affect our generalization.

The NPV is more sensitive to changes in price of grass than the equivalent change in the price or quantity of woody biomass. For instance, an increase in the price of grass products by 50% increases the NPV by about 20% but an equivalent rise in price of woody biomass increases NPV by 12%. As explained in section 4.6.1, this could be attributable to differences in access restriction and starting time of harvesting between the two biomass products. If the values of all benefit items change NPV becomes highly sensitive. For instance, though the NPV remain positive, a fall in the value estimates of all benefit items by 50% decreases NPV by 55% if the land converted to forestry is degraded range area. However, the same percentage fall in value estimates of all benefits will result in a negative net present value (NPV= ETB -123) if a semi-productive land is converted to an exclosure.

We have also tested the sensitivity of NPV per hectare of exclosures for changes in labour cost for guarding, sedimentation, and flood protection values. But we found that changes in these parameters showed very little effect on NPV and hence they are not reported in table 4.5.

4.7 Scaling up/aggregating the result

Scaling up the estimated NPV of a hectare of exclosure to the total land area put under exclosures in the study district enables us to visualize the value of SWC effects at the district level. Three important factors have to be considered to such an aggregation:

1) **Land use type before its conversion to forestry**: As shown in the preceding sections, the productivity of the land converted to forestry activity in alternative economic activities is a critical element in NPV computation. In this regard we follow the three scenarios distinguished in section 4.4.4. (i.e., highly degraded or waste land, semi-productive land, and productive crop land). Though we do not have data on the actual proportion of land reallocated for forestry from each land category, the following cases are proposed in order to obtain a range of scaled up NPV value. Out of the total area of land reallocated for exclosures:
    Case 1: 10% crop land, 75% semi-productive land, and 15% waste land
    Case 2: 0 % crop land, 40% semi productive land, and 60% waste land

2) **Spatial distribution of exclosures**: Some benefit items are not applicable to some of the closed areas in the district. The exact location and distance relative to

some other economic undertakings determine the importance of an exclosure with regard to some specific environmental services. For instance, an exclosure protects crop land from flood damage if it is located in adjacent upslope area at a certain reasonable distance relative to the crop land. Similarly, the larger the distance between an exclosure and a reservoir, the less its effect on protecting the reservoir sedimentation. From our discussions in section 4.4.3.1 and results of table 4.4: three benefit items (woody biomass, grass biomass, and new spring's irrigation potential) are applicable for all closed areas; 60% of the exclosures (7154 ha) protect crop field from flood damage, and 30% (i.e., 3577 ha) is subject to reservoir sedimentation protection service[48]. On the basis of their shares in the total present value of benefits, 76%, 16%, and 8% are respectively accounted by the 'three benefit items' together, sedimentation protection, and flood protection services.

3) **Temporal aspect of exclosures**: In additional to spatial issue, temporal variations (ages of exclosures) also influence the SWC effects of exclosures. It is obvious that recent establishments and areas closed for decades do not have the same effect. However, the temporal aspect has already been taken into account while quantifying and valuing the various benefit items under section 4.4.3.1. So, we do not introduce any temporal adjustment while aggregating.

Taking the adjustments in (1) and (2) above into account and the NPV obtained for the three scenarios from table 4.3 (i.e., ETB 3089, ETB 1579, and ETB –1434 if waste land, semi-productive, and productive crop land respectively are converted to forested land), we can compute the aggregate net present value for all closed areas in the district using the following formula:

$$NPV_{agg.} = \sum_{i} \sum_{p} L_p NPV_p \times A_i \times R_i \qquad (4.5)$$

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[48] Note that the percentages do not add up to 100%, because the services or benefit items from a given closed area are not mutually exclusive.

where $NPV_{agg.} =$ the aggregated net present value for all closed areas

$L_p =$ the proportion of different qualities of land converted to exclosures

$NPV_p =$ the net present value obtained corresponding to each land quality

$A_i =$ exclosure area (in ha) subject to the particular benefit item(s)

$R_i =$ the proportion of the PVB of a particular benefit item(s) in total PVB

Using equation (4.5) an aggregate estimate of the NPV ranges from ETB 14.3 million to ETB 23.6 million (for case 1 and 2 respectively). An intuitive implication of the scaling up result is that as the proportion of waste land increases, the aggregate NPV increases substantially. In the extreme best case scenario where all the land put under exclosures was initially waste land then $NPV_{agg.}$ escalates to nearly ETB 30 million. Assuming that the aggregate NPV is equally distributed over years[49], the annual NPV ranges from ETB 0.48 to 0.79 million (case 1 and 2). In a scenario where the lands converted to forestry were waste lands, the aggregate annual average NPV becomes about ETB 1 million. This accounts for about 0.7 to 1.5% of the district's GDP[50].

4.8 Discussion

We encountered two critical problems while undertaking the analysis. The first is related to lack of data. For projects, such as exclosures, with both economic and environmental dimensions a comprehensive data set that incorporates both socio-economic and environmental aspects is required in order to undertake the cost-benefit analysis. It is highly improbable to get such a data set from existing sources in the context of Ethiopia. This suggests an important future task for researchers. For instance, besides the SWC effects of vegetation restoration in exclosures, other numerous ecosystem functions, such as biodiversity enhancement, microclimate regulation, carbon sequestration, and wild life habitation should be valued in order have a holistic view on economic and ecological

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[49] This is a simplifying assumption. Otherwise, NPVs do not distribute equally over years due to discounting. Thus, NPV declines as the future period gets longer.

[50] As we do not have data for the district's GDP, it is estimated from the Tigray regional GDP of 1994/95 (see Woldehanna ,2002).

functions of exclosures. If sustainable forest use and management and efficient land use planning is sought, due attention should be paid to collection, organization and analysis of both socio-economic and biophysical data which involves interdisciplinary research.

The second problem is related to the quantification and valuation of the benefit and cost items used as inputs in CBA. This is actually a common problem in CBA of most projects related to environmental issues and ecosystem services, because in such undertakings all benefit and cost items are not readily quantifiable and difficult to express in monetary terms. Therefore, values are usually underestimated when the qualitative aspects of the project are left unaccounted. In such circumstances adequate qualitative discussions should supplement the quantitative analysis for better decisions. Additionally, one may also face methodological problems in environmental valuation.

In our case, for example, instead of using market prices for valuing woody biomass the true economic value of domestic fuelwood use could be better captured by its role as a substitute product for animal dung. If woody biomass production from exclosures substitutes for animal dung for domestic energy demand, farmers will apply animal wastes in their field to improve soil fertility and increase crop yield. Consequently, it can be argued that the economic value gained by substituting fuelwood for dung fuel is more than the simple market price of wood. Newcombe (1987) postulated that as population growth and the demand for energy increase, peasants begin to collect animal dung and cereal stalks for home fuel consumption and cash income. The combustion of dung and crop residues lead to lower soil organic matter, poor soil structure, and reduced protection from the erosive effect of rain water. Soil erosion becomes a serious problem over time; nutrient rich topsoil is depleted; crop yields decline; the area under crop falls; food shortage and ultimately starvation.

Thus, if fuelwood becomes available and substitutes dung and crop residues, dung will be left for farm application. Therefore, future research should focus on a more rigorous approach to capture the value of woody biomass production from exclosures by its indirect effect in increasing crop yield via its impact on soil fertility of farmland (as fuelwood substitutes for dung fuel) instead of using the direct current market prices of wood products used at household level. The increased crop output obtained by replacing animal dung as a fuel with firewood from exclosures could be valued as the economic benefit of exclosures in its role as a soil and water conservation method. This requires estimation of annual dung production, sustainable wood harvest from exclosures, and crop yield response functions to the application of dung.

It has been widely observed that the hydrological situation in the study district has shown some improvements due to the influence of vegetation cover in exclosures and other soil and water conservation measures. For instance, in the May-zeg-zeg area (to the vicinity of the district's capital) new springs are developing. Using these new water sources, local farmers are growing high value cash crops such as vegetables and fruits. In our CBA we captured only the potential economic value of new springs for irrigation activity. However, vegetation restoration in exclosures also helps maintain the baseflow levels in streams and rivers (Pattanayak, 2004). Greater availability of water (especially in dry seasons) reduces a household's water collection cost. As rural households in Ethiopia invest a significant amount of their labour in water collection, more availability of water has an important economic value. Consequently, analysis of households' welfare gain attributed to such hydrological improvements induced by exclosures is another important area of future research.

Our sensitivity analysis indicates that the net present value is more volatile to changes in biomass production and the social discount rate. Two important implications can be drawn from this result. First, appropriate management schemes have to be adopted in order to enjoy the maximum attainable biomass products from exclosures. Second, factors that induce local people to give a low value to future benefits, such as credit constraints and absolute poverty, must be properly addressed so that they could be motivated to attach more weights to the future benefits and sustainably manage the resource system.

4.9 Conclusions and policy implications

With the limited data set available to date, this chapter captured the benefits and tradeoffs of establishing exclosures on land with varying opportunity costs. This chapter, focusing mainly on environmental services of soil and water conservation aspect of exclosures and the ensuing economic values, our analysis indicates that establishing exclosures in degraded land has a positive net present value. However, converting productive agricultural land to forestry does yield negative net present values even under some hypothetical scenarios of overestimated values of forest products and low social discount rate. Thus, our findings support all the three hypotheses that we put forward in section 4.4.4.

We also found that if the values of the major benefit items identified in this study fall sharply (say a 50% fall relative to the current level) due either to a decline in the quantity of the products and services produced per hectare of exclosures or a decrease in their market prices, it is not advisable to covert a semi-productive farm land to forests. As can be seen from table 4.5, such a conversion yields a negative net present value (NPV= ETB -123). Sharp falls in prices are not observed in most growing economies. Therefore, the possible candidate that may lead to a fall in economic and ecological values of forested land is a substantial decrease in the flow of benefit items from the forested area. As the forest's economic and environmental services are susceptible to the management schemes adopted, this warns us to adopt sustainable management scheme in order to enjoy larger benefits from a unit area of forested land. If good management schemes are in place such that the flow of goods and services from the forests are not disturbed, our analysis indicates that converting a semi-productive land to exclosures is justifiable in economic terms.

Our findings have important policy implications. Land allocation for alternative uses such as putting certain land units to forestry (exclosures) should be backed not only by ecological reasoning but also by economic justification. As the burden of wrong decisions ultimately fall on the shoulders of the local community and the welfare gains from better actions are also being enjoyed by the same, the tradeoffs and gains should be adequately weighted if we were thinking of the economic welfare of local people and ecological sustainability of the resource system. In the context of the study area, our economic analysis does not provide any supportive argument or justification for the conversion of productive crop land to forest land whatever the ecological reasons might be. Therefore, we suggest that such land conversions should not be practiced. On the other hand, it is economically justifiable to convert degraded or marginal lands to forest land. Since the majority of exclosures in the study area were established in the highly degraded grazing lands and hilly slopes susceptible to further degradation, our analyses give an economic rationale for the land use type conversions undertaken so far. However, as most of the degraded lands in the study area have already been converted to exclosures, future land conversion to forestry use should be carefully analyzed and justified in economic terms.

Appendices 4

Appendix 4.1 Quantitative estimates of some selected variables (adapted from various previous works)

Variable or attribute	Estimate	Remark/comments
1. Annual sediment mass yield (SM)	6625ton/yr	The estimate is based on 10 surveyed reservoirs in Tigray
2. Annual volumetric sediment yield(SV)	5901m^3/yr	,,
3. Specific sediment yield (SSY)	2.37ton/ha/yr - 18.17ton/ha/yr	SSY varies significantly (with average SSY 9.09(±5) t/ha/yr
3. Dry sediment bulk density (average)	1.01ton/m^3-1.42ton.m^3	Haregeweyn et al. (2006, p. 223)
5. Average live storage of surveyed reservoirs	706x10^{3}m^3	
6. Average dead storage of surveyed reservoirs	122 x10^{3}m^3	
7. Dead storage as a % of total storage volume	9%	The distribution of DS ranges from 1%-20%
8. Construction cost of an average reservoir	ETB 1.5-2.0 million	This is the cost of constructing the main dam (excavation); it does not include the cost of irrigation schemes
9. Sediment deposition rates of exclosures	25.6-123.2ton/ha/yr	The estimates are based on field measurements of some selected exclosures in the study areas
10. Weighted average sediment deposition rates	48.6ton/ha/yr	The ages of exclosures are used as weights (computed by the author)
11. Average bulk density of deposited sediments in exclosures	1.24ton/m3	Computed by the author from Descheemaeker et al. (2006)
12. Average storage volume of surveyed reservoirs	828,000m^3	Calculated on the basis of information from the 10 reservoirs surveyed.
13. Local bank lending rate	15%	This is the rate applied by the local microfinance institute (DECSI) on money lent to the local borrowers

Appendix 4.2 Benefit and cost items and their value estimates used in the CBA

year	Fuelwood MAI qty t/ha	Grass qty t/ha	Reservoir value/ha	flood prot. value/ha	new spring value/ha	fuelwood Value/ha	Grass value/ha	total benefit value/ha	labour cost/ha	OCLS (ha)	OCLP (ha)	TC/ha OCLS	TC/ha OCLP
1	0	1.11	83	43	79	0	133.2	338.2	48	230	689	392.5	737
2	0	1.54	83	43	79	0	184.8	389.8	48	230	689	392.5	737
3	0	1.99	83	43	79	0	238.8	443.8	48	230	689	392.5	737
4	0	2.44	83	43	79	0	292.8	497.8	48	230	689	392.5	737
5	0	2.85	83	43	79	0	342	547.0	48	230	689	392.5	737
6	0.49	2.28	83	43	120	147	273.6	666.6	48	230	689	392.5	737
7	0.54	1.82	83	43	120	162	218.4	626.4	48	230	689	392.5	737
8	0.60	1.46	83	43	120	180	175.2	601.2	48	230	689	392.5	737
9	0.66	1.17	83	43	120	198	140.4	584.4	48	230	689	392.5	737
10	0.72	1.01	83	43	120	216	121.2	583.2	48	230	689	392.5	737
11	0.804	1.01	83	43	120	241.2	121.2	338.2	48	230	689	392.5	737
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
30	0.804	1.01	83	43	114	241.2	121.2	621.2	48	230	689	392.5	737

MAI = mean annual increment

Qty t/ha = quantity in ton per hectare

OCLS = opportunity cost of semi-productive land

OCLP = opportunity cost of productive land

TC/ha = total cost per hectare

CBA = cost benefit analysis

Appendix 4.3 Discounted flow of benefit and cost items and NPV computation (15% discount rate)

