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Research Article

Estimating Sustainable Human Wellbeing Embedded in Condition of Plantation Forest Ecosystem in The Upper Hare-Baso River Catchment of Gamo Highlands, Southwestern Highlands of Ethiopia.

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Abstract

The study aimed to assess sustainable human well-being using an improved ecosystem accounting framework (SEEA-EEA12) for the plantation forest in the Gughe massif of Gamo Highlands, southwestern highlands of Ethiopia. Natural capital has remained largely hidden to policy-makers due to the limitations of traditional economic indices such as human development index (HDI) and gross national product (GDP), and due to this integrating, the ecosystem services into national income was limited (empty world view). However, the contemporary environmental economic approach (full world view) initiates the integration of ecosystem services into national income to guarantee sustainable human wellbeing, a healthy environment, and sustainable economic development despite sustainable human wellbeing related studies are small-scale. The stock change method (litter data), species specific models (carbon data), net present value method (monetary value of timber), market price approach (monetary data of litter), petroleum fuels and kerosene tax of Ethiopia (monetary price of carbon), and tracking using GPS (area data) were implemented. Generally, field measurement, and default data were used to estimate opening-closing period data of physical and monetary values. The current change rates, future expected gains and losses of litter, timber and corresponding monetary values are decreasing. The volume change rate of plantation forests was 0.6%/, and expected changes projected for three consecutive years are -56.92, -56.24, and -55.9 for the year 2021, 2022, and 2023, respectively. To concluded that there was fast degradation rate, and if the present rate of change proceeds there will have destruction, and unsecured/fragiled sustainable human wellbeing. The result initiated to recommend Chencha zuria woreda and NGO's to modify the management system/approach, extend plantation to the surrounded pasture lands, and introduce the renewable energy sources to reduce degradation rates, and to detach fuel wood reliance of users.

Keywords: Ecosystem Accounting; Improved Framework; Plantation Forest; Sustainable Human Well-Being; Upper Hare-Baso Rivers Catchment

1. Introduction

Even though the notion of an ecosystem benefit is ancient it became a unit of study for the first time is less than a century ago and provided an initial scientific conceptualization in 1935 [1, 2]. However, the World Commission on Environment and Development (*the Brundtland Commission*) and "*the Earth Summit*" in 1992 were the first global summits on the environmental issues and that participated by the world nations (World Commission on Environment and Development [WCED], 1987). The attempt of summit was to bring the world into a single issue, the environment, and uses as a spring board for the awareness of fragile natural environment, its sustainability mechanism, rehabilitation techniques, and the integration into national income in order to sustain economic development and human wellbeing; [3-7].

In the *anthropocentric view* (philosophy) of environment, human is the central point and environment is given for the human as an instrument [8, 9]. Hence, accounting for each ecosystem flows, and current and expected changes, are in order to maintain the fragiled ecosystems, to sustain the existing ecosystems, to sustain economic development, and finally for the sustainable human wellbeing [5-7]. Sustainable human well-being is the basic material needs for a good life, freedom and choice, health, good social relations, and personal security and/or stands antagonistic to human ill-being [10]. Hence, to fully implement of ecosystem services accounting and integration into national economy, there should be improving of accounting approaches, methodologies, and standardizing and harmonizing of them regardless of different influencing factors in order to implement despite it has been achieved in small scale [3, 4, 11, 12].

The principal pillars of the wealth of nations, such as human and natural capital, were remained largely hidden from policy-makers due to the limitations of traditional economic indices such as gross domestic/national product (GDP/GNP) and human development index (HDI) [13, 14]. For instance, GDP measures only financial and material flows over a given time, while the HDI is an initiative to provide an alternative to GDP in measuring human development progress in terms of life expectancy, education, and income [13, 15, 16]. However, both are failed to demonstrate an indicator to understand and track sustainability by incorporating the ecosystem dimensions and integrate ecosystem goods in a capital accounts to complement GDP of the nation's [3, 17-20]. Therefore, the contemporary environmental economic notions (full world view) dictated over traditional growth theory (empty world view) by conceiving the environment as natural capital although there are limitations of commitment of nations to account for and integrating into national capital using standardized accounting approaches and methodologies [14, 16, 21, 22]. States that the assessment of ecosystem stocks and changes, valuation, and compiling have reduced the scanty of ecosystem services information, knowledges of it, appeals for remedies; and that indirectly addresses sustainable development and human wellbeing [23, 24].

