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Economic Accounting of Ethiopian Forests: A Natural Capital Approach

Abstract

Ethiopia has experienced a long-term deforestation with broad implications for human life and economic activities, but conventional frameworks of economic accounting are not able to assess the country's economic and environmental sustainability in the face of such deforestation problem. In this study, we attempt an economic accounting of Ethiopian forests based on a welfare-economic framework, which assesses changes in the value of forests as natural capital. Our estimates suggest that the recent government re-greening efforts are yet to increase forest assets in the value term, although they have expanded the land areas covered by trees in the country.

Keywords: Forest, natural capital, environmental accounting, ecosystem services, sustainability

1. Introduction

Deforestation has been a long-term problem for Ethiopia. While the exact scale of past deforestation is still up for debate, there is a general consensus that Ethiopia has experienced a significant loss of forest cover throughout its long settlement and agricultural history (Pankhurst, 1995; Gebrehiwot et al., 2014). The problem of forest loss remains an ongoing and acute issue. The Climate-Resilient Green Economy (CRGE), a recent comprehensive and long-term economic development strategy by the Ethiopian government, estimates that 37% of Ethiopia's greenhouse gas emissions in 2010 originates from the forestry sector, which could mainly be attributed to deforestation and forest degradation (Federal Democratic Republic of Ethiopia, 2011). At the same time, as this problem is widely recognized in the country, concerted public efforts for re-greening have recently been taken as well (Lemenih and Kassa, 2014).

Such large-scale deforestation should have brought about broad economic consequences to Ethiopia, especially given people's dependence on forests for

a variety of services ranging from supplying fuel to providing cultural values in the country. Thus, a proper economic accounting of forests is key for assessing sustainability of development in Ethiopia in terms of both the economy and the environment. However, Gross Domestic Product (GDP), the standard indicator of economic accounting, cannot appropriately represent full economic implications of forest services. Many of the benefits from forests do not involve market transactions and therefore are not included in the conventional System of National Accounts (SNA) used to calculate GDP. In addition, the SNA does not account for changes in the national forest stock, particularly those caused by forest degradation, which in effect decreases the amount of national assets. This insufficient inclusion of forest values in national accounting reflects the methodological limitations of the conventional SNA that are recognized by many economists. Reflecting the recognition of these limitations is the growing interest in identifying economic indicators that capture people's well-being better than conventional national accounting (see Stiglitz, Sen, and Fitoussi, 2009). An approach of such alternative accounting is to quantify the extent of changes in national wealth, defined using the welfare economics framework, attributable to an increase or decrease in environmental assets (i.e., natural capital) (e.g., Perrings and Vincent 2003; Dasgupta 2009).

This study aims to economically account for the value of forests in Ethiopia using the above-mentioned welfare economic framework, which has not been attempted thus far. To achieve this objective, the research compiles data from the literature on forest values in Ethiopia, which spread in different sub-fields of research. Our methodology differs from that adopted in existing assessments of forest resource accounting in Ethiopia (e.g., Nune, Kassie, and Mungatana, 2013). To elaborate, while existing studies have aimed to directly associate the results with GDP (i.e., accounting compatible with the System of Environmental-Economic Accounting (SEEA)), our method does not have a direct compatibility with GDP estimates but in return allows us to evaluate sustainability of the economy and the environment related to forest services, that is, whether the asset values of Ethiopian forests inclusive of their environmental benefits are being sustained or not. Our estimates indicate that the recent government efforts toward re-greening are yet to be reflected in an increasing trend for forest assets in the value term. In other words, the country's deforestation continues to diminish national wealth, although the area of tree-covered land appears to have

expanded.

The remainder of this paper is organized as follows. Section 2 presents a theoretical framework used to economically account for forests in Ethiopia. Section 3 provides an overview of the data adopted in this study to evaluate Ethiopian forests. Section 4 explains our accounting of Ethiopian forests. Section 5 offers a discussion of our findings and Section 6 presents our conclusions.

2. Methodology of economic accounting of forests as natural capital

Forests are a source of various economic goods, such as timber and wood fuel, and the conventional SNA accounts for their value if these goods or their secondary products are transacted in the market. Still, the information included in the SNA is not sufficient to accurately capture the economic significance of forests for the following three reasons: it misses the economic value of some forest goods or services that are not transacted in the market, either because of their domestic or informal nature of production or because of their property as an externality (e.g., the hydrological benefits of forests); it does not properly reflect the changes in the forest stock, especially those from forest degradation; or registers some benefits of forests not in the forestry sector but in a different category such as the agricultural sector (e.g., forest coffee production).

Broadly speaking, there are two approaches of economic accounting that address the above problems of accounting forest and other environmental assets. One approach is to extend the SNA to incorporate environmental services while maintaining compatibility with the standard economic indicators such as GDP. Efforts regarding this approach are centered on the System of Environmental-Economic Accounting (SEEA) – Central Framework, which is a satellite account of the SNA adopted by the United Nations Statistical Commission (UNSC) in 2012 (United Nations, 2014a). The other approach is to treat elements of the environment as a form of capital, *natural capital*, to provide humans with flows of benefits, and then evaluate changes of natural capital as changes of national assets. Accounting methods in this group do not have a direct association with the SNA but are instead rigorously grounded in the theory of welfare economics (e.g., Perrings and Vincent 2003; Dasgupta 2009). Although both the former and

latter sets of accounting frameworks have been developed out of similar concerns, some methodological differences exist between the two because they have different foci and intentions—the former’s aim is an extension of conventional macroeconomic indicators to better capture environmental services, while the latter is concerned with whether the social welfare increases or decreases with changes of the environment, in other words, whether the broadly-defined national wealth inclusive of environmental assets is being sustained or not, given the changes in the environment. In a more technical sense, the first approach has the primary aim of tracking economic activities and does not include the consumer surplus of environmental services in evaluation, whereas the second approach sets its basis of evaluation on the total welfare of a nation and thus considers the consumer surplus as well. In a context of Ethiopian forests, Nune, Kassie, and Mungatana (2013) is an attempt of national accounting based on the first approach.

In this study, we take the second approach mentioned above and conduct our estimation of value added due to the forest by drawing on the literature of accounting of natural capital (e.g., Mäler, Aniyar, and Jansson 2008, 2009; Fenichel et al. 2016). Built on the theory of welfare economics, the framework used here is in some ways similar to the framework of the Inclusive Welfare Index, which is proposed by the United Nation and UNEP (UNU-IHDP and UNEP 2012), and that of the Adjusted Net Saving (also called Genuine Saving or Genuine Investment) utilized by the World Bank (e.g., World Bank 2011) and others.¹

Drawing on Mäler, Aniyar, and Jansson (2008, 2009) and Fenichel et al. (2016), the indicators of value we consider are derived from the social welfare (national wealth), which is defined as

$$W_t = \sum_{s=t}^{\infty} \frac{U(C_s)}{(1 + \delta)^{s-t}} \quad (1)$$

where W_t is the social welfare at year t , $C_s = (c_{1,s}, c_{2,s}, \dots, c_{n,s})$ is a vector of consumer goods and services (including ecosystem services) in years, $U(C_s)$ is

¹See Chapter 7 in UNU-IHDP and UNEP (2012) for a discussion on the SEEA frameworks, the Inclusive Welfare Index, and the Adjusted Net Saving as well as their conceptual differences and similarities.

the utility function determined by C_s , and δ is the discount rate (to be set at 5%/year in the following analysis, as in UNU-IHDP and UNEP(2012)). Note that the flow of goods and services C_s may or may not represent the optimal consumption path.