	Present value of each benefit and cost items discounted at base rate (15%)								**NPV(at alternative land opportunity cost)** (base discount rate (15%))		
year	Pv_wood	pv_grass	pv_sedim	pv_flood	pv_spring	pv-ocls	pv-oclp	pv_labour	npv_OCL=0	npv_OCLS	npv_OCLP
1	0	115.884	72.210	37.410	68.730	200.100	599.430	41.760	252.474	52.374	-346.956
2	0	139.709	62.748	32.508	59.724	173.880	520.884	36.288	258.401	84.521	-262.483
3	0	157.130	54.614	28.294	51.982	151.340	453.362	31.584	260.436	109.096	-192.925
4	0	167.482	47.476	24.596	45.188	131.560	394.108	27.456	257.286	125.726	-136.822
5	0	169.974	41.251	21.371	39.263	114.310	342.433	23.856	248.003	133.693	-94.430
6	63.504	118.195	35.856	18.576	51.840	99.360	297.648	20.736	267.235	167.875	-30.413
7	60.912	82.118	31.208	16.168	45.120	86.480	259.064	18.048	217.478	130.998	-41.586
8	58.86	57.290	27.141	14.061	39.240	75.210	225.303	15.696	180.896	105.686	-44.407
9	56.232	39.874	23.572	12.212	34.080	65.320	195.676	13.632	152.338	87.018	-43.338
10	53.352	29.936	20.501	10.621	29.640	56.810	170.183	11.856	132.194	75.384	-37.989
11	51.858	26.058	17.845	9.245	25.800	49.450	148.135	10.320	120.486	71.036	-27.649
12	45.104	22.664	15.521	8.041	22.440	43.010	128.843	8.976	104.795	61.785	-24.048
13	39.316	19.756	13.529	7.009	19.560	37.490	112.307	7.824	91.345	53.855	-20.9618
14	34.009	17.089	11.703	6.063	16.920	32.430	97.149	6.768	79.016	46.586	-18.133
15	29.668	14.908	10.209	5.289	14.760	28.290	84.747	5.904	68.929	40.639	-15.818
16	25.808	12.968	8.881	4.601	12.198	24.610	73.723	5.136	59.321	34.711	-14.402
17	22.432	11.272	7.719	3.999	10.602	21.390	64.077	4.464	51.559	30.169	-12.518
18	19.537	9.817	6.723	3.483	9.234	18.630	55.809	3.888	44.906	26.276	-10.903
19	16.884	8.484	5.810	3.010	7.980	16.100	48.230	3.360	38.808	22.708	-9.422
20	14.713	7.393	5.063	2.623	6.954	14.030	42.029	2.928	33.818	19.788	-8.211
21	12.784	6.424	4.399	2.279	6.042	12.190	36.517	2.544	29.383	17.193	-7.134
22	11.095	5.575	3.818	1.978	5.244	10.580	31.694	2.208	25.502	14.9224	-6.192
23	9.648	4.848	3.320	1.720	4.560	9.200	27.560	1.920	22.176	12.976	-5.384

24	8.442	4.242	2.905	1.505	3.990	8.050	24.115	1.680	19.404	11.354	-4.711
25	7.236	3.636	2.490	1.290	3.420	6.900	20.670	1.440	16.632	9.732	-4.038
26	6.271	3.151	2.158	1.118	2.964	5.980	17.914	1.248	14.414	8.434	-3.4506
27	5.548	2.788	1.909	0.989	2.622	5.290	15.847	1.104	12.751	7.461	-3.096
28	4.824	2.424	1.660	0.860	2.280	4.600	13.780	0.960	11.088	6.488	-2.692
29	4.100	2.060	1.411	0.731	1.938	3.910	11.713	0.816	9.425	5.515	-2.288
30	3.618	1.818	1.245	0.645	1.710	3.450	10.335	0.720	8.316	4.866	-2.019

Pv_wood = the present value of woody biomass

Pv_grass = the present value of herbaceous biomass

Pv_sedim = the present value of reservoir sedimentation protection function of exclosures

Pv_flood = the present value of protecting crop field from flood damage

pv_spring = the present value new spring potential in irrigation use

pv_labour = the present value of the opportunity cost of labour

Pv_ocls = the present value of land opportunity cost for semi-productive land

Pv_oclp = the present value the opportunity cost of productive land

(npv_OCL=0) = the net present value of when the opportunity cost of land is assumed to zero

npv_OCLS = the net present value when a semi-productive land is converted to forest land use type

npv_OCLP = the net present value when productive land is converted to forestry

Chapter 5

Towards sustainable forest management: an application of multi-criteria analysis (MCA) to the sustainability of exclosures

5.1 Introduction

Ever since the publication of Garrett Hardin's seminal article 'the tragedy of the commons' in *Science* (Hardin, 1968), there has been myriads of research interest and publications on issues related to environmental and natural resources degradation, the sustainability of resource systems, and the management problems therein. Since then 'the tragedy of the commons' symbolizes the degradation of natural resources whenever many individuals use a scarce environmental resource in common (Ostrom, 1990; Baland and Platteau, 1996; Agrawal, 2001). The basic problem of the commons is believed that the resource unit withdrawn is greater than the optimal economic level of withdrawal; and as such threatens the long-run sustainability of the resource system. Consequently, the central issue becomes how best to limit the use of common-pool natural resources so as to ensure their long-term economic viability (Ostrom, 1990).

Two extreme institutional policy recommendations have been forwarded as solutions to the problems of the 'tragedy' (Ostrom, 1990; Baland & Platteau, 1996): centralized control and regulation of the natural resource system by government versus the imposition of private property rights. Advocates of both prescriptions accept the central tenet that institutional changes must come from outside and be imposed on individuals. However, as Ostrom (1990) asserted, a single prescription (the "only" way approach) for the problems of the commons have paid little attention to the influence of institutional arrangements. Such policy prescriptions are criticised for advocating oversimplified and idealized institutions without giving due attentions to the practicalities in the field settings.

Another stream of literature on common pool resource (CPR) management seeks to specify the conditions under which groups of users will self-organize and sustainably govern the resources upon which they depend (Ostrom, 1990; Morrow and Hull, 1996; Sethi and Somanathan, 1996; Sithole et al., 2001; Agrawal, 2001; Poteete and Ostrom, 2004; Gibson et al., 2005). In this regard the theory of collective action and game-theoretic formulations have been widely used as the theoretical underpinning in much CPR research. However, it is argued that generating lists of conditions under which commons are governed sustainably does not identify the relative importance of sustainability criteria and indicators from the context of local conditions. Listing dozens of conditions without articulating them in terms of sustainability criteria and indicators and assessing their relative importance in a holistic and systematic way does not sound very practical from a policy point of view.

As exclosures possess the characteristics of common-pool resources, they share the management problems that commons face. The sustainability assessment of exclosures needs a holistic and structured methodological approach that accommodates multiple criteria in the analysis and captures both ecosystem and socio-economic aspects of forests. The assessment must also involve participation of different stakeholders and include both qualitative and quantitative data. In such a scenario, the use of multi-criteria analysis (MCA) is deemed to be an appropriate tool for addressing the problems of sustainability assessment. MCA accommodates the multiple criteria of CPR sustainability indices, works with mixed data (qualitative and quantitative information), and allows the involvement of different stakeholders. Therefore, recent studies focus on the use of MCA to assess the sustainability of resources used and/or managed by many (Prato, 1999; Mendoza & Prabhu, 2000a, 2000b; Mendoza et al., 2003).

Taking the field setting case of exclosures in the highlands of Tigray and using the general procedure of MCA, the objectives of this chapter are: 1) to examine the existing management system of exclosures; 2) to identify specific sets of criteria and indicators for the sustainability of exclosures; 3) to assess the relative importance of the criteria and indicators with respect to the overall objective of sustainable management of exclosures; 4) to evaluate the performance the existing management system against the principles and criteria of sustainable forest management; 5) to pinpoint the best management scenario; and 6) to generate some policy implications with regard to the management of exclosures.

5.2 Definitions of key concepts

Devising ways to define and assess the sustainability of forest use and management is one of the research areas in forestry that is gaining attention. One of the important concepts that have been developed to guide the management of forest resources is the concept of sustainable forest management (SFM).

The concept of sustainable forest management (SFM)

SFM may be defined as "a set of objectives, activities and outcomes consistent with maintaining or improving the forest's ecological integrity and contributing to people's wellbeing both now and in the future" (Prabhu et al. 1996). According to ITTO (1992), SFM involves managing forests to achieve one or more objectives with regards to the production of a continuous flow of goods and services without undue reducing their inherent values and future productivity. To evaluate the sustainability of forest management will therefore be to assess the following two conditions: i) that ecosystem integrity is maintained or enhanced; and ii) that the wellbeing of people is maintained or enhanced.

Schneider (1992; cited in Prabhu et al., 1999) defined ecosystem integrity as the ability to support and maintain a balanced, integrated, adaptive biological community having a species composition, diversity and functional organization comparable to that of the natural habitat in the region. The concept 'wellbeing' comprises the economic, social and cultural aspects of people's lives. Forest management can influence the wellbeing of people, especially those who are significantly dependent on forest products. Numerous tools can be used to evaluate the sustainability of forest management. In recent times, criteria and indicators (C&I) are one of the widely applied tools in assessing the sustainability of community managed forests. Since our assessment of forest sustainability in exclosures is based on C&I, it is important to understand the definition of C&I.

The concept of criteria and indicators (C&I)

Literally speaking, C&I stand for criteria and indicators. However, in practice C&I are used as shorthand for the entire hierarchy of principles, criteria, indicators, and verifiers[51]. By linking local and scientific knowledge in a four-level hierarchical framework in a comprehensive and coherent manner[52], C&I provide a powerful tool for assessing trends in forest conditions and sustainable forest management (Lammerts van Bueren and Blom, 1997; Medoza and Prabhu, 2000a, 2000b). Defining the C&I in the hierarchical framework allows us to decompose complex assessment of forest sustainability problem into structured formal analysis. They provide a conceptual framework for describing, monitoring and evaluating progress towards sustainable forest management. In order to have a clear understanding of C&I, brief descriptions of its four components are given[53]. The relationships among these elements and their hierarchical structure are presented in figure 5.1.

Principle: is a fundamental truth or law used as the basis of reasoning. In the context of SFM, principles refer to a function of the forest or to a relevant aspect of the social system that interacts with it, and they provide a primary framework for managing forests in a sustainable manner and justifications for the criteria, indicators, and verifiers.

Criterion: is a standard that allows making judgement about a given aspect of sustainable forest management. The answer to a criterion will judge whether this aspect is managed sustainably or not (Lammerts van Bueren & Blom, 1997). In the context of SFM, criteria are standards by which the progress of forest management towards meeting the principle or objective of sustainable management is judged.

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[51] Of the four components of C&I, we focus on principles and criteria while assessing the sustainability of the management of exclosures.

[52] The criteria and indicators for the SFM embrace a wide range of forest management issues that include economic, environmental, and biophysical factors (Mendoza et al., 2003).

[53] The descriptions are abstracted from Prabhu et al., 1999; Mendoza et al., 1999; and Ritchie et al., 2000. So, interested readers are referred to these original documents for further understanding.

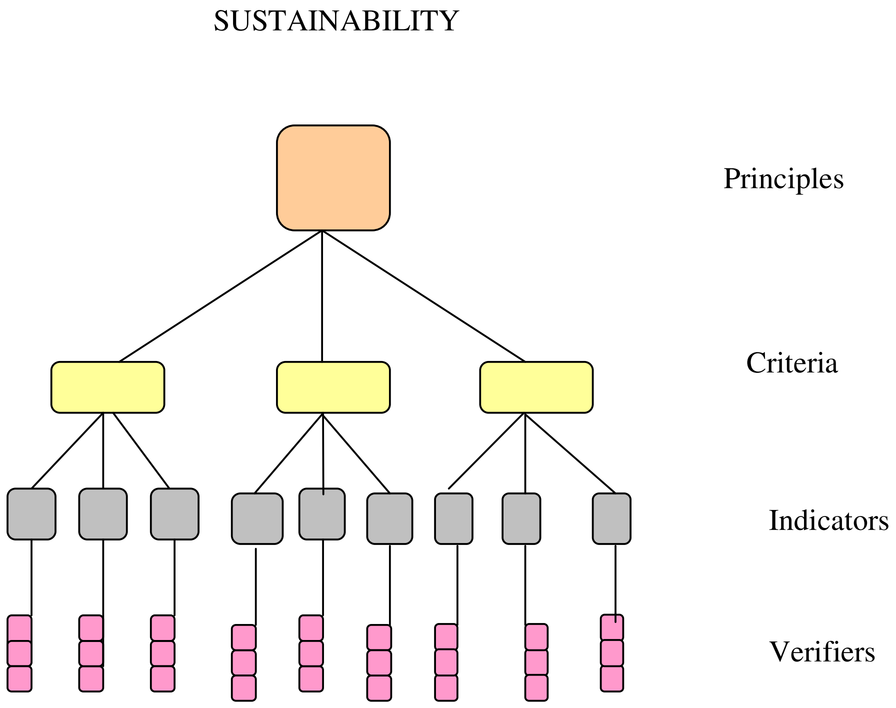

Figure 5.1 Hierarchical structure of C&I.

Indicator: indicators, in a more generic sense, can be conceptualized as variables or factors that can be used to measure or evaluate the condition and change of a system or process (Mendoza & Prabhu, 2003; Mendoza et al., 2003). In the context of SFM, an indicator is a variable or a component of forest ecosystem or management system that implies or indicates the state or condition of a particular criterion of SFM. In other words, indicators are used as measures for assessing the sustainability of forest resource and its utilization.

Verifier: is data or information that provides specific details of desired condition of an indicator. Verifiers often measure performance threshold and add meaning and precision to an indicator.

5.3 An overview of common pool resources (CPR) management

5.3.1 The 'CPR'

Confusion is rife in the subject area of CPR and its usage. The abbreviation CPR is sometimes used to refer to 'common pool resources' and the other times to 'common property regimes'. Whereas the latter refers to the institutions governing the resources, the former refers to the physical characteristics of the resource (McKean, 2000). Similarly, the same pair of adjectives, "public" and "private" are frequently used as labels for three different pairs of things: to distinguish between two different kinds of goods (private goods and public goods), between two different kinds of rights (public rights and private rights), and between two different kinds of bodies that may own things (public entities and private entities). The misunderstanding of the privateness and publicness of *goods, rights*, and *owners* may lead to serious errors in our attempt to design institutional arrangements and management guidelines for the problems of the commons (McKean, 2000). Most people either get mixed up goods and owners, or goods and rights, or rights and owners. Getting goods and owners mixed up emanates from people's habit of thinking that public entities own and produce public goods while private entities own and produce private goods. But, this is a wrong perception. Public entities are capable of producing private goods and private entities may also produce public goods. Second, the mixing up of goods and rights may lead to an attempt to create public rights in private goods and private rights in pure public goods or common-pool goods. Third, mixing up rights and owners arises from the wrong perception that private entities hold private rights and public entities hold public rights.

Definitional clarity on privateness and publicness of goods, rights, and owners have crucial practical significance in terms of the provision, maintenance, and sound management of common-pool goods. Confusing owners, rights, and goods with each other may end up a natural resource system to environmentally inappropriate and economically unproductive system. Hence, before we discuss the problems of the commons and the various sustainability analysis of their management, it is essential to have a clear understanding in separating goods, property regimes, and owners.