The ecosystem services valuation methods are usually site specific (depending of determining factors like climate, soil moisture, socioeconomic and cultural backgrounds of users), and many of them are proxy values (unobservable values) [13]. In other words, the valuations are based upon the price of related goods and services or hypothetical situations and well as socioeconomic and agroecological variations [21]. However, yet the accounting and integration of ecosystem services into national income are challenging projects, even though some governments have started to practice in a good manner [13, 25, 26]. The main reasons for challenges of implementation are: the absence of market prices for some ecosystem goods and services, lack of updated data, less harmonization of accounting methodologies, less commitment to integrate into national income, and awareness matter of users [7, 12, 14, 27, 28]. As a result, most of natural environments are challenged, and our future fate is threatened despite some ecosystem accounting frameworks, viz. improved SEEA has been trying to polish the gaps though implemented in a small scale [23, 29].

The ES asset accounts have consisted of three parts: opening stocks, changes during the accounting period, and closing stocks [16]. The opening stocks are physical or monetary values at the beginning of study; changes during the accounting process are changing of ecosystem volume and money at time of measuring; the closing stocks is the difference between opening and the end of study period [25]. The changes occur during the study periods (opening-closing) are emanated from the economic activities, some extent from natural, and other factors [5, 15]. For example, the changes occurred during the study period are emanated from anthropogenic activities and natural factors [7]. The anthropogenic factors are afforestation (+ve), and degradation due to fuelwood extraction, charcoal production, harvesting damage, and extracting of construction materials (-ve); natural changes are natural growth (+ve), forest fires and insect damage (-ve); other changes of ecosystem asset are regeneration and natural losses [7, 30]. Hence, changes (enhancement Vs reduction) in ecosystem determines sustainable economy, sustainable environmental health, and the sustainable human wellbeing [7, 30].

Although Ethiopia is a natural resource-dependent country with a fragile environment, its extraction amount has been less overwhelmingly accounted for (valued) [31]. Because there is lack of updated forest databases, scarcities in active market prices for some nonmarket ecosystem services, constraints in standardized accounting methodologies for similar ecosystem services in different regions/agroecology, and selective concern (dedicated for market goods) variation for managed and natural ecosystems like forests, and less commitment of practitioners [31-35]. Therefore, investigating and accounting for opening-closing period changes of forest ecosystem services is interesting to estimate the study period change rates, the expected future gains and losses, and to project the sustainable human wellbeing so as to make decision on management issues [19, 36, 37]. However, most researches had studied were on ecosystem stocks/assets changes via monetary and physical metrics, conducted in somewhere else in Ethiopia on the natural forests than plantation, and rare or not at all in the upper Hare-Baso rivers catchment in which the study has already took over.

The purpose of the study was to project the sustainable human wellbeing, improve management intensity, and policy issues. The study aimed to estimate the opening and closing period change rates of plantation forests ecosystem services to approximate the sustainable human wellbeing embedded in an improved SEEA (SEEA-EEA 12). The study was targeted on the selected ecosystem assets and services valuation via physical (area and volume) and monetary prices per opening and closing periods changes, and to estimate future benefit flows and losses of three consecutive years (2021, 2022, and 2023) for standing timber, carbon sequestrated, and litter production.

2. Materials and Method

Study Area Descriptions: Altitudinally, the upper Hare-Baso River catchment is located between 2,329 and 3,442masl; astronomically is located between $6^0$15'0" N-$6^0$22'0" N latitude and $37^0$28'0" E-$37^0$38'0" E longitude (Fig 1); the relative location is under Qogota, and Chencha Zuria woreda (*woreda*: is the second smallest administrative level in Ethiopia) of Gamo zone in Southern Ethiopia.