The annual change of the social welfare between year t and year $t+1$ is given by

$$W_{t+1} - W_t = \sum_{i=1}^n p_{i,t} (K_{i,t+1} - K_{i,t}) + \xi_t \quad (2)$$

Where $p_{i,t}$ and $K_{i,t}$ are the accounting price (shadow price²) and capital stock for good or service i at year t (at the beginning of year t for the capital stock).³ “Capital stock” here could mean both the capital in a conventional sense (man-made capital) and other types of capital including various forms of natural capital. The term ξ_t corresponds to the annual change of social welfare independent of the amounts of capital stocks originating from, for example, technological change independent of capital accumulation.

The accounting price $p_{i,t}$ is given as follows:

$$p_{i,t} = \sum_{s=t}^{\infty} \frac{\frac{\partial U(C_s)}{\partial K_{i,t}}}{(1 + \delta)^{s-t}} \quad (3)$$

Note that p represents the present value of the future changes of consumption due to a marginal change in the stocks today, and that it may be different from the market price. In other words, p is the shadow price of goods or services.

For actual estimations of the accounting price, we use the following formulation,

² As discussed in documentation on SEEA Experimental Ecosystem Accounting (SEEA-EEA; United Nations, 2014a, 2017), the use of shadow price, which accounts for consumer surplus, conceptually differs from that of exchange value adopted in the SEEA-EEA approach.

³ Here, we implicitly apply the property in which the level of p_i does not significantly change in the short-term interval between t and $t + 1$.

which is in essence the same as that used by Fenichel et al. (2016):

$$p_i(K_i) = \frac{MB_i(K_i) + \dot{p}_i(K_i)}{\delta - \dot{\kappa}_i} \quad (4)$$

where MB_i is the marginal benefit of the capital stock (i.e., how much an additional increment of stock raises the level of benefit), $\dot{\kappa}_i$ is the growth rate of the capital stock (if time steps are small, $\dot{\kappa}_i \approx \frac{K_{i,t+1} - K_{i,t}}{K_{i,t}}$), and δ is the discount rate.⁴

Here, p embodies the marginal service flows (dividends) and capital gains of the evaluated stock, adjusted by time discounting and future stock growth.

The above-formulated quantities could in principle be incorporated into the national accounting (specifically, Net Domestic Product, NDP) in the form of the following value added (see Chapter 8 of UNU-IHDP and UNEP 2012; Dasgupta 2009; and Arrow et al. 2012, for detailed discussions). The value added (VA) originating from forests or other tree-covered areas for year t is given as follows:

$$VA_{j,t} = U'(C_t)c_{j,t} + \Delta V_{j,t} \quad (5)$$

where

$$\Delta V_{j,t} = p_{j,t}(K_{j,t+1} - K_{j,t}) \quad (6)$$

In the formula, j denotes the type of tree-covered areas, which this analysis considers natural forest, plantation, woodland, shrubland and trees outside forest

⁴An assumption necessary for this formulation is that human behavior on the use of the stock (the “economic program”) is described as a function of the stock size. But this assumption does not have a critical meaning in a practical context of our estimation below.

(the definitions of those terms are given in Section 4.1). Also, $U'(C_t)c_{j,t}$ is the annual flow of benefits from tree-covered areas of type j at time t , and $\Delta V_{j,t}$ is the annual change in social welfare due to the annual change in forest stock. In the results below, we show both the benefit flows (the first term of (5)) and the change of stock values (the second term) of forests and other tree-covered areas.

3. Value of Ethiopian forests: data available on economic accounting

This section explores the current understanding of and data available on the value of Ethiopian forests, which will be used as the basis for our quantitative estimations in the next section. Hard data are available for some of the types of benefits, while inferences from other similar cases (benefit transfer) are necessary for others. There are also types of services on which quantitative estimation is not yet possible in an Ethiopian context.

Below, we categorize the benefits of forests using the concept of ecosystem services, which are classified into provisioning, regulating, cultural, and supporting services (MEA 2005). Among these, we exclude the supporting services—i.e., the services to support ongoing ecosystem processes (such as maintaining the planetary-scale nitrogen cycles)—from analysis because the benefits of supporting services could in principle be captured as a part of the benefits of other ecosystem services (though those other ecosystem services may or may not be considered forest-related).⁵ Meanwhile, forests also cause harms and disutility to humans (hosting pests, pathogens, and allergens, landscape damage and biodiversity loss by excessive plantation forestry, etc.), and such negative values of forest disservices should in principle be included in an economic accounting. But no quantitative information on these aspects is available for Ethiopia, and therefore we do not include their values in our value estimation. See our earlier working paper (Narita et al., 2017) for a discussion of forest disservices in Ethiopia.

⁵Supporting services are similarly excluded from valuation in, for example, a global estimate of ecosystem values by De Groot et al. (2012), a study made by the TEEB project.

Provisioning services

Timber, fuelwood and various non-timber forest products (NTFPs) are produced in Ethiopian forests, and the provision of such goods constitutes the provisional services of forests. Some of those goods are formally sold and purchased as market products, and their market values are to be estimated from those records. A significant part of those goods, however, are either domestically used or only informally exchanged in Ethiopia, and their values cannot be drawn directly from market data. It is therefore necessary to make inferences on missing values based on the information of dispersed data sources. Some previous studies, namely Nune, Kassie, and Mungatana (2013) and the more recent Forest Sector Review (Ministry of Environment, Forest and Climate Change, 2017: henceforth referred to as FSR), conduct estimations of the quantities and values of forest products in Ethiopia, relying on a combination of market data, generalizations of representative values, and expert judgments. We primarily use the FSR data, with adjustments, for our value estimation (See Section 4.1 and Appendix 2).

We also draw on the FSR for the value estimation of NTFPs. A discussion of our adjustments of these data is also found in Section 4.1. The following are the major NTFPs that originate from Ethiopian forests, which we consider in the analysis: forest coffee, honey, bees wax, gums and incense, spices, bamboo, traditional pharmaceutical products, fodder, and wild foods.

Among them, forest coffee, honey, bees wax, gums and incense, and spices are products originating from plants or bees in the forest and may be sold and bought in the market. Coffee could grow not only in forests but also in plantations or semi-forest settings, but the natural forest is a no less favorable environment for coffee production than the plantation is, as the maximal production of coffee is obtained from coffee trees under shade, which trees in natural forests provide. Bamboo is used mainly for making light furniture. Traditional pharmaceutical products and wild foods are primarily for domestic consumption and made from plants growing in the forest.