Goods/resources

The privateness or publicness of a good is a physical given having to do with excludability and subtractability of a good. These two attributes of a good are important to understand what humans can do and can not do with the different kinds of goods. In economics three main types of goods are distinguished[54].

Private good: a private good is defined as a good that exhibits two important properties: *excludability* and *rivalry*. A good is said to be excludable if it is reasonably possible to prevent a class of consumers (e.g., those who have not paid for it or contribute to its provision) from consuming the good. Rivalry in consumption refers to the condition that consumption of the good by one consumer prevents simultaneous consumption by other consumers. Private goods are goods that are both excludable and rivalrous.

Public goods: these are goods that are not easily excludable and nonsubtractable (nonrival in consumption). The consumption of a pure public good by an individual does not reduce the quantity available to others to consume. In other words, pure public goods are nonrival in consumption or nonsubtarctable. Therefore, they are not depleted. The chief problem with pure public goods is the problem of provision or supply due to free-rider motives of users (consumers) and not depletion of whatever quantity supplied/produced.

Common-pool resources (CPR)[55]: refer to goods where, as with public goods, it is costly or difficult to exclude potential users, but which are sustractable (rival in consumption), like that of private goods. CPRs exhibit two key characteristics, namely: 1) that it is difficult to physically exclude potential users from them, and 2) that their consumption is rivalrous or subtractable i.e. increased consumption by one agent implies that less is available for others and can thus be depleted. Thus, CPRs pose both the problems of provision and the risk of depletion. CPRs do not fulfil the pure public goods characteristics of non-subtractability. Thus, they are susceptible to the risk of over extraction.

On the basis of the physical description of goods presented above, exclosures (forests) fall under the category of CPRs. Thus they are subject to rivalry in consumption and

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[54] Sometimes ‘club goods’, such as cable television, are classified as a fourth separate category.

[55] To avoid confusion, in this chapter and throughout the entire thesis we use the abbreviation CPR to refer only common-pool resources, as defined here. Thus, in our case, neither common property regimes nor common-pool regimes nor common property resources are abbreviated as CPR.

difficulty in exclusion, the combined effect which may lead to depletion or degradation if they are not managed appropriately. The problem of supply and temptation of free-riding are also inherent in CPRs that emanate from non-excludability property. Most environmental resources fall under this category (McKean, 2000).

Property regimes

Four different types of property regimes have been identified in ‘property’ literature.

Private property regimes: a type of property right which assigns property to identifiable individuals, guarantees them the control of access and the rights to socially acceptable uses (Black, 1968; cited in Hanna & Munasinghe, 1995).

Public property regimes: is a form of property regime in which the property right is vested in the state (public agency) and citizens have the right to use the resource within the rules established by that agency.

Common property regimes: common property regimes can be defined as “institutional arrangements for the cooperative (shared, joint, collective) use, management and sometimes ownership of natural resources” (McKean, 2000). Common property regimes define the conditions of access to and control over a stream of benefits arising from collectively used natural resources (Swallow and Bromley, 1995). In these regimes, no member of the user group has the right to exclude others, but the group has the right to exclude non-members from the use of the resource. It is sometimes described as ‘collective privatisation’. Common property is a form of resource management in which a well delineated group of competing users participate in extraction or use of a jointly held resource according to explicitly or implicitly understood rules about who may take how much of the resource (Stevenson, 1991). When the group of individuals and the property rights they share are well defined, common property should be considered as a form of shared private property (McKean, 2000). In this regard, McKean argues that the ‘privateness’ of property rights has to do with the clarity, specificity, and exclusivity of rights, not to the identity or size of the right holder.

Open access regimes: this refers to the situation where there is absence of property rights and no one has defined rights or duties. This means that no one has a legal right to exclude anyone else from using a resource. Sometimes people tend to use open-access and common property regimes synonymously. But this is a wrong perception[56]. While there is no defined property rights in the case of open-access, in common property regime a particular group of individuals share rights to the resource and possesses legal ability to exclude others from the resource. Under open access, no one has the right to prevent free-riders from exploiting the resource without contributing to its maintenance. In contrast, in common property regimes there is 'rights' rather than the 'absence of rights' and these rights are common not to all but to a specific group of users. Access is not open to all but limited to a specific group of users who hold their rights in common (Ostrom, 1990; Rasmussen & Meinzen-Dick, 1995; McKean, 2000). For example, the herding example used by Hardin (1968) to demonstrate the problems of commons with ultimate 'destination towards ruin' more accurately describes a condition of 'open access' rather than 'common property'. Despite theoretical arguments and empirical evidence refuting Hardin's "tragedy", there are still many instances that the "tragedy" thesis has been reflected in actual natural resource policy and research to refer 'common property' (Swallow& Bromely, 1995). Thus, "the 'disaster' of open access has been attributed to common property without recognizing the important distinction between the two"(Larson & Bromley, 1990, p.239).

In the context of our case study, users of exclosures are known and well defined. Only members of a defined village or group of villages have the right to access a specific exclosure and non-members are excluded. Thus, on the basis of the foregoing discussions on types of property regimes, exclosures are readily classified under common property regimes, not under open access regimes.

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[56] Failure to distinguish between common property and open access situations may lead to not only intellectual confusion but also contribute to mistaken policies of privatization or nationalization of natural resources. It is partly from such misunderstanding that the 'tragedy of the commons' is wrongly applied to the CPR and either 'privatization' or 'nationalization' is prescribed as the 'only' remedial measure for the problems of the commons (Ostrom, 1990; Baland and Platteau, 1996).

Owners

'Owners' refers to different kinds of bodies or entities (public entities, governments, private entities, or individuals) that make representational claims on things. The privateness of an entity/or a body has to do with its representational claims in that private body represents itself whereas public body claims to represent the general population. On the other hand privateness of a right has to do with the right, and not the entity holding it (McKean, 2000). It is not a requirement for an entity to be a single individual to enjoy a private right. The three common kinds of representational entities (owners) are: private entities (owners), public entities (owners), and community or shared entities (owners). On the basis of the preceding discussions, table 5.1 summarizes of the semantics and typology of goods, rights, and owners.

Table 5.1 Types of goods, rights, and owners

	Goods	**Rights**	**Owners**
Semantic	-A natural given (nature of a good) -Can not be manipulated by humans	- An institutional invention - Human invention - Can be manipulated by humans	-Entities that make different representational claims -Can be manipulated by humans
Private	-Excludable -Substractable	-Specifies *clearly* what the rights-holder is entitled to do -Is *secure* so that the holder of the right is protected from -Confiscation by others is *exclusively vested* in the holder of the right and definitely not in nonholders of the right	-Represents only itself.
Public	-non-excludable -non-substractable	-Rights of access and use that do not include the right to exclude others from such use	-Represents the general population and not just a single individual
CPR	-non-excludable -substractable	-Group of individuals share private property rights -Systems of shared private rights owned by private entities	-Group of individuals (shared, joint or collective) ownership -Community ownership

5.3.2 Factors affecting sustainable management of CPR at local level

Scholars of commons have identified myriads of factors to assess the sustainability of CPRs. The multiplicity of factors identified can be grouped into three broad categories: the characteristics of the resource system (both the physical and technical characteristics), the characteristics of the user group, and the attributes of the institutional arrangements (formal and informal rules and regulations that govern the use and management of the CPRs) (Ostrom, 1990; Rasmussen and Meinzen-Dick, 1995; Baland and Platteau, 1996; Agrawal, 2001; Gibson et al., 2005). The relative importance of these factors in conditioning sustainable management of the commons depends on the conditions of the local area under consideration.

Physical and technical characteristics of the resource

As indicated under section 5.3.1, the degrees of excludability and subtractability of the good are the two essential attributes that condition property rights and hence the efficiency of management of natural resources. Resources with high excludability can be managed efficiently as private property. If a resource system is characterized with both low excludability and low subtractability, it is a public good which the state can provide. Resources with low excludability but high substractability are common pool resources which are susceptible to degradation if suitable management entities are lacking. Excludability and subtractability, in turn, are affected by the natural boundedness and size of the resource system. The technology used for withdrawing the resource unit influences the extent of resource extraction.

Characteristics of user groups

The variables identified under this category are primarily the socio-economic characteristics of the users. Users' demand for the resource, dependence on the resource, and knowledge of the resource are important factors in conditioning the incentives for natural resource management. The number of users and the degree of homogeneity (such as similarity in resource access and perceptions of the risk) have considerable effect on the possibility of group cooperation (Ostrom 1990; Rasmussen and Meinzen-Dick, 1995; Baland and Platteau, 1996, 1999; Sekher, 2001; Agrawal, 2001). The proximity of the residence of the users and the location of the resource as well as the residence of the users to each other is supposed to facilitate voluntary organization. The openness and stability of the community are also considered as important determinants of cooperating in managing the commons. Many scholars argue that as the rate of social mobility, migration, and market integration increases, the possibility of voluntary cooperation for local resource management decreases (Ostrom, 1990; Bardhan, 1993).

Institutional arrangements

Institutional issues have received due attention in investigating the determinants of collective action in managing common pool resources in a sustainable manner. Clear, flexible and fair operational rules – boundary and access rules, allocation rules (who is getting what), input rules (in what way the users contribute), monitoring and sanctioning rules, and conflict resolution rules – are supposed to enhance the possibility of cooperation (Ostrom, 1990). Similarly collective choice rules in formulating, changing and enforcing operational rules and external public regulations such as property rights also play a key role in determining community based natural resource management. The major factors identified that condition the sustainability of local CPR management are summarized in table 5.2. Most of the C&I identified in the field setting to assess the sustainability of exclosures correspond to the factors listed in table 5.2.

Table 5.2. Factors affecting local management of commons

physical & technical characteristics of the resource system	**characteristics of the user group**	**institutional arrangements**
• size of the resource system	• size of user group	• access rules
• clarity of boundaries	• group homogeneity	• withdrawing and provision rules
• technology for withdrawing the resource units	• traditions/shared norms	• monitoring , sanction, and enforcement rules
• excludability of resource i.e. cost of exclusion technology	• source of livelihoods, dependence on, & demand for natural resource	• collective choice rules (collective decision making process)
• substractability or rivalry of the resource	• users' knowledge	• external rules/arrangements and interventions
	• market access or openness	• operational rules
	• job opportunities	• ability to change rules
	• proximity to resource and between users.	
	• stability of the community	

Source: adapted from Rasmussen and Meinzen-Dick (1995)

5.3.3 *Evolution of environmental conservation initiatives in Ethiopia and environmental policy failures*

The crux of most environmental reclamation initiatives, including exclosures, in Ethiopia is generally attributed towards responding to the continual deterioration of the nation's natural resource base, especially since the second half of the 20th century. In the beginning of the 19th century, about 40% of Ethiopia's land mass was said to be covered by natural forests. The scene has continuously been changing in the twentieth century and today the nation's forest areas have shrunk to less than 3 percent of the total land area (Campbell, 1991; Gilliam, 2004; Mesfin Tilahun et al., 2007). Particularly the highlands of the northern parts of the country are almost devoid of natural forests. The situation is much more severe in Tigray than many other parts of Ethiopia. According to the TFAP (1996) estimate, the current forest land of Tigray region is less than 2% of its total area. This coupled with other factors such as population pressure, drought, market failures, and ineffective or absence of use regulations of common pool resources has resulted in severe resource degradation and productivity loss of the nation's resource base. As a result, Ethiopia is a frequently cited country in terms of the severity of environmental degradation in Africa with the consequent implications for food shortage and famine (Campbell, 1991).

Ethiopia aims to combat these severe resource degradation problems; national level ecological conservation efforts have been started since the 1970s, with particular focus in the fast deteriorating highland areas of the country. However, in comparison to the accelerating rate of natural resource degradation, in the 1970s little was accomplished in the area of natural resource conservation. For instance, in 1974-75 the Ministry of Agriculture (MoA) achieved only 10.5 millions seedlings, 2000 hectares planted, 7000 km terraced, and about 1000 hectare planted in community forests (Campbell, 1991). The Ethiopian agrarian revolution of 1974 and the subsequent land reform and introduction of new forms of rural political & administrative organizations called Peasant Associations (PAs) in 1975, has paved the ground for accelerated environmental conservation. Backed up by the food-for-work (FFW) programme of the World Food Programme (WFP), in the second half of the 1980s, for instance, large-scale afforestation projects and catchments preservation programs were constructed with peasant labour. Peasants constructed more than one million kilometres of soil and stone bunds on agricultural land and built almost half a million kilometres of hillside terraces. More than 80,000 hectares of hillside were closed off from most forms of use to foster natural regeneration, and planted 300,000 hectares of trees; much of it was community wood lots (Hoben, 1995). Unfortunately, most of these structures were either harvested or destroyed in the aftermath of the fall of the military regime (popularly known as the ‘Derg’) in 1991. Particularly the experience with exclosures and community woodlands during the military regime was disappointing (Campbell, 1991; Hobben, 1995).

Tigray is known not only for the severity of natural resource degradation but also for its concerted efforts to combat the problem. The information obtained from elders of the community, local leaders, and key informants unanimously confirm that it was during the feudal monarchy reign of Emperor Haileselassie (before 1974) that establishment of exclosures in Tigary could be traced. The ages of some exclosures in the study district validate this hypothesis. More efforts were exerted during the 17 year period of the Derg’s regime.

However, it is since the 1991 that massive, organized, and concerted efforts of environmental reclamation have been undertaken in Tigray. Closing land areas from human and animal interference to promote natural regeneration, commonly called exclosure (with or without enrichment plantation), is among the major strategies of environmental rehabilitation and protection adopted in Tigray (Gebremedhin et al., 2003). Since 1991, exclosures and community woodlots have been practiced in large scales aiming to foster the natural regeneration of indigenous plant species and rehabilitation of the environment.

Despite the exertion of massive efforts on environmental rehabilitation and conservation in Tigray, how to sustainably manage the natural resources, mainly the region’s vegetation (forests), is still not yet a well addressed question. Sustainable management of forests requires harmonizing and compatibilizing the economic goal of local people and the environmental sustainability of the resource systems. In this regard Shyamsundar & Kramer (1996) argue that a primary constraint to the successful management of protected areas in the tropical countries is the luck of clear linkages between the well-being of the local residents and the conservation efforts undertaken in protected areas. The mismatch between protecting a land area and the local economic needs results in conflicts and this erodes the protective measures undertaken. Thus, the need to design a 'win-win' strategy that takes into account both the economic and environmental goals is inevitable when we talk about the sustainable management of communal resources. Sustainability criteria and indicators should be carefully identified and prioritized from the perspectives of local community and targeted interventions have to be made to optimize the twin goals development and environment.