The physiographic feature of the area is part of rugged terrain of Gamo highlands that extended north to south with rising elevation up to 4200masl, Mt. Gughe, the highest peak in the southwestern physiographic features of Ethiopia. Pre-

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dominantly, upper Hare-Baso river catchment comprises two mountain peaks namely Maylo and Surra and are seen above the surrounding lands. Mountain Maylo is the watershed divide of Hare-Deme while mountain Surra is the watershed divide of Baso-Hare and Baso-Deme.

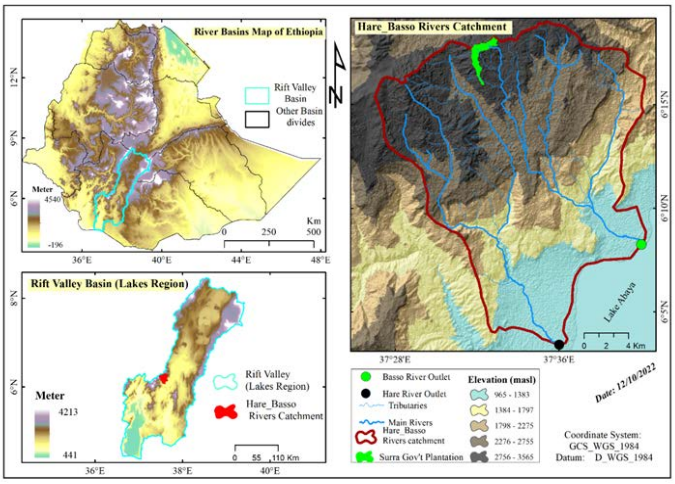

Figure 1: The physical map of Hare-Baso river catchment.

(Source: own design via ArcGIS 10.5, 2021).

According to updated Koppen's major climate classification system, the agroclimatic of the study area is tropical highland climate (mountain climate type) represented by capital letter 'H', and locally named as dega. The mean annual rainfall of the area varies from 1,100 to 1,300mm, and receives bimodal rainfall. The first rainfall season is from March to April while the second is from June to August. The average minimum and maximum temperature of the area is 18^0 C and 23^0 C respectively.

The types of soil for the upper Hare-Baso rivers catchment is allotted under region 20, and that is part of the moistest southwestern highland of Ethiopia. The soil of region 20 is a part of the relief that dominated by basaltic parent rock. The soils of red and fairly deep dominant Eutric-nitosol is associated with *Humic-cambisols, Vertisols, Ferralsols* and *Acrisols* are originated from basaltic parent rocks.

The old and historic settlement of people in the catchment depleted natural forests. The natural forest, except in sacred places, has dwindled due to population pressure caused increment for demand of arable land, fuel wood and house construction materials. Although natural forests on private lands are almost depleted, and one can see here and there the patches of natural forests in the pocket areas, and are found on graveyards, meeting places (*Dubusha*) and others sacred sites. Hill tops in the catchment are covered by Afro-montane grasses and permanently grazed. The remainder indigenous tree species found in the area were *Arundinaria alpina* and *Juniperus procera.* However, the coverage of plantation forests such as individual woodlots, community plantation, and government plantations had been substituting the natural forests. For example, the government plantation forests of exotic tree species were established during the *Dergue* era by donation of United Nation Sudano-Sahelian Office (UNSO), African Development Fund (ADF), and World Bank (WB) as part of Ethiopian highlands' plantation project. Consequently, in the upper Hare-Baso river catchment, two major government plantation forests were established in 1980's notably Maze and Surra government plantations as part of Ethiopian highland plantation forest expansion project.