There are no hard estimates of national wild food consumption in Ethiopia, but their importance should not be overlooked. Wild foods provide nutrients for

millions of people in the world. The UN Food and Agricultural Organization points out that forests support the entire four pillars of food security—food availability, access to food, stability over time, and food use (HLPE, 2017). The role of wild foods in combating problems of food security is paramount in Ethiopia too.^{6, 7} Meanwhile, there are also some recognized demand for and practices of hunting in Ethiopia (e.g., Yitbarek et al., 2013; Fischer et al., 2015), part of which is performed in forestlands either for subsistence or recreation. However, no quantitative estimates exist about how large is the scale of hunting activities taking place specifically in forests areas in Ethiopia.

Some of the ecosystem services provided by Ethiopian forests entail not a benefit for humans at present but a potential benefit in the future, i.e., option values. Forests are home to various plants and microorganisms, which have potentially useful genes for humans in terms of developing new crop varieties and medicines. Those genes and their use may not be well known at present but may bring monetary benefits in the future, and in this sense, conserving forests involves an option value. Ethiopian forests are the place of origin for Arabica coffee (*Coffea arabica*). Hein and Gatzweiler (2006) have estimated the values of the genetic resource of coffee in terms of the possibility for potential varieties of naturally decaffeinated coffee, high yield, or high disease resistance. According to their estimation, the total net benefits of coffee-genetic diversity in Ethiopia amount to 1458million USD, assessed for the year 2004 (at a 5% discount rate), or 883 million USD⁸ excluding the benefit of providing varieties of decaffeinated coffee, which Reichhuber and Requate (2012) argue one should. More generally, Ethiopia is located in one of the world's biodiversity hotspots (namely Eastern Afromontane), and thus its forests have the potential to hold useful medicinal substances (bioprospecting). We base our estimation of the bioprospecting value on Costello and Ward (2006), who compute their estimates by examining the approaches in the preceding literature on the topic. We use their mean estimate

⁶In this study “wild foods” refers to all plant and animal resources that are not domesticated but gathered and hunted from forests and bush-lands for the purpose of human consumption (Guyu and Muluneh 2015).

⁷ The study conducted in the so-called “green famine belt of Ethiopia” shows that the mean amount of wild foods obtained by households is 156.61 kg per household per annum, which is about 5% of gross food and 9% of net food available from all sources (Guyu and Muluneh 2015). The study concluded that wild foods play an important role in households' resilience to food shortages and are likely to continue to do so in the future. The study calls for the adoption of a comprehensive policy that ensures a sustainable supply of wild foods.

⁸As per the 2013 dollar unit, this is equivalent to USD 1,104 million.

for Eastern Afromontane, which is USD 0.06/ha (1.1 ETB/ha).⁹ Biodiversity associated with Ethiopian forests could also include values other than those of potential medical benefits (e.g., existence values of species); however, we do not include these in our assessment given the lack of quantitative estimates.

Regulating services

A large number of both global and Ethiopia-specific studies have found that the forests offer a variety of regulating services. The carbon sequestration service, which is the absorption and retention of carbon dioxide as a greenhouse gas, is one type of regulating service provided by forests that is relatively easy to define and has been discussed extensively worldwide both by academics and practitioners. Aside from this, Ethiopian forests provide other important regulating services such as their hydrological functions.

Globally, carbon dioxide (CO₂) emissions from forestry and other land use constitute 11% of the total anthropogenic greenhouse gas emissions in 2010 (IPCC 2014, Figure SPM.2). With its relatively long persistence in the atmosphere, emitted CO₂ is globally dispersed, affects the global climate, and has negative consequences on human activities, such as a declining crop yield and intensifying natural disasters from extreme weather. Thus, the unit cost of deforestation in Ethiopia, or the unit benefit of REDD (Reducing Emissions from Deforestation and Forest Degradation) measures in Ethiopia, should in principle be identical with the Social Cost of Carbon (i.e., an estimate of the global economic damages associated with a unit increase in CO₂ emissions in a given year) that is estimated globally (e.g., Interagency Working Group on Social Cost of Carbon 2013).

The value of forest carbon is calculated by multiplying the amount of carbon mass in the forests of Ethiopia and the price of a unit of carbon (tCO₂e), which reflects the climate policy. For our estimation of the carbon price level, we use a benchmark value (US\$12/tCO₂e at a 5% discount rate, adjusted to a 2013 dollar unit) of the Social Cost of Carbon presented by the US government (Interagency Working Group on Social Cost of Carbon 2013, updated in 2015), which is based on three of the best-known global Integrated Assessment Models of climate and

⁹Their estimation assumes a range of discount rate between 1%/year and 10%/year.

the economy (FUND, PAGE and DICE).

There is a widespread recognition by both academics and policymakers that much of the Ethiopian land has been experiencing a serious problem of soil erosion and that vegetation can mitigate the problem (e.g., Hurni et al. 2015). Previous economic valuation studies of Ethiopia also consider this issue, using various estimation approaches to assess the value of vegetation for soil erosion mitigation. Nune, Kassie, and Mungatana (2013) calculate the value of soil erosion mitigation by forests from estimates of two parameters: the crop productivity loss per unit of soil loss and the soil conservation efficiency of forestland. Meanwhile, Reichhuber and Requate (2012) estimate the value of watershed services by forests including erosion control by referring to figures from a case study in the Mount Kenya Forest Reserve.

Another set of relevant studies use cost-benefit assessments of exclosures to provide estimates of the benefits of exclosures on soil erosion affecting agricultural productivity. Balana et al. (2012) calculate the benefits of vegetation on soil as the increased productivity of plant biomass. Mekuria et al. (2011) and Mekuria (2013) estimate the value of soil nutrition retention by forests by both investigating physical properties and conducting a socioeconomic survey.

In our estimation, we consider the benefits of soil erosion mitigation not for forests in general but only for exclosures, whose benefits on farming are clearer than those for other types of tree-covered areas, and we estimate monetary-equivalent benefits by parameterizing with a case study by Mekuria et al. (2009).