On the basis of TFAP (1996), communal forests in Tigray are administered by the local rules (locally known as *'serit')* set by the communities. The rules specify the conditions under which forest products could be withdrawn and the sanctions and fines on rule violators. However, in most cases these rules are not backed up by strong and effective monitoring and enforcement channels. In most villages, social ties, kinship, and reciprocity dominate i.e. strong 'social capital'. As a result, there are widespread violations of rules but these are underreported due to the prevalence of strong 'social capital'. This and other issues related to the current management problems of exclosures are discussed in section 5.5.1.

Another major problem for sustainability of exclosures is related to the ambiguity in the tenure system of land and other natural resources in Ethiopia[57]. Most exclosures are nominally community-owned but there appears a feeling of insecurity and little sense of ownership amongst the community. A study conducted by Chisholm (2000) in four districts of Tigray reveals similar household behaviour regarding tenure insecurity. Such ambiguity and sense of insecurity of rights hamper and distort household level incentives to sustainably manage the resource system.

5.4 Methodology

5.4.1 The data

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[57] Concerning the constitutional code of land tenure and property rights to natural resources in Ethiopia, readers may refer to section 2.3 in chapter 2. For more details interested reader may refer to article 40 of the Constitution of the Federal Democratic Republic of Ethiopia (FDRE, 1994).

The data used in this chapter were collected by employing two major methods: focus group discussion and stakeholder MCA workshop. In addition, key informants from the local people and some relevant experts[58] were interviewed to receive additional insights on issues related to the management of exclosures.

Focus group discussion

Preliminary information about the existing use and management schemes of exclosures and the views and perceptions of the local community were elicited with the help of focus group discussions in 18 selected groups in the study area (for the details see appendix 5A). The focus group discussions were conducted prior to the stakeholders' workshop on principles and criteria (the C&I elements) of sustainability. Consequently, the information obtained via focus group discussions become important inputs and feed-backs in C&I and the MCA process.

Stakeholder workshop on C&I

MCA was used to systematically generate a set of C&I that were believed to measure forest sustainability in the context of exclosures. A team of 13 stakeholders[59] (consisting of experts, practitioners and local resource users) were carefully selected. Experts were selected to achieve an appropriate balance in terms of representation, professional background, knowledge and experience on the administrative, technical, and historical perspectives regarding exclosures in the study area, and field experience. Local or indigenous knowledge, degree of involvement in local collective action, specific role or contribution in the management of exclosures, and experience in local leadership were considered in selecting the local users for the team membership. A three-day (27-29 September 2006) workshop was convened in the

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[58] Expert interviews were conducted with the head of the Department of Natural Resources and Environmental Protection (DNREP) of Tigary; the head of Forestry Section (within the DNREP), a soil and water conservation expert from Relief Society of Tigray (REST), and an agriculturalist from the *Woreda* Office of Agriculture.

[59] For local level sustainability analysis, studies suggest a team of 8-12 persons is sufficient to generate C&I and to carry out the MCA techniques such as ranking and pair-wise comparisons (Mendoza et al., 1999; Mendoza and Prabhu, 2000, 2003). Therefore, we believe that a team of 13 persons in our case study would generate fairly reliable data for assessing the management of exclosures. The composition of the workshop participants are: three socio-economists; two local extension and rural development agents; three local people (a local community member, a local administrative leader and social court chairperson, and a local religious leader); two experienced guards of exclosures; one soil and water conservation expert and employee of *woreda* agriculture office; one forester working for the local commercial forestry enterprise; a researcher on soil, water and vegetation cover who conducted research on exclosures and church forests for four years in the study area.

capital of the study district (Hagereselam). Using the CIFOR C&I generic template as a base and adapting, examining its applicability, relevance, and importance to the management of exclosures the initial set of C&I were proposed by the researcher. The proposed C&I were translated into the local language in advance. The first day was devoted to discuss the criteria and indicators proposed *a priori* by the researcher and to generate the final set of relevant C&I and in the next two days ranking, pair-wise comparisons, and scoring techniques were undertaken. Three facilitators, all conversant with the local language (Tigrigna), were assigned to moderate the sessions. Facilitations, discussions, and questions were all done in the local language. The researcher also participated as an observant to the process (with no direct input in the last two days of the workshop).

Alternative management scenarios and their scoring

The group discussions and the stakeholder workshop have provided sufficient information for the understanding of the existing forest management system and the local conditions. Using this information, alternative forest management scenarios were set and each scenario was scored on a 9-point scale (see footnote 63) against the criteria of SFM. The scenario setting and scoring of the different forest management schemes were undertaken by experts.

5.4.2 Multi-criteria analysis (MCA)

It is often observed that in community based forest management (CBFM), various stakeholders may advocate different and possibly conflicting views, objectives and perspectives about the forest. Thus, these diverse views, objectives and perspectives of stakeholders should be accommodated in order to make the decisions about forest management strategy suitable to all parties (Mendoza & Prabhu, 2000a, 2000b, 2005). The neoclassical economic approach based on optimization of a single objective function has limited applicability in multi-attribute decision problems such as forest management. This necessitates a need for a rigorous, structured and systematic framework for analyzing the multitude of preferences and perspectives of stakeholders. MCA offers an analytical framework that accommodates the stakeholders' multiple views, objectives and perspectives.

What is an MCA?

MCA is a general decision-making tool developed for decision problems involving complex multiple criteria or dimensions that include qualitative and/or quantitative aspects. As the information used in C&I to assess the sustainability of forests include multiple stakeholders' interests and views of both qualitative and quantitative nature, MCA provides an appropriate tool for addressing the methodological challenges involved in C&I assessment[60].

MCA methods (Ranking, pair-wise comparisons, and scoring)

The MCA methods used in this study are ranking, pair-wise comparisons, and scoring.

Ranking

Ranking is an MCA method that involves the assignment of a 'rank' to each decision element depending on the perceived importance of the decision element using certain predetermined points of scale. In our study a nine-point scale was used[61]. The relative weight of a decision element can be calculated on the basis of the ranks assigned to the decision element by different stakeholders. Following Mendoza and Prabhu (2000a, 2000b), suppose that there are j number of criteria $(j = 1,2,...,J)$ under a certain principle (p). Assume that each criterion 'C_j' has 'm' indicators and represented as:

$C_j \in \{I_{j1}, I_{j2},..., I_{jm}\}$, where $I_{j1}, I_{j2},..., I_{jm}$ are the 'm' indicators $(m = 1,2,...,M)$ under criterion 'C_j'.

Suppose that ranking responses are obtained from k stakeholders. If the k respondents assign $r_{j1}, r_{j2},..., r_{jk}$ ranks to the criterion C_j and $r_{jm1}, r_{jm2},..., r_{jmk}$ ranks to

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[60] A number of useful attributes that make MCA as a very useful and appropriate tool for assessing forest sustainability using C&I are described in Prabhu et al., 1999; Mendoza & Prabhu, 2000a, 2005; Mendoza et al., 2003.

[61] Note that the judgement or evaluation of sustainability is undertaken from the local point of view. 1=weakly important; 3= less important; 5= moderately important; 7= more important; 9= extremely important. 2, 4, 6, and 8 are intermediate assessments which could also be used for ranking purposes.

the respective indicators of criterion C_j, then the relative weight for the j^{th} criterion and m^{th} indicator under criterion j, respectively can be calculated as follows:

$$w_j = \frac{\sum_k r_{jk}}{\sum_j \sum_k r_{jk}} \times 100 \qquad (5.1)$$

$$w_{jm} = \frac{\sum_k r_{jmk}}{\sum_m \sum_k r_{jmk}} \times 100 \qquad (5.2)$$

where w_j and w_{jm} are the relative weight of the j^{th} criterion and the m^{th} indicator under criterion j, respectively.

Pair-wise comparison (PC)

PC involves one-on-one comparison between the indicators. The PC method can also be used to assign relative weights to the indicators. Pair-wise comparisons distil the complex decision problem into a series of one-on-one judgements regarding the significance of each *indicator* relative to the *criterion* that it describes. Each indicator under a criterion is compared with every other indicator under that criterion to assess its relative importance[62]. A pair-wise comparison of m indicators of the j^{th} criterion $\{I_{j1}, I_{j2}, ..., I_{jm}\}$ to reflect the importance of each of the indicators in influencing the criterion, involves constructing an m by m matrix which shows the dominance of the indicators listed in the left-hand side column with respect to each indicator in to top row (see appendix 5C).

Scoring

Scoring is a method used to examine and judge the *current condition* of each indicator relative to a *perceived target or desired condition* of the indicators under each

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[62] Nine-point numerical scale is used for comparative judgement (pair-wise comparisons) of indicators. 1=equal importance; 3= moderately more important; 5= strongly more important; 7= very strongly more important; 9=extremely more important. 2, 4, 6, and 8 are intermediate assessments which could also be used in pair-wise comparisons.

criterion in order to evaluate the performance of the forest management. The desired condition is used to reflect or represent a ‘sustainable state’ of the indicator. In multi-criteria analysis, a 9-point scale can be used to elicit information[63].

With the help of the weighted scoring technique (Mendoza and Prabhu, 2000), the overall performance score of the j^{th} criterion (S_j) can be calculated as a weighted average as follows:

$$S_j = \sum_m w_{jm} \times s_{j\,m} \qquad (5.3)$$

where w_{jm} is the estimated relative weight of indicator m (see equation (5.2)); s_{jm} is the average score of indicator m (both w_{jm} and s_{jm} are under criterion j). The relative weight (w_{jm}) could be estimated either from the ranking method or the pair-wise comparison method. In our case, we estimated w_{jm} from both methods in order to compare the scores computed using the two different weights. Data were analyzed using the excel spread sheet and DecisionPlus(version 3.0) software.

5.5 Results

5.5.1 Analysis of existing management practices of exclosures: insights from focus group discussion

As the information obtained from the focus group discussion is mainly qualitative, the findings are usually presented in qualitative form. The qualitative information obtained from the focus group was very useful in subsequent C&I identification and assessment. The following is a summary of the results of the focus group discussion.

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[63] A score is given to each indicator by comparing the indicator’s current state relative to some desired condition. 1= the indicator is in *poor/unfavourable* condition relative its to the desired condition; 3= The indicator is in *fair but below average* condition; 5= The indicator is in *average and acceptable* condition relative to its desired condition; 7= The indicator is in *good condition* relative to its desired condition; 9= the indicator is in *excellent/outstanding performance* condition relative to its desired condition. 2, 4, 6, and 8 are intermediate judgments which could also be used in scoring.

The resource system: Knowledge of the physical boundaries of the resource system is one of the important factors in sustainable management of CPR (Ostrom, 1990). In this regard community members asserted that they clearly know the boundaries of their resource system and the boundary of the user groups (who has the right to use a specific exclosure). Thus, according to the participants, knowledge about the "boundary of the resource system" is not a problem among the community members sharing the resource system. Participants also claimed that community participation was sufficiently high for the recently established exclosures (established since 1991).

Products (the resource unit): Participants claimed that exclosures were mainly established for ecological reasons rather than for short-run economic benefits. But this does not mean that harvesting products from closed areas is totally banned. Community members are allowed to harvest some forest products from exclosures. Fodder for livestock and thatching grass (in a *cut-and-carry* system) are the two main forest products that community members are allowed to harvest. These products are harvested periodically when they are ripe. Bee keeping (honey production), collection of deadwoods for fuel (allowed in some limited number of villages) and mature wood products for the construction of kindergarten, public schools, rural health posts, houses for disabled, old and widows of the deceased war veterans are additional benefits that communities are enjoying from exclosures. In addition to the tangible benefits, some environmental benefits such as microclimatic regulation and soil and water conservation were also mentioned as important services of forests. Such economic and environmental benefits are generating incentives for the community to manage their resource system.

Users and accessibility: Group size and homogeneity, exclusion right, and power structure within the community are among the important factors in the collective action literature (Ostrom, 1990; Baland & Platteau, 1999; Jones, 2004; Poteete & Ostrom, 2004). In this regard, though the group size of beneficiaries varies from village to village, for most exclosures there is a defined number of beneficiary households. Households that do not belong to the beneficiary group do not have access rights and cannot harvest any product.

Concerning the issue of benefit sharing among the members, participants unanimously expressed that all members are equally beneficial. For instance, the amount of grass a member household obtains is not contingent to any individual level characteristics such as number of livestock one owns, social status, and sex. Every member of the community obtains an equal share of grass irrespective of inter-household variation in factors such as wealth and social status. If the actual harvest of grass in a particular period is less in quantity to distribute to all members, a lottery system is applied so that a certain section of the community utilizes the product in that particular harvest period and the rest of the community will obtain the product in the next harvesting period. The major complaint of the community is that there are restrictions on the range or mix of allowed products. During the discussion it was repeatedly raised that the range of allowed products is limited and restricted. Communities expect and demand more economic benefits out of their commons. This creates increasing pressure on the resource system.

Rules and regulations governing exclosures: Discussions under this topic were conducted in two sub-topics: use rules and management rules. By definition, rules constrain human actions, shape interactions of humans with others and nature, promote stability of expectations, and consistency in actions. As such there exist both formal and informal rules that govern the use of forest products from exclosures. Since the primary objective of establishing exclosures was for ecological reasons, in general, the existing use rules prohibit most forest products from exclosures, with few exceptions such as the noticeable case of the *cut-and-carry* system. However, in some specific cases some community members may be allowed to harvest forest products other than grass[64], otherwise, according to the participants, products from exclosures are highly restricted.

The major hindrance to the effectiveness of management rules are kinship and social ties, low incentive packages to the guards, the nature of the resource system (e.g., some exclosures are very large in size to monitor), weak rules, and ineffective monitoring and enforcement. Members of a community are highly interlinked and tied

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[64] Female headed households (especially widowed women of the former deceased TPLF fighters), disabled, and aged people may get a special grant from the community to harvest products other than grass such as construction woods.

in terms of kinship, blood relationships, and other social linkages. The dominance of such social ties induces people not to expose rule violators. On the other hand guards often claim that they are poorly paid (either paid in cash or in kind or allowed to harvest some forest products) and hence reluctant in monitoring.

Most of the participants demand more stringent rules to effectively shape communities' behaviour. Communities also demand more decentralization in rule modification and resource allocation. For example, they complained that the allocation and use of revenues collected in the form of fine from rule violators is not at their disposal. Some participants even claimed that "we do not even know where our money is going and who is using and for what. So we need more decentralized practices". Participants also raised the crucial importance of community awareness creation for the sustainability of exclosures.

Problems of the existing system: Community members have identified the key problems of the existing system in relation to the management of exclosures. According to them the existing system: is too weak to effectively prevent illegal harvesters; lacks a clear and well-defined operational manual; does not have channels to disseminate awareness and build the capacity of user groups through recurrent community meetings, discussions and the like; and is not effective in monitoring and enforcing the rules.