The main economic activities of the upper Hare-Baso river catchment was mixed high land farming on degraded and highly fragmented farmlands. Hence, the economic condition of the people in the catchment was food insecure and is said to be one of the foods inconfident areas in the Southern region (SNNPRS) of Ethiopia. The farm sizes are extremely marginal and per capita holding is less than 0.25 hectare. Tilling using hoe is dominant over oxen plough because of the scarcity of grazing land and high land fragmentation [9]. Since it is tropical highland agroclimatitc region the dominant highland crops growing are root crops and cereal; major cereal crops growing in the catchment are viz. barley, wheat, peas and beans while the root crops are potato, enset (*Enset ventricosum*), and *qolxo* (*sisume*) [9]. *Enset* is the staple foodstuff in the area and part of subsistence agriculture. The raising of livestock is an integral part of the economy and is practiced by tethering at homesteads and gates as well as free grazing at the communal grazing lands and governmental plantations. The dominant highland livestock reared are sheep, horses and cattle. The nonagricultural economic activities practiced in the catchment were petty trade, weaving and collecting of BLTs. Weaving with its long history in the area is dominant livelihood supporting practice. Moreover, the introduction of apple fruit (suitable for tropical highland climate) is becoming hope to improve income for the rural poor people [38].

2.1 Methodology

Sampling and data acquisition

Physical data:

Area data: the opening area data of sampled plantation forest was assessed using GPS Garmin H72 [39]. However, the closing area data were obtained by adapting the closing period data of plantation forests of Ethiopia [33]. The opening and closing area of plantation forests in Ethiopia was 909,500 ha with no change of area, and therefore, the corresponding opening and closing area of sample plantation forests in the catchment was quantified.

Volume data: the opening and closing period volume of plantation forest in the upper Hare-Baso rivers catchment was obtained by adapting the opening and closing period volume of plantation forests from the forest database of the Ethiopian government, and were 162,800,500 and 161,876,250, respectively [33, 35]. Thus, the acquired volume of opening and closing period data of plantation forests in the study catchment was mathematically converted as follows (Eq 1):

$$V = \left(\sum_{i=1}^{n} -(X_1 + X_1 + \dots Xn)\right) + \left(\sum_{i=1}^{n}(Y_1 + Y_2 + \dots Y_n)\right) \dots\dots \quad (1)$$

where V represents the volume of the plantation forest; -(Xn) represents reducing factors; Y represents increasing factors, and z represents different types of factors (negatively/positive changing).

Carbon data: the biomass data of sampled plantation forests of the upper Hare-Baso was acquired by inferring the height (H), diameter at breast height (DBH) and wood density (WD). The H data were acquired from field surveys using clinometer and measuring tape prepared stick. The calipers and measuring tape were used to acquire the DBH data [40]. However, the wood density (WD) data were acquired from other sources [41]. The species-specific allometric equation and Pan tropical allometric model were used to infer the aboveground biomass (AGB) for *Eucalyptus globulus*, *Cupressus lustanica* and *Pinus radiata* respectively (Eq 2) [41, 42]. The belowground biomass (BGB) of the same forest was obtained by considering the Tolunay's estimation approach of belowground biomass (BGB), and hence AGB was multiplied by 20% (0.2) [43].

$$AGB_{best} = 0.762 * (DBH)^{2.2509} * (H)^{-0.449} * (D)^{0.5266} \quad (2)$$

where AGBest = aboveground biomass for the live tree (ton/ha), DBH represents diameter at breast height (1.3 m) (cm), H denotes height (M) and WD represents wood specific density (cm/g^3)

$$AGBest = 0.0559 * (\rho D^2 H)^{0.976} \quad (3)$$

AGBest = aboveground biomass of live tree (ton/ha), ρ represents wood density (cm/g^3), D denotes the diameter of the tree at 1.3 m above ground (cm) and H represents total height (m).

Litter/BLTs data: To acquire the sample plots of the BLTs/litter the 'plot method' was implemented, while to collect litter production per wet and dry sampled month the stock change approach was used [44]. Hence, 30 small plots ($1*1m^3$) were selected purposively from opposite corners of minor plots (look at chapter 2, fig 3 above). Therefore, the BLT/litter of eucalyptus tree species data were acquired from two seasons, August (wet season) and January (dry season) and extrapolated into hectares (Eq 4).