Soil erosion not only reduces nutrients in farmlands but also causes sedimentation of dams and reservoirs. Keeping natural forests helps reduce the problem of sedimentation, as natural forests are largely able to retain soil on the land (Ahmed and Ismail 2008). This benefit of forests to mitigate sedimentation could be quantified by a replacement cost method.¹⁰ Removal of sediments from dams and reservoirs is widely performed across Ethiopia, involving costs borne

¹⁰Replacement cost methods are widely used for the valuation of forests, including for the benefit of sedimentation prevention, but it is noted that the method could overestimate or underestimate the true value of ecosystem services (e.g., Croitoru 2007). In our estimation, we adopt this method not because we regard it as an ideal approach but as a result of data limitations on other valuation methods.

by public expenses. In his valuation study of deforestation in south-west Ethiopia (the Baro-Akobo Basin), Sutcliffe (2009) estimates the cost of deforestation from increased sedimentation by assuming it to be equivalent to the increase of removal costs of sediments. In this study, we take a similar approach to estimation to Sutcliffe (for our case, as a benefit of keeping forests, not as a cost of deforestation) by using more recent data from observational studies of Haregeweyn et al. (2012) in Tigray and of Mekonnen et al. (2015) in Amhara. We calculate monetary values by taking an average of their estimates of the Specific Sediment Yield (SSY), and applying the unit removal cost by machinery, 33.35ETB/m³, as used by Haregeweyn et al. (2012).

Tree coverage includes other regulating services through its influence on the hydrology of river basins, water quality, flood frequency, and flood damage. However, conclusive quantitative data are unavailable on these aspects in the context of Ethiopia. See Narita et al. (2017) for a further discussion.

Cultural services

Forests provide numerous cultural services such as tourism, amenities, spiritual and existence values, cultural heritage, and identity. Although the entirety of these features cannot be fully captured by economic valuations that are based on a utilitarian framework (for a discussion, see MEA 2003, Chapter 6), a part of these cultural services can be assigned monetary-equivalent values using economic valuation methods.

The values of forests on tourism are the simplest to be evaluated among all their cultural services. Forests often characterize the landscape and also support the wildlife, and consequently the presence of forests may determine how attractive certain natural areas are to tourists. The number of visitors and the amount of revenues in entry fees to the protected areas (wildlife reserves) in Ethiopia are recorded by the Ethiopian Wildlife Conservation Authority (EWCA); in our estimation below, we count this revenue as the benefit of the forests for tourism.¹¹ In Ethiopia, all the protected areas could be regarded as natural forests or woodlands. In principle, the economic benefits of protected areas should include

¹¹Data are obtained through written communication with EWCA.

secondary benefits such as revenues earned from visitors by hotels and restaurants. But there are no such data available for our analysis, and so they are excluded from estimation.

The cultural services of forests are not limited to tourism but consist of a wide range of features such as religious, spiritual and identity-shaping functions. There are certain cultural meanings of forests found specifically in Ethiopia, such as the tradition in some parts of the country that religious facilities be surrounded by tree-covered areas (also known as “church forests”). Although any quantitative research has not been attempted yet for Ethiopia, in principle, such functions of forests should be considered in a comprehensive accounting of the value of forests. More discussion on this aspect is found in our earlier working paper (Narita et al., 2017).

4. Estimation of forest value in Ethiopia

4.1 Data and estimation approach

The data on forest coverage and composition are essential for an economic accounting of forests. The availability of such forest statistics, however, is seriously limited in Ethiopia. The last comprehensive dataset on Ethiopian forests at the national level is the Woody Biomass Inventory and Strategic Planning Project published in 2004 (WBISPP 2004). The more recent Global Forest Resources Assessment by FAO (2010) does not document original data on forest coverage and simply use projections of the WBISPP data. Global databases on forest coverage, which are being made easily available (e.g., Hansen et al. 2013), are not yet sufficiently accurate for the purpose of our analysis, and furthermore lack key information such as data on tree compositions.

In the following assessment, we use our estimated values of Ethiopian forest resources for the years 2013 and 2000 (as a reference), the most recent two years for which solid estimates of forest characteristics are available. Since some ecosystem services provided by forests are hard to separate from those provided by other types of tree-covered lands (especially for cultural values of forests), we examine not only the narrowly defined natural forest but also four other types of

tree-covered areas: the plantation, the woodland, the shrubland, and the trees outside forests. The definitions of these types we use are consistent with those in the WBISPP.¹² Here we note that the “woodland” includes the lands subject to area enclosure, which is a widespread practice in today’s Ethiopia and is to protect degraded areas mainly through social fencing from any form of cultivation, cutting trees and shrubs, or grazing by livestock in order to restore the lands. In many cases, a substantial amount of tree coverage is found in those enclosures (see, e.g., Lemenih and Kassa 2014).

The data used in the study are sourced from the secondary literature. Two major literature sources were used to extract forest statistics. The first is WBISPP (2004), which details the extent of forest areas in 2000 and the biomass or carbon estimate per unit area in the various forest types. The second is the FSR, which includes data on forest areas for 2013, the year in which this study was conducted. Both sources offer the most comprehensive national-level documentation on Ethiopia’s forest sector. Appendix 1 presents a detailed description of the data used in this study.

The data obtained for these two years were further analyzed in terms of annual area, volume, and carbon accounting. For the three sets of quantities, the opening stock (referring to the resources at the beginning of the year), increment (stock change during the year) and the closing stock (which is the resource at the end of the year) were calculated. The data provides information on changes in the variables at the beginning and end of the year, hence annual accounting.

Area accounting

¹²WBISPP makes explicit the definitions of “forest,” “woodland,” and “shrubland.”

Forest is “a relatively continuous cover of trees, which are evergreen or semi-deciduous, only being leafless for a short period, and then not simultaneously for all species. The canopy should preferably have more than one story.”

Woodland is “a continuous stand of trees with a crown density of between 20-80%.”

Shrubland is “a continuous stand of shrubs with a crown density of between 20-100%.” “Shrubs” are defined as “a multi-stemmed woody plant in which most of the stems appear at or very close to the ground (i.e., less than 30 cm).”

In our assessment, a plantation means a patch of tree-covered land where trees are planted and managed by land owners, as appeared in the governmental statistical records of Ethiopia. By “Trees outside forest,” we mean scattered or patches of trees existing on areas that belong to none of the other four categories such as on farmlands, grazing lands or in various forms of agroforestry.

For area accounting, we calculate the opening area which is the area coverage of the five forest types (natural forests, plantation, woodlands, shrublands, and trees outside forests) at the beginning of the accounting year (2000 and 2013), the area lost and/or gained from deforestation or reforestation/afforestation (AR) during the year, and the area at the end of the year after incorporating the deforestation or AR that took place during the year. The base data are obtained from the WBISPP (2004) and the FSR as shown in Table 1.

The average annual deforestation rate for 2000–2013 was obtained by subtracting the forest area estimates for 2013 from those of 2000 and dividing the result by 13. The closing area at the end of the accounting year was then calculated by subtracting the opening area at the beginning of the year minus the change in area during the year owing to deforestation for the natural forests and woodlands. For natural forests, the effects of AR are considered negligible relative to those of deforestation (the effects of afforestation and reforestation are in principle assigned to “Net effects of deforestation and afforestation” and “Rehabilitation and reclassification of area type,” respectively). For plantations, we assumed the annual change (i.e. AR) to be zero since there exists no data on long term systematic afforestation or reforestation in Ethiopia to estimate the average AR rate. However, for the trees outside forest, we assumed that areas deforested from natural forests and woodlands are converted into farmlands with the traditional agroforestry system that is popular throughout Ethiopia. Areas deforested from natural forest and woodlands are therefore included into the trees outside the forest area but with a much reduced stock as estimated in the WBISPP (2004). For the 2013 data, areas regenerated through area enclosure based management are included into the woodlands category as regeneration after estimating the total areas under area enclosure and understanding the rate per year, which happened to be 1%.