5.5.2 The C&I set for exclosures

The C&I used in this chapter for the assessment of forest sustainability in exclosures were developed in two stages. First, the hierarchically structured generic template of criteria and indicators developed by CIFOR (1999) and their formulation is adapted following Larmmets van Bueren & Blom (1997). Taking the contextual factors relevant to the management problems of exclosures in the study area into account, the researcher specified the initial sets of C&I[65]. Second, the proposed sets of C&I were thoroughly revised at the stakeholders workshop. After the revision an overall

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[65] The work of Lammerts van Bueren & Blom (1997) on the formulation of sustainable forest management standards and the detailed generic C&I set developed by CIFOR (1999) to assess the sustainability of forests are commonly used as the initial set in the development of specific set of C&I for a particular problem under investigation (Mendoza & Prabhu, 2000a, 2000b; Mendoza et al., 2003).

consensus has been reached on C&I elements to be used in the assessment. Accordingly, two broad objectives, six principles, and forty-three criteria were identified as the final C&I set. The lower C&I hierarchy (indicators and verifiers) were not included in our study as they are usually too specific to evaluate. Table 5.4 presents the list of C&I elements used in our analysis (with their relative weights).

5.5.3 Relative importance of principles

Using equation (5.1), we estimated the relative importance or weight of each of the principles on the basis of the ranks assigned directly to the principle. Stakeholders were asked to rank each principle according to their perceived importance with respect to the objective of our analysis (sustainable management of exclosures). The result obtained from this analysis is presented in table 5.3. According to the result, principle 5 (i.e., empowering local community with adequate knowledge and awareness about sustainable management of exclosures) is ranked as the most important principle for the sustainability. This is also the principle voted most consistently by all the participants as reflected by its least variability in the votes (SD=0.98). This means that persuasion, awareness creation, environmental education, familiarization, and human capital development at local level, in short, acquainting local people with environmental knowledge and sustainability issues, is the most important factor for sustainable use and management of exclosures. This seems sound because very often as the level of environmental awareness increases people tend to use natural resources in a sustainable fashion. Local people having sufficient knowledge on all the negative consequences of unsustainable resource utilizations are more likely to cooperate for protecting and conserving their CPR and comply with the rules and regulations governing the commons compared to ignorant ones.

Except for principle 6, the rest of the principles show only marginal differences in the magnitude of their relative importance. On the basis of table 5.3, principle 1 occupies the second position in importance for forest sustainability. The implication is that stakeholders perceive ‘enhancement of natural regeneration of vegetation’ in closed areas as a second important principle in forest sustainability. Flow of economic benefits to the local users (principle 3) and prevalence of enabling institutional conditions (principle 4) have received equal relative weights in terms of their importance to forest sustainability.

Table 5.3 Relative weights of principles (on the basis of ranking method)

Principles	Ave.wt*.	SD	Relative wt.(%)
P1. Natural regeneration of vegetation or forests should be enhanced	7.54	1.56	17.44
P2. The soil and water conservation effect of exclosures should be enhanced.	7.31	1.44	16.90
P3. Management of exclosures should maintain or enhance the flow of economic benefits to the local community	7.38	1.19	17.08
P4. Enabling institutional conditions for sustainable management of exclosures should be put in place	7.38	1.39	17.08
P5. Local community should have adequate knowledge and awareness about sustainable management of exclosures	8.46	0.98	19.57
P6. Functioning buffer zone should exist.	5.15	1.67	11.92

*Ave.wt.= average weight. The average weight has to be judged at a 9-point scale preference ranking (see foot note 61) and the relative weights are in percentages; SD = standard deviation

The SD in table 5.3 shows the differences in priorities amongst the team members with respect to the six principles identified for sustainability assessment of exclosures. The largest difference or disagreement lies in principle 6 ('existence of buffer zone') with most respondents considering the sixth principle to be of least important. The remaining five principles have been prioritized more or less consistently by most participants. For instance, there is high degree of consistency of ranking with regard to principle 5 ('local community should have adequate knowledge and awareness about the need for managing exclosures sustainably') among most team members. The relative weighting in table 5.3 shows that except the sixth principle, all the other principles are important for forest sustainability in exclosures and hence subject to further analysis (pair-wise comparison and scoring). Since principle 6 is the least prioritized and most inconsistently ranked, in the subsequent analysis of the C&I we give less attention to it.

The five principles deemed important for the assessment of forest sustainability in exclosures can be further aggregated into three broad factors: (1) ecological factors (principles 1 and 2); (2) economic factors (principle 3); and (3) socio-institutional factors (principles 4 and 5). On the basis of the stakeholders' preferences (ranking responses) the social and institutional factors, ecosystem factors, and economic factors received first, second, and third priority respectively. But the aggregated relative importance of the three factors varies only marginally (34.86%, 32.66%, and 32.48%).

5.5.4 Relative weight or importance of criteria

In any C&I assessment, analysis at criterion or indicator level is supposed to be the crux of the forest sustainability assessment because it is at this level that measurable and observable sustainable management can be directly assessed (Mendoza & Prabhu, 2000a). Hence, in this section the votes/judgments of stakeholders elicited via ranking and pair-wise comparison techniques are analyzed. Using equation (5.2) relative weights of the criteria under each principle were calculated. The calculated relative weights are 'composite' weights in the sense that the votes of all participants via both ranking and pair-wise comparison methods were considered. Table 5.4 presents the calculated relative weights using ranking method (column 2) and pair-wise comparison method (column 3) (see appendix 5C for procedural details of computing relative weights in pair-wise comparison method).

In prioritizing or ordering the relative importance of criteria under each of the six principles there is relatively consistent agreement among the two MCA methods (ranking and pair-wise comparison). A very interesting result arises when a criterion that received the first rank or order by 'ranking technique' has also received the first order of importance in 'pair-wise comparison method' under all the six principles. Accordingly, criteria C1.1, C2.1, C3.1, C4.3, C5.1, and C6.2 are consistently ranked first (under their respective principles P1, P2, P3, P4, P5, and P6) by both MCA methods. This zero level of disagreement in the priority rankings implies that all the participants agree on the priority order of the criteria. A careful examination of table 5.4 also reveals that the level of disagreement in the priority rankings given by the two methods is generally low. For instance, most of the criteria ranked second or third by pair-wise comparison method have also received either second or third order of importance by the ranking technique, though the positions of ranks may reverse in the two methods.

Within the ecological principles of sustainable forest management (principles 1 and 2), enhancement of the natural regeneration of indigenous plant species (criterion C1.1) and reduction or minimization of erosion and other forms of soil degradation (criterion C2.1) were identified as the two most important criteria to infer the status of forest ecosystem sustainability. Enhancement of plant biodiversity (criterion C1.3), improvement in water retention capacity of soils (criterion C2.3), and protection of downstream areas from flooding (criterion C2.5) were also among the high rated indicators. On the other hand criteria C1.2, C2.4, and C2.6 were rated lower than the rest of the criteria. Under the economic factor (principle 2), the perception of local people in benefit share (criterion C3.1) is identified as the most important attribute in assessing the economic principle of sustainable forest management. Participants unanimously agreed that the existence of fair mechanism in benefit sharing and local communities' perception of the fairness of the mechanism is essential for sustainable management. Under the social and institutional principles (principles 4 and 5), clear understanding and awareness (knowledge) about the economic and environmental benefits of exclosures (criterion C5.1), community participation at the various levels of forest management (criterion C4.3), and clear definition of the boundaries were given the top most important priorities in indicating or measuring the socio-institutional criteria of sustainable forest management.

Table 5.4 also presents the SD of the ranking preferences of the team members. As the SD of ranking measures the (in)consistency or (dis)agreement of ranks among the team members, it can be seen from the last column of table 5.4 that in general criteria with larger relative weights show less variability (higher consistency) in the rankings. Moreover, inconsistency in the rankings of the individuals tends to increase as the relative weights of the indicators decrease. The important implication of larger inconsistency is that there exist significant differences among the stakeholders in the importance order of the particular criterion to the principle it measures or the overall sustainable forest management. Mendoza and Prabhu (2000a) suggest the use of the relative weights obtained from pair-wise comparisons if a significant difference persists (even after repeating the ranking and pair-wise comparisons exercises). As pair-wise comparison method involves one-on-one comparisons between each of the indicators, it is supposed to be more refined and accurate approach.

Table 5.4 Analysis of relative weights[+] and priority rankings of criteria

Indicator	Relative weight[a] (%) (RM)[b]	Relative weight[a] %) (PWC)[c]	SD. of ranking (RM)[b]
Principle (1) The natural regeneration of vegetation or forests should be enhanced			
C1.1 Natural regeneration of indigenous plant species are enhanced in exclosures	23.78(1)	27.33(1)	1.0919
C1.2 The size of forested area is increased	16.44	7.97	1.8432
C1.3 Plant biodiversity is enhanced	20.67(2)	20.57(3)	1.0682
C1.4 Microclimatic conditions are improved.	19.78(3)	19.06	1.573
C1.5 Wildlife population are increased	19.33	25.07(2)	1.6525
Principle (2) The soil and water conservation effect of exclosures is enhanced			
C2.1 Erosion and other forms of soil degradation are minimized	20.61(1)	35.92(1)	0.5991
C2.2 Soil fertility is improved	16.27	12.94	1.2558
C2.3 Water retention capacity of soil is enhanced	17.54(3)	19.34(2)	1.2659
C2.4 New springs are originated	15.73	13.34	1.4936
C2.5 Protection of down stream areas from the negative effects of periodic Flooding is enhanced.	18.08(2)	18.46(3)	1.3156
C2.6 Improvement in quality and availability of water from the catchments.	11.75	*	1.8708
Principle (3) Management of exclosures should maintain or enhance the flow of economic benefits to the local community			
C3.1 Mechanisms for sharing benefits are perceived as fair by local communities.	13.68(1)	25.45(1)	1.0801
C3.2 Exclosures are established in marginal or less productive land (not on farm land).	12.11(2)	13.86	2.178
C3.3 People have access to fuel wood for subsistence use and sale	11.71	12.65	1.9513
C3.4 People obtain construction materials	10.53	11.55	1.5191
C3.5 People produce farm implements and furniture	11.71	20.06(2)	1.9513
C3.6 The interest of local people to harvest Non-Wood Forest Products is not unnecessarily restrained.	11.97(3)	16.43(3)	1.7321
C3.7 High opportunities exist to harvest apiary values (bee keeping values).	12.11(2)	*	1.2558
C3.8 Crop damage by wild animals and rodents harboured within exclosures is not significant.	9.21	*	2.1809
Principle (4). Enabling institutional conditions for sustainable management of exclosures should be put in place			
C4.1 Exclosures boundaries are clearly defined and agreed upon by the Community	11.27(2)	13.26(2)	1.4142
C4.2 Well-defined property rights (security of tenure is clear and documented)	10.73(3)	10.18	1.3253

Table 5.4 (*Continued*)

C4.3 Community participates at various levels of forest management and decision-making mechanisms	11.81(1)	17.98(1)	0.7679
C4.4 Access rules to products from exclosures	9.53	8.22	1.3634
C4.5 Clearly defined management rules	10.73(3)	9.41	0.7679
C4.6 Clearly defined benefit sharing rules	10.18	10.59	1.6408
C4.7 Appropriate monitoring and control mechanism	10.62	11.96(3)	1.2659
C4.8 Appropriate sanctioning and enforcement system	9.86	9.55	1.6833
C4.9 Appropriate mechanism of conflict resolution	9.32	8.85	2.0631
C4.10 Periodic revision of management plan	5.96	*	2.2361
Principle (5): Local community should have adequate knowledge and awareness about the need for managing exclosures sustainably.			
C5.1 Community has clear knowledge about the socio-economic & environmental services provided by exclosures.	15.13(1)	26.46(1)	0.5547
C5.2 Children are educated formally or informally about the importance of trees and natural resource management	13.03(2)	16.88	1.1929
C5.3 People recognize the need to balance number of people with natural Resource use	11.71	14.01	0.9871
C5.4 People invest in their surroundings (time, effort (labour), and money)	12.11	16.90(3)	1.2558
C5.5 Local community meet with satisfactory frequency to discuss issues Related to the management of exclosures	12.63(3)	25.75(2)	1.1929
C5.6 Local community is able to compare future long-term benefits to short-term benefits from forested lands.	11.97	*	1.7321
C5.7 All people keep the rules	11.84	*	1.1152
C5.8 No cutting of live trees	11.58	*	1.8777
Principle (6) Functioning buffer zones should exit.			
C6.1 Buffer zones exists for grazing and browsing	14.21	8.16	2.6092
C6.2 Local people respect the boundaries of exclosures (no encroachment)	20.37(1)	26.80(1)	0.8697
C6.3 Low levels of conflict at the boundaries of exclosures	16.07	12.07	1.7097
C6.4 Forest guards have demonstrated attempts to protect exclosure boundaries	17.01(2)	13.74	1.291
C6.5 Forest unit is zoned into areas to be managed for various functions (fodder areas; periodic grazing areas; ….)	16.45(3)	16.34(3)	1.5359
C6.6 having enough grazing areas for livestock out of exclosures	15.89	22.90(2)	1.7134

RM= ranking method; PWC= pair-wise comparison; [+] The calculated relative weights under RM & PWC are composite weights which consider the votes of all participants in the stakeholders' workshop; [a] numbers in the parentheses are priority ranking of criteria (only the first three prioritizations of indicators under each criterion for both RM and PWC methods were presented); [b] the relative weight is calculated using RM; [c] the relative weight is calculated using PWC method; *Pair-wise comparisons were not undertaken for these indicators.

5.5.5 Assessment of the performance of existing forest management

One of the main objectives of this chapter is to assess the performance of prevailing management systems of exclosures against the C&I elements. For this purpose the participants were asked to 'score' the performance of the existing management scheme (*zero grazing, zero wood harvesting, and partial cut-and-carry management scenario* (see section 5.6)) relative to each of the principles and criteria of sustainability.

Table 5.5 Analysis of performance of the principles

Criteria	Average scores	SD. of scores	Weighted scores(RM[a])	weighted scores(PWC[b])	Relative weights (%)
Principle 1	2.77 (4)♥	1.42	3.27 (4)	3.21 (4)	17.44
Principle 2	5.62 (1)	1.62	4.81 (1)	5.14 (1)	16.90
Principle 3	2.92 (3)	1.26	3.67 (3)	3.66 (3)	17.08
Principle 4	3.38 (2)	1.89	3.75 (2)	3.96 (2)	17.08
Principle 5	2.38 (5)	1.39	2.49 (6)	2.50 (6)	19.57
Principle 6	0.46 (6)	0.52	2.87 (5)	2.95 (5)	11.92

[a]RM= ranking method. In the column-4 the weights used are relative weights of the criterion calculated by RM;
[b]PWC= pair-wise comparison. In column-5 the weights used are the relative weights calculated by PWC method.
♥Numbers in the parenthesis are the order of 'performance scores' of the principle.

Table 5.5 presents the average and weighted 'performance scores' (equation 5.3 was used in calculating the weighted performance scores). To facilitate our comprehension of how the existing forest management performing against the relatively important C&I elements, the 'relative weights' of each principle from table 5.3 is reproduced in the last column of table 5.5.

Based on the results of table 5.5, the following major points can be noted:

1. The performance scores or measures indicate that all the principles, except principle 2, are performing below what is considered *average and acceptable.* According to the scoring guide (see footnote 63) a score of 5 or above is average and acceptable. On the basis of both the average and PWC weighted scores, principle 2 (i.e. "The natural regeneration of vegetation or forests should be enhanced") performs slightly above the *average* level. This is an interesting

result that reflects the real condition of the study area. In Tigray region in general and particularly in *Douga* Tembien district (the study area) the massive soil and water conservation activities undertaken so far have resulted in significant improvements in conserving the district's soil and water. Since an exclosure is among the major soil and water conservation practices implemented in the study area, the observed high performance score indicates its success in terms of soil and water conservation.

2. Principle 5, the principle that received the highest relative weight (i.e., the most preferred principle in terms of its importance for the sustainable management of exclosures), shows the least performance score. With a weighted performance index of 2.5, this principle performs in between '*poor*' and '*fair but below average'* performance levels. This implies that current level of public awareness and knowledge on sustainable forest management is inadequate to serve the management objective.
3. In general, the existing management of exclosures has not performed well as evidenced by lower performance indices based on both average and weighted scores.
4. The performance indices were not sensitive to the MCA methods used. In other words, using RM and PWC weights have not affected the order of performance scores.

Table 5.6 presents the performance indices at the criteria level. As with the case in performance indices of principles, most of the criteria show below average level of performance. Comparing all the criteria under principle 2 with the rest of the criteria, we see that the former performs well relative to the latter. This is consistent with the performance results at the principle level (table 5.5). As can be seen from table 5.6, most criteria received performance indices between 3 and 5 which mean that the existing forest management is performing between the '*fair but below average*' and '*average and acceptable*' levels against these criteria. Consequently, we can safely generalize that forest management in the study district is not performing well on the basis of most of the criteria used in this study.

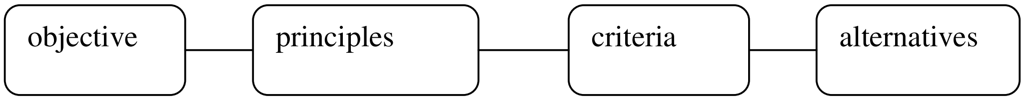
Table 5.6 Analysis of performance of current forest management against the C&I elements

Criteria	average scores	SD. of scores	Relative weights		criteria	average scores	SD. of scores	Relative weights	
			RM[a]	PWC[b]				RM[a]	PWC[b]
Principle (1)									
C1.1	3.23	1.96	23.78(1)▲	27.33(1)	C4.3	4.38	2.10	11.81(1)	17.98(1)
C1.2	3.31	2.53	16.44	7.97	C4.4	4.00	2.08	9.53	8.22
C1.3	3.69	1.97	20.67(2)	20.57(3)	C4.5	3.85	2.19	10.73(3)	9.41
C1.4	3.69	2.06	19.78(3)	19.06	C4.6	4.15	1.82	10.18	10.59
C1.5	2.38	2.22	19.33	25.07(2)	C4.7	3.54	1.66	10.62	11.96(3)
Principle (2)					C4.8	3.15	1.14	9.86	9.55
C2.1	5.77	1.92	20.61(1)	35.92(1)	C4.9	3.46	1.20	9.32	8.85
C2.2	4.54	1.39	16.27	12.94	C4.10	1.50	1.96	5.96	*
C2.3	4.38	1.19	17.54(3)	19.34(2)	**Principle (5)**				
C2.4	4.54	1.71	15.73	13.34	C5.1	3.15	1.68	15.13(1)	26.46(1)
C2.5	5.54	2.07	18.08(2)	18.46(3)	C5.2	1.92	1.61	13.03(2)	16.88
C2.6	3.42	1.98	11.75	*	C5.3	1.46	1.13	11.71	14.01
Principle (3)					C5.4	2.15	1.72	12.11	16.90(3)
C3.1	4.00	1.63	13.68(1)	25.45(1)	C5.5	3.00	1.78	12.63(3)	25.75(2)
C3.2	5.85	2.79	12.11(2)	13.86	C5.6	2.69	1.44	11.97	*
C3.3	2.92	1.55	11.71	12.65	C5.7	2.62	1.45	11.84	*
C3.4	1.69	1.32	10.53	11.55	C5.8	2.77	1.92	11.58	*
C3.5	2.77	2.24	11.71	20.06(2)	**Principle (6)**				
C3.6	4.15	2.44	11.97(3)	16.43(3)	C6.1	0.85	1.14	14.21	8.16
C3.7	5.23	2.74	12.11(2)	*	C6.2	3.00	1.87	20.37(1)	26.80(1)
C3.8	4.77	2.09	9.21	*	C6.3	3.77	1.74	16.07	12.07
Principle (4)					C6.4	4.23	2.01	17.01(2)	13.74
C4.1	5.31	2.21	11.27(2)	13.26(2)	C6.5	1.92	1.80	16.45(3)	16.34(3)
C4.2	3.00	2.35	10.73(3)	10.18	C6.6	3.15	2.48	15.89	22.90(2)

[a]RM= ranking method. In this column the relative weights of the criterion are calculated by RM; [b]PWC= pair-wise comparison. In this column the relative weights are calculated by PWC; ▲Numbers in the parentheses are performance orderings of criteria (only the first three performance orderings of criteria under each principle for both RM and PWC methods were presented); *Pair-wise comparisons were not undertaken for these criteria.

5.6 Analysis of alternative forest management scenarios

Choosing a particular forest management option that can best satisfy the objective of sustainable forest management among a number of conceivable alternatives involves a systematic comparison of the alternatives against one another with respect to a set of factors or criteria. The alternative that rates the highest becomes the preferred one when comparison is made. In decision or choice problems that involve multiple criteria/attributes, the decision criteria should be prioritized and grouped in order to organize information and make judgements in selecting a preferred alternative (InfoHarvest, 2001). The analytical hierarchy process (AHP) is the preferred method of organizing decision information and judgments. With the help of this method, decision problems are structured as a layered diagram starting with the goal, then the most important criteria (principles in our case), followed by layers of subcriteria, and finally the alternative as shown below.



The objective or goal is what we want to achieve. The principles are the factors that we want to consider in our choice and the criteria or subcriteria are factors that reflect detailed knowledge of the choice problem. Alternatives are compared one another with respect to the criteria and the alternative that rates the highest becomes the preferred one.

In analyzing the choice of a particular forest management alternative, in this section, we consider the six principles and forty-two criteria identified in the stakeholders' workshop and used in the analysis of the preceding sections. The weights to the relative importance of the principles with respect to the overall goal of sustainable forest management and all the criteria with respect to the principles (parent criteria) were already assigned by the stakeholders. Stakeholders have also given scores to the existing forest management scheme against each of the principle and criterion (see section 5.5.5). In order to evaluate, compare and choose the most preferred forest management scheme that can best satisfy the goal of SFM, six forest management scenarios or alternatives were identified.

- Scenario-1 **(A1)**: *Existing management system* (zero grazing, zero wood harvesting, and partial cut-and-carry).
- Scenario-2 **(A2)**: *Reference Scenario* (open access, free resource utilization, no property rights, tragedy of the commons).
- Scenario-3 **(A3)**: *No access scenario* (full closing; nothing is allowed to harvest from exclosures).
- Scenario-4 **(A4)**: *cut-and-carry, controlled pruning, and controlled thinning* scenario.
- Scenario-5 **(A5)**: *(A4) + rotational grazing scenario* (cut-and-carry, controlled pruning, controlled thinning, controlled rotational grazing).
- Scenario-6 **(A6)**: *(A4) + enrichment plantation scenario (*cut-and-carry, controlled pruning, controlled thinning, enrichment plantation of indigenous species).

As discussed earlier (A1) was scored during the stakeholders' meeting against each principle and criterion. Alternative management scenarios (A2) to (A6) were given scores by experts against each of the criteria. Given the weights of the criteria and scores of the alternatives, the basic algorithm in multicriteria decision or choice analysis is to multiply the scores of each alternative against each of the criterion by the relative weight of the criterion. Summing those products over all criteria provides the overall decision score which serves as a measure of how best a particular alternative satisfies our goal.

Using the Criterium DecisionPlus (cdp version 3.0) software, the six principles and forty two criteria are structured hierarchically (figure 5.2) by applying the AHP. On the basis of the hierarchical structure in figure 5.2, the six principles are the first level factors to be considered in analyzing the choice problem and the forty two criteria give detailed information or measurements of the principles. As scoring of alternatives are against the criteria, they are linked directly with the criteria.

Note: SFM= sustainable forest management; NWFPs= non-wood forest products; SR= short-run; LR=long-run

Figure 5.2 Levels of decision hierarchy (structure of the choice problem)

Once the decision factors are put in a hierarchical structure figure 5.2), the weight assigned to each principle and criterion and the score assigned to each alternative against the criteria are fed to the DecisionPlus software and AHP rating technique is used. Execution of this programme results in the final score of each alternative (figure 5.3) (see appendix 5D for the details of AHP decision scores).

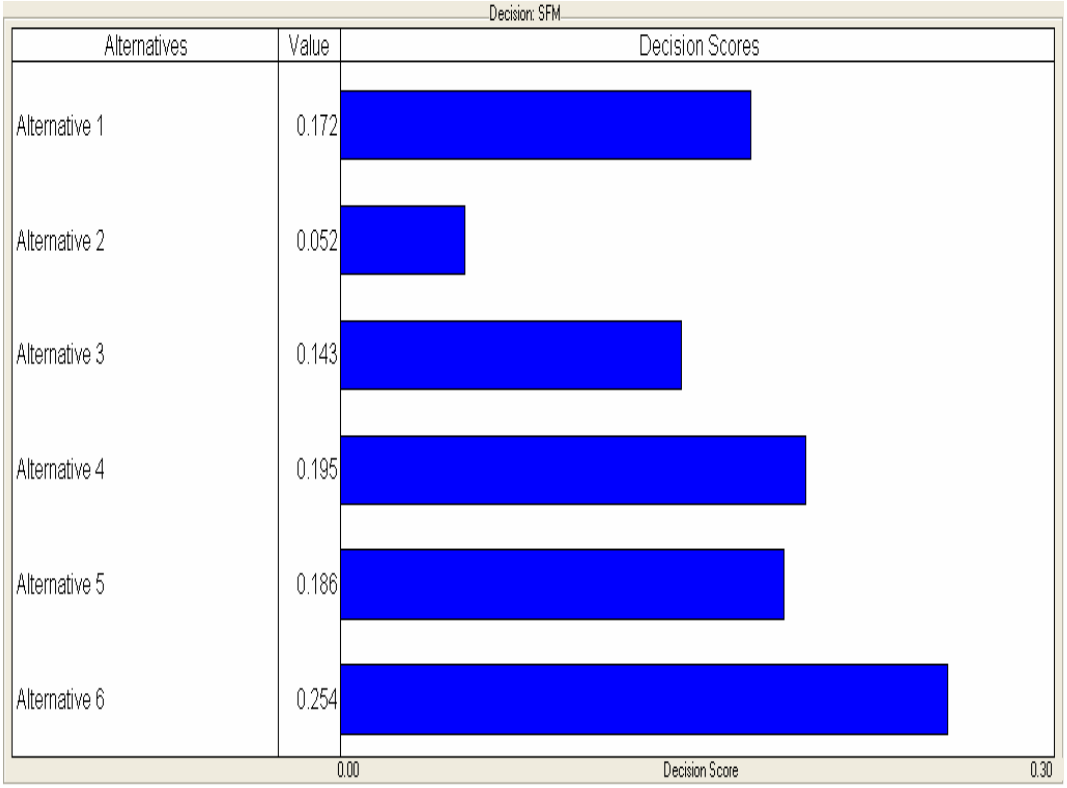


Figure 5.3 Scores of alternative forest management scenarios

On the basis of figure 5.3, the sixth alternative (scenario) – the scenario with *cut-and-carry, controlled pruning, controlled thinning, and enrichment plantation of indigenous tree species* – obtains the highest score i.e., it is the best forest management scheme comparing with all the scenarios presented in figure 5.3. The current management system of exclosures (A1) ranks fourth out of the six management scenarios and as expected the *reference scenario* (alternative 2) receives the least score (last rank). As the reference scenario reflects an ‘open access’ situation, it is *a priori* expected that this scenario does not satisfy most of the principles and criteria identified for SFM.

Further examination of the sixth management alternative against the SFM principles identified would provide the reason as to why this scenario is the most preferred scenario. The cut-and-carry, controlled pruning, and controlled thinning practices provide essential forest products (mainly grass for animal feed and fuelwood) which induce important economic incentives for local people to manage forests sustainably. Enrichment plantation of indigenous tree species, on the one hand, contributes to the ecological sustainability of forests and enhances forest environmental services such as soil and water conservation and microclimatic regulation. On the other hand, local people's exertion of labour and time on enrichment plantation strengthens the sense of local ownership of the resource system. People feel more responsible for the sustainable management of their resources and are induced to develop effective resource management and use rules. They are motivated to place effective monitoring tools in order to prevent free-riders. This implies that the sixth forest management scenario is in favour of the major principles of SFM. It is because of the positive accommodation of SFM principles that alternative-6 has got the highest score and considered as the best alternative.

Though both alternative-4 and alternative-5 possess similar practices of cut-and-carry, pruning, and thinning as in alternative-6, because of the absence of enrichment plantation in alternative-4 it scores less on ecological criteria. The addition of rotational grazing practice in alternative-5 results in a further decline of its scores on ecological criteria. As grazing reduces biomass production, the volume of herbaceous (cut-and-carry) and wood production will decrease. Grass production also seems more efficient if grass is harvested in a cut-and-carry system when it matures at the maximum yield level rather than letting livestock to graze. Grazing and cut-and-carry inevitably involve trade-offs. The cut-and-carry system seems more economical in biomass production. It may be due to this reason that alternative-4 ranks second while alternative-5 has the third rank in satisfying the goal of SFM.

5.7 Discussion

Our analyses provide important insights into the management problems of exclosures in Tigray. Environmental rehabilitation and conservation interventions by both governmental and non-governmental organizations alike are focusing mainly on installing biophysical measures/structures and pay less attention to the socio-economic and institutional side of the coin. This led to the poor performance of many of the environmental reclamation programs in Ethiopia. For instance, despite its large-scale introduction since 1991, the performance of exclosures in Tigray has been lagging behind the excepted outcomes. This is attributable to the management problems of the resource system.

Decisions towards sustainable management of natural resources such as community forests with its multiple functions and many stakeholders (possibly with conflicting interests and preferences) need to accommodate the range of goods and services provided by forests, involve the participation of multiple interest groups, and incorporate as much data as possible (both qualitative and quantitative). This entails identifying the principles, criteria and indicators of sustainability that reflect the local context, assessing their relative importance to management objectives, and taking appropriate measures to improve the overall performance of forest management. In this respect MCA provides an appropriate tool for addressing the challenges of sustainable forest management.