Volume accounting

For the volume-based accounting, the opening volume was obtained by multiplying the area at the beginning of the year, whose calculation is described above, with the average volume of woody biomass per unit area for each forest

type. The closing volume was calculated by subtracting the volume of various products removed from the forests during the year from the opening volume plus incremental yield during the year. The volume of products removed refers to the volume of timber, construction wood, and fuelwood harvested plus the volume of wood lost along with the deforested forest area during the year. See Table 1 for our parameter choices.

Carbon accounting

The capacity for carbon retention by forests and woodlands obviously varies depending on prevailing tree species, tree density, and age structure, and the estimation of carbon contents should in principle take into account the heterogeneity of such features across all the forest areas of the country. However, such spatially detailed information of forest characteristics is not available in our case. Given these limitations, we take the following approach to estimation: The annual carbon stock balance or change was calculated by converting the volume-based balance into a carbon equivalent and then carbon dioxide equivalent (CO₂e) quantity. That means the volume at the beginning of the year, the volume of timber, construction wood, and fuelwood harvested during the year were all converted to carbon stock equivalent using a Biomass Conversion and Expansion Factor (BCEF) for the various forest types, and using a carbon fraction of 50%, i.e. assuming half of the biomass being carbon based on the IPCC good practice guide (IPCC 2006). The average Root to Shoot (R/S) ratio of 25% was applied to calculate the below ground carbon stock. The range of R/S ratio applied varies from 20 to 30, based on forest types. The carbon stock is converted to CO₂e by multiplying the carbon stock by the factor 44/12. See Table 1 for details of our parameter choices.

Estimation of monetary-equivalent values

We conduct estimation of both benefit flows and of changes in stock values. For the latter, the value of stock from future benefit flows is computed based on the framework described in Section 2, combined with the option value (the value of genetic resources, which generate potential monetary benefits in the future) and

the values associated with land use conversion (i.e., the added value as farmland and the lost value of carbon retention). In the estimations, we consider that carbon retention does not concern flow benefits but changes the stock value of forest, as carbon dioxide sequestration by a current increase in the forest stock does not bring immediate benefits for the humans at present but does affect the intertemporal welfare in the form of mitigated damage of climate change in the future, i.e., increased levels of future consumption.

We estimate the monetary equivalent values of forest goods and services by multiplying the respective tree volume, area, or carbon content by their effective prices, whose information is drawn from the literature, with adjustments of our own. As already noted in Section 3, we draw a great deal of information from the FSR for our value estimation.¹³ However, for most goods, the FSR only shows the gross value (i.e., the value inclusive of production costs), and hence some adjustments are necessary to use its information for our purpose, which requires the net value (rent) of wood only. Appendix 2 shows a description of our adjustment approach. Meanwhile, the unit value of farmland is calculated based on the assumptions that 40% of agricultural production is attributed to land input (an assumption taken by Reichhuber and Requate 2012), and that all the deforested land (corresponding to the “Net effects of deforestation and afforestation” category) is converted to farmland. Agricultural production (agricultural GDP) data are from the Ministry of Finance and Economic Development. Previous studies of environmental valuation (e.g., Ovando et al., 2016; Sjaastad, 2005) imply that while the provisional benefits of forest should be equal to the value of environmental goods minus the labor costs, the work for forest good collection is often made by self-employed labor whose opportunity cost is unclear under the condition of free access to forest. In our analysis, we assume the opportunity cost of self-employed labor to be at the same level as that of a standard rural wage in Ethiopia (see Appendix 2). In Ethiopia, all types of land are publicly owned, but members of communities have free access to forests in their communities for the collection of forest goods. Note that the level of labor opportunity cost assumed in this study is not an empirically tested value in the context of our forest accounting and thus it may be subject to potential bias

¹³The FSR only presents the total gross production of the nation’s forest goods and does not decompose figures into the categories of tree-covered areas (e.g., natural forests and woodlands). We apply our expert judgment to perform such decompositions.

in the estimations of forest asset values, as indicated by the above-cited studies.

Forest accounting is an extensively discussed topic in the double-counting of values (e.g., Croitoru, 2007). In sectoral assessments such as ours, double-counting may occur both internally (i.e., across the estimated values in our dataset) and externally (i.e., the estimation overlaps between our assessment and an external reference value such as GDP). In the latter, the constituents of an overlap are not obvious and depend on the focus of the estimation. Given the methodological difference between the SNA/SEEA framework and our estimation, our estimated values are not meant to be directly compared with GDP. But still, following Barbier (2013), we treat the estimates as if they are to be added to GDP and separate the values that are already included in a non-forestry aspect of GDP, namely those related to NTFPs and to tourism,¹⁴ and those related to other goods and services. Only the latter is used for stock valuation. Even if they are not meant to be added to GDP, the values of the former category are still meaningful to be presented as they show the production values that are not included in the forest-sector GDP but should in principle be included there in the national accounting (as discussed by Nune, Kassie, and Mungatana 2013).

As noted in Section 2, the benchmark discount rate used for the estimation of capital value is set to be 5%. The extent of capital gain (the increase rate of the capital price) is in principle an endogenous quantity to be derived as a model solution (Fenichel et al. 2016), but the data limitation does not allow us to compute it endogenously. Alternatively, we consider given levels of 0%/year and 2%/year for the rate, the latter of which is consistent with the finding by Asfaw and Demissie (2012, Table 2) that the price of fuelwood has increased from 7 ETB/GJ to 18 ETB/GJ (from 0.81 to 1.25 USD/GJ) during 2005-2010, evaluated at the current price. As yet another alternative case, we also make an estimate with a 10%/ year discount rate and a 0% increase in capital price.

¹⁴In his wealth accounting study of Thai mangrove areas, Barbier (2013) excludes regulating services (specifically, flood protection by mangroves) from the accounting by arguing that such benefits are already implicitly included in property values. In Ethiopia, however, land ownership is strictly regulated, and it is not plausible that any regulating services of ecosystem are implicitly taken into account in land transactions. We therefore do not exclude regulating services in stock value assessment.

4.2 Results

This section reports our estimates of area, volume, and carbon accounts for Ethiopian forests for 2013 and 2000 as well as the annual values of forest services in Ethiopia for 2013.

Physical accounts

Appendix 3 presents our estimates for the areas of tree-covered land and the volumes and carbon contents (on a CO₂-equivalent scale) of woody biomass at a national level by area type. These estimates are for 2013 and 2000 as the base year. The data for area accounting (Appendices 3-1 and 3-2) quantitatively support the overall recent changes in Ethiopian forests, as described in Lemenih and Kassa (2014) and similar works. That is, while the deforestation of natural forests prevails in the country, considerable rehabilitation of tree-covered areas remains an ongoing effort in the form of exclosures. In terms of area, the tables show that woodlands and shrublands are dominant forms of wood-covered areas in Ethiopia in 2013 (and also in 2000).