Among the important lessons learnt during the stakeholder workshop was the immense potential and ability of the local community in identifying a range of factors (P, C&I elements) for sustainability assessment. One key element that attracted the attention of many participants of the workshop was the debate on the importance of 'alternative energy sources' for the sustainable management of forests in Tigray. According to the participants, fuelwood is the sole source of domestic energy in the rural areas of the study district and most urban households also use fuelwood. They argued that cutting trees for domestic energy is the major factor for the recent deterioration of forests in the area. In the absence of alternative energy sources the rising local demand for fuelwood would become the major threat for forest degradation. It is also argued that rural households in the study area do not have access to alternative energy for domestic use. In rural areas the supply of alternative energy is almost zero and even if such sources were available, people would not afford them because of the simple reason that they are poor. Similarly, poverty forces poor urban households to use fuelwood as it is relatively cheaper compared to alternative urban energy sources such as electricity. After a long and lively debate over this issue, most participants agreed that including ‘alternative energy sources’ in the list of P, C&I for sustainable management of exclosures does not have practical importance in the context of the study area. Because, at present, such sources are not available in the rural areas. Hence we have not included this criterion in the MCA. However, two essential implications are learnt from the debate: 1) a local community has the capacity and potential to identify the P, C&I elements relevant for their own condition; and 2) the provision of ‘alternative energy sources’ is an important policy issue and concerned government agencies and donors should critically examine the technological and economic feasibility if such intervention pays for sustainable forest management in Tigray.

Another important issue was the evaluation of the current forest management practice in the study area and the possibility of introducing alternative management scenarios. In this regard, on the basis of the P, C&I elements identified the performance score of the current forest management is low in most of the P, C&I elements. Thus, judged by the P, C&I elements of forest sustainability, the current forest management cannot be considered to be a sustainable path. On the basis of our analysis (section 5.6), a more flexible forest management alternative that allows more forest products to the local community and that involves the participation of local people not only in benefit sharing and management decision but also in provision/supply of the CPR in terms of enrichment plantation and tenure security should be introduced.

5.9 Conclusion and policy implication

This chapter has demonstrated the process of identifying C&I elements for forest sustainability and assessing sustainable resource management using MCA as a framework of analysis. On the one hand, the framework enables the accommodation of diverse views, interests, preferences, and expertise of stakeholders and on the other hand, it provides an analytical structure in evaluating the importance and/or impact of the decision elements (the P, C&I elements in the hierarchy) from the points of views of various stakeholders with respect to the overall objective of sustainability in forest management.

With the help of MCA, we identified the relevant P, C&I elements and assessed their relative importance and performance against the objective of sustainable forest management. Our analyses indicate that most of the P, C&I elements show poor performance. This implies that the existing management of exclosures does not reveal forest sustainability. Thus, the application of 'standardized environmental management packages' which pays due attention to the ecological aspects alone has to be substituted by the research-based holistic management prescriptions so that the objective of sustainability may be attained.

If we were to harmonize both developmental and environmental objectives of exclosures in a sustainable manner, locally relevant sets of criteria and indicators of sustainability should be carefully identified and evaluated from the local perspectives. The criteria and indicators have to be prioritized according to their relative importance to the sustainable management of forests .Any environmental intervention, resource use and management plan, and design of rules and regulations should be holistic and take into account the prioritized preferences of stakeholders.

Based on our findings two key policy recommendations are forwarded: 1) due attention should be paid to community awareness and knowledge dissemination, as this is the criterion that received the highest relative importance to forest sustainability but currently with below average performance level; and 2) the poor performance of most of the C&I elements of sustainability under the current management scenario send signals to re-think and introduce appropriate management options by taking into account the multiplicity of forest functions and diversity of stakeholders' interests and preferences.

Appendices 5

Appendix 5A. Focus group discussion: Preparation, selection of participants, discussion guides, and conducting the sessions

1) Preparation and selection of the participants:

The villages where the participants are drawn for the focus group discussions are those villages that the earlier rural household survey[66] was conducted. From each of the six selected villages three groups of participants (a total of 18 focus groups) were identified. The number of participants in each group ranges from 5-8 persons (the optimum group size suggested for focus group discussion). Regarding the composition of the three groups; the first group consists of local *'Tabia'* level leaders including the *Tabia* chair-person and other local administrative and religious leaders. In the second group, we have included ordinary but active male farmers. The third group consists of only women participants. All the participants are identified and recruited with the help of local contact persons and facilitated by the moderators.

2) Facilitators/Moderators:

All the facilitators are grown up and have sufficient knowledge of the study area. They have enormous field experience in data collection for numerous researchers (as enumerators, translators, interviewers, facilitators/moderators, and field workers). Two of them have already obtained their Diploma in Agricultural Science and the other two are undergraduate students at Mekelle University, one in Economics and the other in Management Science. Half-day training on how to facilitate a focus group was given to the moderators two days before the actual focus group discussions took place.

3) Discussion Guides:

Focus group discussion involves a way of learning about opinions, views, attitudes, and experiences (in-depth qualitative information) of selected group of individuals about a particular topic. As such it requires organized discussions/interviews with a

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[66] From March - April 2005, a rural household survey was conducted in 12 villages of the *Douga* Tembien district (the study area). In this survey 360 households were sampled to elicit detailed quantitative information regarding the livelihood portfolio of rural dwellers, particularly emphasizing on the products and services that rural people harvest or extract from environmental resources in general and exclosures in particular.

small number of carefully selected people. To keep the discussion focused, key open-ended discussion guide questions have to be developed carefully. Accordingly, the following discussion guides was developed.

- *Exclosures (the resource system*[67]): Under this heading participants are expected to share their knowledge and experience on issues, such as: the number of exclosures belonging to the community, whether they know the exact physical boundaries of each of the exclosures, the period or time when these exclosures were established, who and how they were established, and additional related information probed by the facilitator.
- *The products (the resource unit)*: the type of products that households are allowed to harvest from exclosures, the importance of these products to household livelihood system, products that are prohibited, the type of products that people are willing to harvest but not permitted, and other similar issues related to environmental products from exclosures are supposed to be discussed under this discussion guide.
- *The users (appropriators) and accessibility*: the boundaries of users, their size, whether there exists some discrimination in access, whether there exists households and/or groups in the community denied of access to exclosures, and the like.
- *Rules/Regulations*: This is the major discussion topic under which both the use and management rules were supposed to be discussed in detail. The existing formal and informal use and management rules, their evolution, community participation in the formulation of these rules, the monitoring, enforcement and sanctioning mechanisms, the acceptance of these rules by the community, and other related issues probed during the discussions are considered.
- *Problems, conflicts, and violations*: the problems of the existing institutions, inter and intra community conflicts, causes of violations of rules, and similar issues were discussed under this topic.
- *The need to change/improve use and management rules*: questions such as, "Are the existing use and management rules are best for sustainable exclosure management? What changes/modification should be introduced to fit the rules

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[67] Resource system refers to the physical stock of the natural resource base from which products and services are appropriated. In relation to exclosures, resource system is physical base of exclosure itself.

with sustainability objective? How and who should introduce the changes?" were some of the questions dealt under this topic.

4) Discussion Sessions:

All the focus group discussions were held in the month of March 2006. On the basis of the above six broad discussion topics, 2-3 hrs discussions were convened with each of the team. Group participation was sufficiently high. Convenient places/venues were carefully chosen in each of the villages. Each discussion is held in an open-air area under a big tree with sufficient shades in such a way that participants can easily see their exclosures physically during the discussion. Such an arrangement allows the participants to relate and easily remember their experiences and views regarding the issues about exclosures during the discussions.

All the discussions were held in local *'Tigrigna'* language. Each session is facilitated by two moderators- a principal moderator and an assistant. *Tigrigna* is the mother-tongue of both facilitators. The principal moderator's role is providing clear explanation of the purpose of the meeting, helping people feel at ease, facilitating interaction between group members, probing additional query or information when necessary, and keeping the discussion appropriately focused. The assistant tape records the discussion and keeps notes of comments. The researcher has also attended all the discussions.

Appendix 5B. MCA methods (Ranking, pair-wise comparisons, and scoring)

1. Ranking

Nine point scales is to be used in ranking. Ranking is an MCA tool that assigns each element - relevant to the decision process - a **'rank'** depending on its perceived importance. Ranks are assigned according to the following 9 point scale**.** Numerical scale used for ranking of criteria and indicators to indicate the **relative importance** of the **criterion** to sustainable forest management and **indicator** to the respective criterion are given as follows:

1	3	5	7	9
Weakly important	Less Important	Moderately important	More important	Extremely important

Note: 2, 4, 6, and 8 are intermediate assessments which can also be used in ranking the relative importance of the decision element.

2. Ranking format

The following format is used to elicit responses from respondents about their opinions on the relative importance of each of the criteria relative to the overall forest (exclosure) sustainability or indicator relative to the criterion it indicates. The purpose of this form is to estimate the relative importance or weight of each criterion and on the basis of the data from the experts and stakeholders.

Criteria	**Ranking**
Criterion 1.	
Criterion 2.	

Indicators	**Ranking**
Indicator 1.1	
Indicator 1.2	

3. Pair-wise comparison

Pair-wise comparison (PWC) involves one-on-one comparison between the indicators. The relative importance of each pair of indicators in terms of the criteria they measure are judged using the PWC method. The following 9 point numerical scale is used for comparative judgement (pair-wise comparisons) of indicators.

Scale	Meaning/interpretation
1	Equal importance
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important

4. Data collection format for PWC

To calculate the relative weights of, for example the five indicators under criterion-1, using the PWC method each team member is given a response format of the following type and asked to compare each indicator to the other four indicators under criterion-1. In the format the shaded cells the ones chosen by a team member the relationship between the each pair of the indicators compared. For instance, the shaded cell (number 5) in the first row indicates that from the point of view of one team member, I1.1 is ‘strongly more important’ than I1.2 with respect criterion-1. All team members do their comparisons individually in the similar manner for all indicators. Other shaded cells can be interpreted in a similar manner.

I1.1	9	8	7	6	[✓ 5]	4	3	2	1	2	3	4	5	6	7	8	9	**I1.2**
I1.1	9	8	7	6	5	[✓ 4]	3	2	1	2	3	4	5	6	7	8	9	**I1.3**
I1.1	9	8	7	[✓ 6]	5	4	3	2	1	2	3	4	5	6	7	8	9	**I1.4**
I1.1	9	8	7	6	5	4	[✓ 3]	2	1	2	3	4	5	6	7	8	9	**I1.5**
I1.2	9	8	7	6	5	4	3	2	1	2	[✓ 3]	4	5	6	7	8	9	**I1.3**
I1.2	9	8	7	6	[✓ 5]	4	3	2	1	2	3	4	5	6	7	8	9	**I1.4**
I1.2	9	8	7	6	5	4	3	[✓ 2]	1	2	3	4	5	6	7	8	9	**I1.5**
I1.3	9	8	7	6	5	4	[✓ 3]	2	1	2	3	4	5	6	7	8	9	**I1.4**
I1.3	9	8	7	6	5	4	3	2	1	2	3	[✓ 4]	5	6	7	8	9	**I1.5**
I1.4	9	8	7	6	5	4	3	2	1	2	3	4	[✓ 5]	6	7	8	9	**I1.5**

5. Scoring

Scoring is a method used to examine and judge the *current condition* of each indicator relative to a *perceived target or desired condition* of the indicator. The desired condition is used to reflect or represent a ‘sustainable state’ of the indicator. In multi-criteria analysis, a 9-point scale can be used to elicit information.

1	3	5	7	9
The indicator is in **poor /unfavourable** condition relative its to the desired condition	The indicator is in **fair but below average** condition	The indicator is in **average and acceptable** condition relative to its desired condition	The indicator is in **good condition** relative to its desired condition	The indicator is in **excellent/outstanding performance** condition relative to its desired condition

Note: 2, 4, 6, and 8 are intermediate assessments which can also be used in scoring the performance of the decision elements.

Appendix 5C. Illustration of relative weight calculation method from 'pair-wise comparison' data (responses)

The relative weights of indicators from the responses or data collected using pair-wise comparison method can be easily calculated by using a comparison matrix. We will illustrate the calculation by generating the comparison matrix from the numbers in the shaded cells of the sample pair-wise comparison format given under appendix 5B as follows. The numbers are the response of one of the participants of the workshop in comparing each of the indicators under criterion-1 to one another.

	I1.1	I1.2	I1.3	I1.4	I1.5
I1.1	1	5	4	6	3
I1.2	0.2	1	0.33	5	2
I1.3	0.25	3	1	3	0.25
I1.4	0.17	0.2	0.33	1	0.2
I1.5	0.33	0.5	4	5	1

Let's explain the data in the matrix using some values from the *first row* as an example.

- The first number is 1 because indicator I1.1 is being compared to itself.
- The second number is 5 because the participant considers I1.1 to be 'more strongly important' (value 5) than I1.2. Hence the value 5 is placed at the intersection of row I1.1 and column I1.2 and the value 1/5 or 0.2 (the reciprocal) is placed at the intersection of row I1.2 and column I1.1.
- The third number in the first row is 4 because I1.1 is considered as 'more important' in comparison to I1.3 by the team member. Hence the value of 4 is placed at the intersection of row I1.1 & column I1.3 and the reciprocal of 4 i.e. 0.25 is put at the intersection of row I1.3 & column I1.1. All the remaining entries of the matrix can be read or interpreted in the similar fashion.

After we transform the data into matrix from, we follow the following steps to calculate the relative weights of indicators.

1. Sum the elements of each column. Then normalize the elements in each column by dividing by the column sum. For instance, the sum of the first column is 1.95. If we divide all the entries in the first column we will obtain

0.5128, 0.1026, 0.1282, 0.0872, and 0.1692 (rounded to four decimal places). Applying similar arithmetic in all the columns, we will get the following matrix.

	I1.1	I1.2	I1.3	I1.4	I1.5
I1.1	0.512821	0.412371	0.414079	0.30	0.465116
I1.2	0.102564	0.034021	0.034161	0.25	0.310078
I1.3	0.128205	0.103093	0.10352	0.15	0.038760
I1.4	0.087179	0.034021	0.034161	0.05	0.031008
I1.5	0.169231	0.412371	0.414079	0.25	0.155039

2. Add the normalized elements of each row. Then divide the row totals by the number of indicators compared (5 in our case). These two operations result in the following values. The shaded column gives the relative importance (weights) for each of the indicators according to this team member.

horz_sum	**sum/5**
2.104387	0.420877
0.730824	0.146165
0.523577	0.104715
0.236369	0.047274
1.400719	0.280144

3. Following the same procedure calculate the relative weights from data or responses of each participant (for example, in our case for each of the 13 participants of the workshop). Then sum up the corresponding relative weight value of all the participants for each indicator separately and divide by the number of participants. This will give us the final relative weight for each indicator.