In contrast to the area estimates, those for tree volume (Appendices 3-3 and 3-4) indicate that natural forests continue to have considerable national-level significance, particularly if tree coverage is evaluated in volume. In 2013, the total volume of woody biomass for Ethiopian natural forests is close to that of woodlands in the country (362 million m³ for natural forests and 404 million m³ for woodland) and the relative share of natural forests to woodlands remains nearly the same for 2000 and for 2013 (about 90%). The data reflect that large amounts of trees are harvested from natural forests for timber and wood fuel. Still, they suggest that the plantation is the most important source of timber and the woodland the most important source of woodfuel.

The estimates of carbon content (Appendices 3-5 and 3-6) are consistent with those of area and tree volume. In 2013, carbon content is larger for woodlands (1,204 Mt CO₂e) than for natural forests (1,079 Mt CO₂e). Similarly, for the same year, the annual change in carbon content for woodlands (–142 Mt CO₂e) is larger than that for natural forests (–62 Mt CO₂e). In fact, the dominance of woodlands

over natural forests in terms of carbon content is already observable in 2000 (Table 5-2). In an analysis similar to ours, the Ethiopian government's CRGE (Federal Democratic Republic of Ethiopia, 2011) estimates that the emissions from forestry amounted to 53 Mt CO₂e in 2010. While it is not explicitly stated, the CRGE's estimate probably accounts only for natural forests, and in this case, its numbers are broadly consistent with those reported in this study.

Monetary-equivalent values of forest services

Tables 2 and 3 show the flow of benefits ($U'(C_t)c_{j,t}$ in Eq. (5) of Section 2) and the changes in stock value ($\Delta V_{j,t}$ in Eq. (5)) for 2013. The currency unit used is the 2013 Ethiopian Birr (calculated as 18.5 ETB = 1 USD).¹⁵

Of the flow benefits shown in Table 2, the most important are those from forest coffee production in natural forests (9.1 billion ETB, which is equivalent with USD 0.49 billion) and wood fuel production from woodland areas (10.0 billion ETB, or USD 0.54 billion). While it should be emphasized that the estimates are based on limited information, the benefit flows from goods mainly for household consumption (e.g., spices) and those from regulating services (e.g., soil erosion control affecting crop farming and sedimentation) are minor relative to the above-mentioned items. The total annual amount of flow benefits is 44.9 billion ETB (USD 2.43 billion), including all goods and services, or 28.5 billion ETB (USD 1.54 billion) if we exclude double-counting with other sectors.

Meanwhile, reflecting the stock losses through deforestation, the annual change of stock value shown in Table 3 exhibits generally negative values. Substantial losses are associated with losses of future benefit flows (nearly 14.3 billion ETB, or USD 0.77 billion, in total, with the order of magnitude remaining constant under different assumptions for the discount rate and the rate of increase in capital value). The value associated with carbon dioxide retention is even larger (60.2 billion ETB, or USD 3.25 billion), suggesting a substantial potential impact

¹⁵This rate is based on the UN Operational Rates of Exchange for 2013: <http://treasury.un.org/operationalrates/Default.aspx>.

of a potential REDD policy. These negative values are not offset by the positive values from land use conversion to farmland (which produces output). It is also noteworthy that the recent Ethiopian efforts at re-greening are hardly translated into a moderation of stock value loss, as these efforts, while substantially increasing the amount of tree-covered areas, have not yet increased the total tree volume.

5. Discussion

Our estimates imply that forests and other woodlands hold substantial significance to the economy and lives of people in Ethiopia. Relative to the Ethiopian nominal GDP of 864.7 billion ETB (equivalent with USD 46.7 billion) in 2013,¹⁶ the total flow benefits and (negative) changes in stock value in our estimation amount to 5% and 6%, respectively. However, it should be noted that our estimates are not meant to be directly comparable with GDP, as discussed in previous sections.

The area and volume accounts in our study are roughly consistent with those in Nune, Kassie, and Mungatana (2013). However, while these authors reported a value of 9 billion ETB (4 billion ETB plus 5 billion ETB; see Table 17 in their study) for flow benefits from the production of timber, wood fuel, and other NTFPs in 2005, our estimations present substantially higher values. This discrepancy can be partly attributed to Ethiopia's rapid economic growth between 2005 and 2013, which is our reference year. Note that since Nune, Kassie, and Mungatana (2013) has taken the SNA-compatible approach (i.e., the first approach discussed in Section 2), their study is unable to assess the changes of wealth (asset values) associated with forests and hence does not show results as those shown in our Table 7.

Our analysis has some similarities to some studies of ecosystem valuation in Ethiopia (Jagger and Pender 2003; Sutcliffe 2009; Reichhuber and Requate 2012; van Zyl 2016), but a direct comparison between ours and these is not possible due to our differing foci in terms of areas and types of ecosystems being considered. However, these studies, ours, and the one conducted by Nune,

¹⁶The rates are based on The Economist Intelligence Unit: <http://country.eiu.com/ethiopia>.

Kassie, and Mungatana (2013) are built on frameworks that are similar to international studies on the value of ecosystems such as de Groot et al. (2012) and Costanza et al. (2014), although some methodological differences among them do exist at a fundamental level (see also Section 2).

As studies of a related but different approach, research of household surveys on the role of forests on livelihoods has also been made for various locations in Ethiopia (Babulo et al. 2008, 2009; Chilalo and Wiersum 2011; Melaku, Ewnetu, and Teketay 2014; Worku et al. 2014; Tadesse et al. 2014). A global study based on such a framework (Angelsen et al. 2014) exists as well. Since we do not have the data about how many people in Ethiopia live alongside forests or other types of tree-covered areas, we cannot present a comparison of our results with those estimates here. Using data on spatial distributions of population, however, it would be in principle possible to make a comparison between our estimates and those survey-based data.

In addition to its use as a supplementary indicator of GDP, a comprehensive accounting of Ethiopian forest values will be useful as the basis for a REDD-Plus policy. Our results suggest that it is possible to obtain considerably large monetary values for carbon retention by forests when the evaluation uses the Social Cost of Carbon . In addition, the results show that the carbon retention benefits of not only natural forests but also of other types of tree-covered land can be substantial.

Our findings offer practical and direct policy implications. For instance, they contribute to achieving the CRGE strategy and Ethiopia's Growth and Transformation Plan II (GTP II). The forestry sector has been receiving strategic attention under GTP II as a key sector that can contribute to Ethiopia's industrialization goals, particularly through the expansion and sustainable management of the forest resource base to foster the growing wood-based industries. Ethiopia's economic growth warrants an increasing amount of forest resources, including wood and non-wood products. In line with this strategic attention, GTP II has stipulated increasing the contribution of the forestry sector to GDP as a key target. Therefore, our findings can assist the Ministry of Finance and Economic Cooperation (MOFEC), the Central Statistical Agency (CSA), the National Plan Commission (NPC), and the Ministry of Environment, Forest and

Climate Change (MEFCC) in better understanding the extent to which Ethiopia's forests contribute to the national economy and in incorporating our results and recommendations in the REDD-Plus strategy and the implementation of GTP II. Further, by highlighting gaps in the knowledge and data, which needs to be remedied to conduct a fuller accounting of forest values in Ethiopia in the future, our study emphasizes the need to update Ethiopia's System of National Accounts (ESNA) with more accurate and updated accounting methods. In particular, it is imperative to regularly perform a national forest inventory that includes physical data on forest areas and tree volumes as well as economic data including the structure of the forestry sector and sector-related taxes.

6. Conclusions

Forests offer various services in Ethiopia and there is a growing interest in accounting for the diverse economic benefits derived from these forests on a national scale to supplement standard economic indicators such as GDP. This study attempted a national economic accounting of forest values in Ethiopia using a welfare-economic framework that treats changes in forest stock as a form of capital accumulation or depreciation. The results reveal that the recent regeneration of woodlands in Ethiopia is yet to increase forest assets when evaluated in monetary terms. This suggests that the long-term deforestation in Ethiopia continues to reduce the national wealth inclusive of environmental assets, consequently diverting the economy from a sustainable path that could maintain and increase the country's level of wealth.

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Table 1. Parameter levels for wood growth, volume and carbon content calculations. The levels are set based on WBISPP (2004) and the FSR.

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest
Standing stock, m ³ /ha	132	179	21	15	3.33
Mean Annual Increment (MAI), m ³ /ha/year	5.65	12.5	0.8	0.5	0
Biomass Conversion and Expansion Factor (BCEF), t/m ³	1.3	0.7	2.8	2.8	1.3
Carbon fraction	0.5	0.5	0.5	0.5	0.5
Root to Shoot (R/S) ratio	0.25	0.25	0.25	0.25	0.25

Table 2. Flow benefits of ecosystem services provided by the Ethiopian forests in 2013 (Unit: 2013 billion ETB)

Type	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Timber (round wood, wood for furniture use, etc.)	2.2	4.0	0.0	0.0	0.0	6.2
Wood fuel (firewood and charcoal)	4.8	1.2	10.0	3.9	1.0	20.8
Other NTFPs						
<i>Forest coffee</i>	9.1	0	0	0	0	9.1
<i>Honey</i>	1.2	0	0.1	0	0	1.32
<i>Bees wax</i>	0.1	0	0.01	0	0	0.1
<i>Gums and incense</i>	0	0	0.1	0	0	0.1
<i>Spices</i>	0.016	0	0	0	0	0.016
<i>Bamboo</i>	0.02	0	0.04	0	0	0.06
<i>Traditional pharmaceutical products</i>	1.1	0	1.6	0	0	2.7
<i>Fodder</i>	0.7625	0	2.3	0	0	3.1
<i>Wild foods and game</i>	N/A	N/A	N/A	N/A	N/A	
Regulating services						
Soil erosion control (exclosures)	0	0	0.06	0	0	0.06
Reduction of sedimentation	1.4	0	0	0	0	1.4

Cultural services						
<i>Tourism</i>	0.01	0	0	0	0	0.01
Flow of benefits, total (i.e., including italicized items)	20.8	5.2	14.1	3.9	1.0	44.9
Sum of entries that could be included in national accounting (i.e., excluding italicized items) -- (i)	8.5	5.2	10.0	3.9	1.0	28.5

Table 3. Change of the value of the Ethiopian forests in 2013 (Unit: 2013 billion ETB)

Type	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Change of the stock value (5% discounting)	-16.5	-1.1	-24.4	-1.9	-3.8	-47.8
Value of future flow benefits (based on (i) of Table 6)						
5% discounting, no capital gain	-4.4	-0.5	-6.8	-2.0	-0.6	-14.3
(5% discounting, 2% increase in p)	-5.4	-0.8	-7.8	-2.5	-0.7	-17.2
(10% discounting, no capital gain)	-3.0	-0.3	-5.1	-1.4	-0.4	-10.2
Retention of carbon dioxide	-13.7	-0.6	-31.4	-11.2	-3.2	-60.2
Option values (genetic resources)						
Coffee genes	-0.4	0	0	0	0	-0.4
Bioprospecting	-7E-05	0	0	0	0	-7E-05
Value as agricultural land (conversion from forest)	2.0	0.0	13.8	11.3	0.0	27.1

Appendix 1. Data sources for forest accounting

Data type	Source	Description	Data quality
Forest area in 2000	WBISPP (2004)	This is the first ever comprehensive national scale forest data obtained from original forest inventory. It provided forest area coverage (nationally and for regional states) and standing stock and incremental yield per unit hectare for the various forest types found in the country.	Excellent
Fuelwood supply of 2000	WBISPP (2004)	This data is also obtained from the WBISPP document, which is primary survey data.	Excellent
Timber/industrial wood supply of 2000	Bekele (2011) &FAOSTAT (2000) &)	This data is a compilation of national wood product statistics reported to FAO as part of global data collection. The same data was checked and verified from FAOSTAT for Ethiopia for the year 2000. The data were collected from forest industries and government office.	Medium
Forest area of 2013	FSR (2015)	The FSR(Forest Sector Review) carried out in 2015 is the most compressive assessment of the forest sector of Ethiopia since the Woody Biomass. However, unlike the Woody Biomass Inventory the FSR data was based on projection of the	Medium

		Woody Biomass Data of 2000, integrating several socio-economic changes in the country such as population growth, energy sector changes, economic status change and others. The estimate provided is the most plausible to use for this paper as other national scale primary data are not available.	
Wood product supply and demand for 2013	FSR (2015)	The data on wood product supply and demand for 2013 is also obtained from the FSR (2013) document. The data is compiled from various sources of national statistics such as custom authority of import, Central Statistical authority for industrial wood consumption, forest enterprises for data on local production as well as other sources of data.	Medium
Forest increment	WBISPP (2004)	Incremental yield for the forest and plantation of Ethiopia is obtained from the woody biomass document.	High

Appendix 2. Adjustments to Forest Sector Review data for this study

In our quantitative estimation, we primarily use the Forest Sector Review (FSR) estimates for the production and consumption of wood products in Ethiopia. The estimation methods adopted by FSR are as follows. The volume of consumption (and trade¹⁷) is estimated from the assumed quantities of use per household or per product for individual types of wood products, namely construction material (e.g., poles and posts), industrial wood for furniture, utility poles, firewood, and charcoal. According to the FSR, pulp and paper production remains negligible in Ethiopia. Using the estimates for wood production volume, we calculate the value of produced wood using the representative average market prices in the FSR. Here, we describe the adjustments made to the value estimations using FSR data.