Appendix 5D. The AHP decision scores

Criteria	*Alternative 1*	*Alternative 2*	*Alternative 3*	*Alternative 4*	*Alternative 5*	*Alternative 6*	*Model Weights*
Indigenous plant species are enhanced	0.169	0	0.302	0.151	0.113	0.265	0.043
Size of forested area is increased	0.167	0	0.145	0.217	0.181	0.29	0.028
Plant biodiversity is enhanced	0.212	0	0.236	0.158	0.118	0.276	0.036
Microclimatic condition are improved	0.19	0	0.211	0.176	0.141	0.282	0.035
Wildlife population is increased	0.147	0	0.32	0.16	0.107	0.267	0.034
Soil degradation is minimized	0.254	0	0.213	0.186	0.133	0.213	0.04
Soil fertility is improved	0.194	0	0.23	0.173	0.173	0.23	0.031
Negative downstream are protected	0.283	0	0.249	0.156	0.125	0.187	0.035
New springs are developed	0.243	0	0.206	0.138	0.138	0.275	0.03
Soil water holding is enhanced	0.2	0	0.237	0.178	0.148	0.237	0.034
Benefit sharing mechanism is fair	0.213	0.128	0.043	0.234	0.17	0.213	0.026
Exclosure are established on marginal lands	0.244	0	0.151	0.202	0.202	0.202	0.022
Access to fuelwood	0.117	0.244	0	0.213	0.183	0.244	0.022
Access to construction materials	0.044	0.319	0	0.191	0.255	0.191	0.019
Access to farm implements and furniture	0.116	0.229	0	0.262	0.262	0.131	0.022
Access to NWFPs	0.142	0.181	0.045	0.181	0.226	0.226	0.022
Bee-keeping opportunities exist	0.232	0.082	0.137	0.165	0.137	0.247	0.022
Crop damage by wild life is low	0.186	0.296	0.049	0.148	0.148	0.173	0.016
Appropriate sanction/enforcement exists	0.177	0	0.123	0.247	0.206	0.247	0.017
Tenure security is well-defined	0.133	0	0	0.267	0.267	0.333	0.019
Appropriate conflict resolution exists	0.206	0	0.084	0.251	0.251	0.209	0.016
Access rules are clearly defined	0.118	0.235	0.039	0.196	0.196	0.216	0.016
Management rules are clearly defined	0.16	0	0.168	0.224	0.168	0.28	0.016
Benefit-sharing rules are clearly defined	0.156	0.149	0	0.199	0.248	0.248	0.018
Appropriate monitoring mechanism exists	0.137	0	0.162	0.216	0.216	0.27	0.019
Revision of management plan exists	0.053	0	0	0.211	0.316	0.421	0.009
Boundaries are clearly defined	0.223	0	0.155	0.207	0.207	0.207	0.02
Community participates in decision-making	0.2	0	0	0.237	0.267	0.296	0.021
No cutting of live trees	0.12	0	0.203	0.203	0.203	0.271	0.023

People compare SR an LR benefits	0.133	0	0	0.236	0.315	0.315	0.024
People comply with rules	0.081	0.249	0.149	0.174	0.149	0.199	0.024
Regular community meeting	0.174	0	0.043	0.174	0.261	0.348	0.025
People invest in their surroundings	0.095	0	0.082	0.247	0.247	0.329	0.024
People balance population with resource	0.062	0	0.134	0.268	0.268	0.268	0.023
Children are educated about environment	0.074	0.04	0.081	0.242	0.242	0.322	0.026
Sufficient local knowledge exits	0.152	0.071	0.141	0.141	0.212	0.283	0.031
Grazing/browsing buffer zone exists	0	0	0.333	0.333	0	0.333	0.015
People respect boundaries	0.2	0	0.2	0.3	0.1	0.2	0.023
Boundary conflict is low	0.188	0.339	0.068	0.135	0.135	0.135	0.018
Guards protect boundaries	0.275	0	0.171	0.085	0.171	0.298	0.019
Forests are managed for various uses	0.116	0	0	0.126	0.379	0.379	0.018
Grazing areas are available out of exclosures	0.35	0	0.163	0.163	0.163	0.163	0.018
Scores	0.172	0.052	0.143	0.195	0.186	0.254	

Chapter 6

Conclusions and Recommendations

6.1 General conclusions

This dissertation is prepared in such a way that each of the four core chapters can be read more or less independently. Accordingly, on the basis of the findings of each chapter, conclusions and policy recommendations/implications were given at the end of each chapter. Therefore, in this chapter we provide only short concluding remarks and policy recommendations.

In this dissertation we formulated six major research questions that guide our empirical analyses (chapter 1 section 1.2). In order to answer these research questions, data (mainly primary data) were collected from the study district and various analytical tools were applied. Poverty indices and decomposition of Gini coefficients were used to investigate the 'poverty-environment' relationship. Multinomial logit models, cost benefit analysis (CBA), and multi-criteria analysis (MCA) were applied in the analysis of livelihood strategy choice, economic trade-offs of exclosure establishment, and sustainable management of forests respectively.

Generally, the central focuses of this study were the quantification and valuation of the economic contributions and environmental services of a specific type of common-pool natural resource system – forest environmental resources (with particular reference to exclosures) – to the local community and the assessment of sustainable management of the exclosures from local perspectives in the highlands of Tigray, Northern Ethiopia. Our empirical analysis shows that forest environmental products contribute significantly to the wellbeing of rural households and to the reduction of income inequality. In terms of relative dependence, households constrained with livelihood capitals are more dependent on forest environmental products. The analysis of soil and water conservation of exclosures indicates that the conversion of less productive land to forestry is justifiable and rational decision in economic terms (positive net present value). On the other hand, if productive crop land is converted to exclosures, social losses outweigh social benefits. Even in the degraded land case, despite the positive NPV, access restriction and tenure insecurity generate dissatisfaction and belief among the majority of the surveyed households that the social cost of exclosures is high. Established as a response to tackle the ongoing environmental crisis in Tigray, exclosures generate economic tradeoffs to the local community and consequently face serious management problems which become a threat to the sustainability of the resource system. Land areas reallocated to exclosures were being used either for grazing or source of wood and non-wood forest products or farm land by local people. However, the economic roles of forest environmental resources to the local community and local economic tradeoffs due to land use conversion were not put in the agenda while deciding to convert the land area to exclosures. As the establishment of exclosures were promoted mainly via ecological reasoning, local economic tradeoffs and appropriate compensatory policy schemes were not developed. Except some pieces of local use regulations (‘*serit*’), efficient and effective self-sustaining management schemes that take into account the twin objectives of development and conservation did not exist in the study area.

In general, the major or key findings of this study were: (1) forest environmental products play a significant role in the rural economy of the study areas in terms of mitigation of rural poverty and reduction of income inequality, (2) ‘asset poverty’ increases household dependence on forest environmental products, (3) conversion of degraded waste land to forestry generates positive net present value, and (4) the existing management scheme of exclosures is not sustainable.

6.2 Recommendations

Based on our findings, the following policy implications/recommendations are drawn.

1. As rural households generate various products from forest environmental sources and these products contribute significantly to the poverty and inequality of rural households, any forestry development programme (including the establishment of exclosures) should focus not only on the ecological benefits but also on the local economic trade-offs. In this regard, local economic costs of establishing exclosures and the range of benefits foreseen should be carefully analyzed and communicated to the community and any future conversion of land to forestry activity should be participatory and in agreement with the community before such conversions.

2. A constraint to access to livelihood assets is found to be the major reason for relative dependence of households on forest products. Therefore, the positions of asset-poor households should be enhanced by targeted rural interventions. As land holding decreases over time due to high population growth, access to natural capital (land) to landless or land-poor households can not be increased. We found that access to financial capital or cash-constraint is the major bottle-neck that impairs households' involvement in high-return economic activities such as off-farm small-scale business undertakings. Therefore, rural financial services must be expanded so that households will shift from extractive activities to high return economic activities with dual advantages: better economic benefit and resource conservation due to the shift of forest dependent household to other activities. This also minimizes illegal harvest of forest products from exclosures.

3. Our cost-benefit analysis of the soil and water conservation effects of exclosures shows that conversion of degraded land to forestry use has a positive net present value. Therefore, we recommend that highly degraded land but put to land use types other than forestry should be converted to exclosures. On the other hand, re-allocation of productive farm land to forestry should be avoided as such conversion will result in a negative economic return.

4. The increasing demand for fuelwood over time is one of the main reasons for the deterioration of forest resources in the study area and illegal wood harvest from exclosures. As population growth and the demand for energy increases, animal dung and cereal stalks are used to satisfy the increasing demand for energy. These activities lead to the deterioration of forest resources and further degradation of land with the consequent negative economic effects. Therefore, potential sources of alternative rural energy should be identified and concerned agencies have to intervene in the production or supply of alternative sources of rural energy.

5. Our assessment of the existing forest management scheme in the study area using C&I and MCA methods indicates that the current forest management is performing poorly. Under this system most of the C&I elements of sustainability are performing at below average levels. Therefore, a new forest management alternative that can better satisfy the sustainability criteria should be introduced. Stakeholders' interests and preferences should be taken into account and local community should participate while in the generation of C&I elements.

6. The prevailing use and access rules of exclosures are perceived to be highly restrictive by the local community. The number of allowed forest products is very limited. Therefore, local rules should be reformulated in such a way that harmonizes the economic and environmental objectives of exclosures. In our analysis of alternative forest management scenarios (chapter 5 section 5.6) the forest management scenario which incorporates diverse allowable forest products (cut-and-carry, controlled pruning and thinning) and enrichment planting (alternative 6) (see section 5.6) obtains the highest scores against the criteria of sustainable forest management. This alternative harmonizes both the economic and environmental goals and hence substantiates arguments for the introduction of new forest management system. Thus, flexibility in rules, periodic revision of rules, and diversifying the set of allowable forest products should be incorporated as part and parcel of the new forest management system.

7. Concerned bodies should give utmost concern in choosing locations for new excloure establishments. In this regard, an exclosure has to be located in areas where all the possible on-site and off-stie benefits are maximized and local social costs are minimized.

8. As most of the existing exclosures are established on formerly degraded lands, these forested areas should not be converted back to other land use types such as agricultural lands. Such a coversion would mean wastage of all the efforts made so far in environmental rehabilitation and coming back to the situation of highly degraded environment of the past.

6.3 Limitations and implications for future research

Environmental valuation is a complex task; it needs a comprehensive data set and involves diverse methodological tools. Similarly, there is no a 'simple blueprint' solution or 'one-fits-all' framework for the problems of the sustainable management of common-pool resources. Depending on the resource system under consideration, the study objectives, and the realities on the ground numerous valuation approaches can be pursued and various resource management schemes can be suggested. Hence, in many cases valuation results are considered as indicative rather than definitive. By the same token, resource management schemes are subject to amendments, revisions, and modifications.

Our data have some limitations. The data for the study of 'poverty-environment' relationship were obtained from household survey and based on the household's reported values. Respondents may not recall part of the forest products they harvested; they may neglect the use of some forest products used at smaller scales; and the forest products collected may vary from year to year but our survey comprises data only for one year. Therefore, there exists certain degree of probability that our findings may understate or overstate the situation. The data used in the cost benefit analysis (CBA) were organized from various secondary sources and limited mainly to the soil and water conservation effects of exclosures. The major part of the data used in CBA is generated via extrapolation from the limited data set at hand. Similarly, for that analysis of SFM, though the C&I elements of forest sustainability were developed and evaluated in a participatory manner, we still feel that more comprehensive set of criteria and indicators should be generated for actual implementation at the ground.

We suggest the following areas for future research:

- To enhance the accuracy of the true contribution of forest products in the rural economy, future research should be based on time-series data. Analysis should be based not only on household's own-reported value but data obtained in other value elicitation methods should also supplement in order to validate the findings.
- An interdisciplinary research work is sought for a comprehensive cost benefit analysis that incorporates the full range of economic and environmental aspect of exclosures in order to appraise future land reallocation for forestry.
- Cutting trees for domestic energy has been identified as the major factor for the degradation of forest resources in the study area. Therefore, future research should pay due attention on the technical and economic feasibility of alternative rural energy sources to combat the problems of deforestation.
- For sustainable and self-enforcing management of exclosures local economic and ecological incentives should be carefully scrutinized in a participatory approach. In this regard, the whole set of C&I for forest sustainability should be generated and evaluated and the relative importance of each of the C&I elements has to be assessed. A specific forest management scheme to be applied has to be based on research. This call for a comprehensive and multidisciplinary research and hence future research in this respect will contribute to the sustainability of exclosures.

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Curriculum Vitae

Bedru Babulo was born on 28 January 1972 in Dawuro zone, Southern Nations, Nationalities, and People's Region (SNNPR), Ethiopia. In 1990 he passed the Ethiopian School Leaving Certificate Examination (ESLCE) and joined Addis Ababa University (AAU). In July 1994, Bedru obtained his Bachelor's of Art degree in Economics from AAU. From 1995-1998 he served as a full time teaching staff at the Makalle Business College. In September 1998, he joined Panjab University-Chandigarh (India) for his graduate study and obtained Master of Arts degree in Economics in August 2000 with the rank of first division. Coming back to Ethiopia in September 2000, he resumed his teaching post at the University of Mekelle, Ethiopia. He taught courses such as Microeconomics, Statistics, and Econometrics for undergraduate students for many years. Besides teaching, he involves actively in research undertakings and community services. He is an active team member of a collaborative research group of the MU-IUC socio-economic research project which is funded by VLIR (Flemish interuniversity cooperation, Belgium).

He has participated and presented scientific papers in a number of national and international workshops and conferences. Some of the international conferences he presented and presented academic papers were: an international conference on "Ecological Sustainability and Human Welfare", organized by the International Society of Ecological Economists (ISEE), held in New Delhi, India, 15-19 December, 2006; International Conference on "Economics of Poverty, Environment and Natural Resource Use", 17-19 May 2006, Wageningen, Netherlands; highLAND2006 international conference on" Environmental Change, geomorphic processes, land degradation and rehabilitation in tropical and subtropical highlands" 19-22 Sept. 2006, Mekelle, Ethiopia; a symposium on the Rehabilitation of Dryland Forests in Ethiopia: Ecology and Management, Mekelle, Ethiopia, 22-24 September 2004; and a CTA Seminar 2004 on "Role of Information and Communication Tools in Food and Nutrition Security in ACP Countries" Maputo, Mozambique, 8-12 November 2004.

In addition to teaching and research, Bedru has also involved in a number of administrative and management activities of Mekelle University. He has served as a head of the planning and programming office of Mekelle University for two years. In September 2003, he joined the Agriculture and Resource Economics division of the Katholieke Universteit Leuven (KULeven), Belgium for his PhD. He successfully completed all the requirements for a PhD award at KULeuven and obtained his PhD in Agricultural and Resource Economics in October, 2007.