Timber and wood fuel

Following Reichhuber and Requate (2012), we assume that the production of 1m³ of wood necessitates labor work of two man-days. Reichhuber and Requate's calculation is based on the estimated level of rural wage for 2003 (3 ETB/day). We assume a 10-fold increase in wage level between 2003 and 2013 (i.e., increasing to 30 ETB/day), considering the changes in agricultural GDP and rural population, whose data are taken from the Ministry of Finance and Economic Development and the World Bank. For timber and fuelwood, we subtract the unit cost from the goods' market prices in the FSR. As for charcoal, we assume that the net value of wood as input is the same as that of fuelwood.

Forest coffee

Following Reichhuber and Requate's (2012) approach to estimating the production cost of semi-forest coffee, we assume that the production of 1 kg of coffee necessitates 16 ETB in labor cost. Here, we make the same adjustment to rural wage (a 10-fold increase in labor cost during 2003–2013) as in the case of timber and wood fuel.

¹⁷Alem (2015) investigates the Ethiopian trade of forest products in more detail than the FSR. However, there is no substantial difference in the sources of data between the two.

Other Non-Timber Forest Products

The FSR presents the value add (i.e., values exclusive of production costs) for bamboo, traditional pharmaceutical products, and fodder, and thus we use these estimates without adjustments. For the remaining products, we adopt the following adjustments approach, which is in line with that of Reichhuber and Requate (2012). For products that warrant substantial processing and transportation for sale in the domestic and foreign markets (e.g., honey, bees wax, and gum and incense), we assume a production cost that amounts to 40% of the sales values, and for products consumed by households or locally (e.g., spices), we assume a production cost that is 20% of the sales values.

Appendix 3-1. Area account of the Ethiopian forests in 2013 (ha)

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Opening area	2,900,000	909,500	21,500,000	20,100,000	21,298,529	66,708,029
Net effects of deforestation and afforestation	-64,253	0	-450,500	-369,104	0	-883,858
Rehabilitation and reclassification of area type	0	0	1,642,000	0	514,753	2,156,753
Net change	-64,253	0	1,191,500	-369,104	514,753	1,272,896
Closing area	2,835,747	909,500	22,691,500	19,730,896	21,813,282	67,980,925

Appendix 3-2. Area account of the Ethiopian forests in 2000 (ha)

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Opening area	4,072,998	501,522	29,242,950	26,356,068	21,298,529	81,472,067
Net effects of deforestation and afforestation	-90,242	0	-612,742	-483,987	0	-1,186,971
Rehabilitation and reclassification of area type	0	0	0	0	702,984	702,984
Net change	-90,242	0	-612,742	-483,987	702,984	-483,987
Closing area	3,982,756	501,522	28,630,208	25,872,081	22,001,513	80,988,080

Appendix 3-3. Volume account of the Ethiopian forests in 2013 (m³) (all in round wood equivalent)

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Opening volume (stock)	382,800,000	162,800,500	451,500,000	301,500,000	70,924,102	1,369,524,602
Increment	16,385,000	11,368,750	17,200,000	10,050,000	0	55,003,750
Timber (round wood, wood for furniture use, etc.)	-1,827,000	-5,500,000	0	0	0	-7,327,000
Wood fuel (firewood and charcoal)	-26,818,000	-6,793,000	-55,278,000	-21,454,400	-5,363,600	-115,707,000
Net effects of deforestation and afforestation	-8,481,415	0	-9,460,502	-5,536,566	0	-23,478,483
Rehabilitation and reclassification of area type	0	0	16,420		452,626	469,046
Net change	-20,741,415	-924,250	-47,522,082	-16,940,966	-4,910,974	-91,039,688
Closing volume	362,058,585	161,876,250	403,977,918	284,559,034	66,013,127	1,278,484,914

Appendix 3-4. Volume account of the Ethiopian forests in 2000 (m³) (all in round wood equivalent)

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Opening volume (stock)	537,635,736	89,772,438	614,101,950	395,341,020	70,924,102	1,707,775,246
Increment	23,012,439	6,269,025	23,394,360	13,178,034	0	65,853,858
Timber (round wood, wood for furniture use, construction, etc.)	-559,670	-1,684,830	0	0	0	-2,244,500
Wood fuel (firewood and charcoal)	-20,187,610	-5,113,522	-41,611,258	-16,150,088	-4,037,522	-87,100,000
Net effects of deforestation and afforestation	-11,911,996	0	-12,867,580	-7,259,807	0	-32,039,383
Rehabilitation and reclassification of area type	0	0	0	0	625,121	625,121
Net change	-9,646,837	-529,327	-31,084,478	-10,231,861	-3,412,401	-54,904,904
Closing volume	527,988,899	89,243,111	583,017,472	385,109,159	67,511,701	1,652,870,341

Appendix 3-5. Physical carbon account of the Ethiopian forests in 2013 (tCO₂e)

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Opening stock	1,140,425,000	485,009,823	1,345,093,750	898,218,750	211,294,719	4,080,042,042
Increment	48,813,646	33,869,401	51,241,667	29,940,625	0	163,865,339
Timber (round wood, wood for furniture use, etc.)	-5,442,938	-16,385,417	0	0	0	-21,828,354
Wood fuel (firewood and charcoal)	-79,895,292	-20,237,479	-164,682,375	-63,916,233	-15,979,058	-344,710,438
Net effects of deforestation and afforestation	-25,267,549	0	-28,184,411	-16,494,354	0	-69,946,315
Rehabilitation and reclassification of area type	0	0	48,918	0	1,348,447	1,397,365
Net change	-61,792,133	-2,753,495	-141,576,202	-50,469,962	-14,630,611	-271,222,403
Closing stock	1,078,632,867	482,256,328	1,203,517,548	847,748,788	196,664,108	3,808,819,639

Appendix 3-6. Physical carbon account of the Ethiopian forests in 2000 (tCO₂e)

	Natural forest	Plantation	Woodland	Shrubland	Trees outside forest	Total
Opening stock	1,601,706,464	267,447,055	1,829,512,059	1,177,786,789	211,294,719	5,087,747,086
Increment	68,557,890	18,676,470	69,695,698	39,259,560	0	196,189,618
Timber (round wood, wood for furniture use, etc.)	-1,667,350	-5,019,390	0	0	0	-6,686,740
Wood fuel (firewood and charcoal)	-60,142,255	-15,234,035	-123,966,872	-48,113,804	-12,028,451	-259,485,417
Net effects of deforestation and afforestation	-35,487,820	0	-38,334,667	-21,628,175	0	-95,450,662
Rehabilitation and reclassification of area type	0	0	0	0	1,862,340	1,862,340
Net change	-28,739,535	-1,576,954	-92,605,841	-30,482,419	-10,166,111	-163,570,860
Closing stock	1,572,966,929	265,870,101	1,736,906,218	1,147,304,369	201,128,608	4,924,176,226