The average litter/BLT production/ha/yr is theoretically decomposed as follows:

$$\mathbf{TLPA} = \left(\frac{L_w + L_d}{2}\right) * Y * A \quad (4)$$

where TLPA = total litter production per annum; L_w = litter of the wet season; L_d = litter of dry season; 2 = represents two seasons (wet & dry); Y = months of a year (12); A = area of the eucalyptus plantation (172.4 ha).

2.2 Monetary data

Plantation forest (timber): The monetary value data of timber were obtained by adapting the gross production costs (GPV) and net value added (GVA) of timber of Ethiopian plantation forests [33]. The GPV and GVA of timbers in Ethiopia depended on the tree species, wood industries, and round wood types per cubic meter (m3). The monetary value of timber for the plantation forests were, therefore, quantified using the net present value (NPV) method (Eq 5) [7]. Thus, the monetary value of timber is, therefore, theorized as follows:

$$\boldsymbol{V_t} = \sum_{\tau=1}^{N_t} \frac{RR_{t+\tau}}{(1+r_t)^{\tau}} \quad (5)$$

where V_t is the value of the asset of time *t; N* is the asset life: *RR* is the resource rent, and *r* is a nominal discount rate; RR_t+τ (τ =1, 2... N_t) is a nominal value of expected future resource rents.

Litter/BLTS: The monetary value data of BLTs/litter/kg/ha and the total/kg were surveyed from the market of Chencha town. The monetary price/kg was collected by weighing a bale of litter and its corresponding monetary price concurrently using a checklist and divided the bale of litter to corresponding prices to get average price/kg. Consequently, data were acquired from 33 bales (bundles) of litter/BLTs per two seasons. The total annual monetary value of litter is, thus, theorized as follows:

$$\mathbf{TMVL}_{(BLTs)} = TAPL_{(BLTSs)}/kg * MVL_{(BLTs)}/kg \quad (6)$$

where $TMVL_{(BLTs)}$ = Total monetary value of litter or BLTs obtained from the forest; $TAPL_{(BLTSs)}$/kg = Total annual production of litter per kg; $MVL_{(BLTs)}$/kg = Monetary value of a kg of litter (BLTs) in the local market.

Carbon: The monetary value data of carbon were obtained by adapting the monetary equivalent value of a ton of carbon from different kinds of literature [45]. Hence, the monetary value of carbon/ton was estimated based on the petroleum fuels and kerosene taxes of Ethiopia in 2018 [46]. Thus, the monetary value of carbon produced from the plantation forests was assessed by multiplying the total production of carbon/ton/yr.

2.3 Social welfare

Expected change: Unlike nonrenewable resources, plants and animals have the potential to reproduce, grow and die over time [47]. In ecosystem accounting, changes in renewable resources determine sustainable human wellbeing. Thus, to determine the changes (negative/positive, expected holding of gains or losses) of a stock and flows it was accounted in terms of physical and monetary values. In particular, the opening and closing period changes were assessed to estimate the expected future gains and losses (changes) (increment/reduction) [3, 24]. The expected future change in ecosystem stock is mathematically decomposed as follows:

$$S_t = X'_{t-1} - X'_t \quad (7)$$

where S_t is the expected depletion during time t; X_t' is the expected quantity at year t; and X_{t-1}' is the expected quantity at year t-1.

The expected change balance-sheet entry for the value of different ES service flows of plantation forests at the end of year t-1 was assessed [14]. In this regard, the carbon, litter, and timber volume of plantation forests at the end of closing period t, in this context at the end of 2023, was accounted for (Eq 8) and was theorized as follows:

$$\boldsymbol{VC} = \sum_{i=1}^{z} (X'_{t-1} - X'_t) \quad (8)$$

where z is the different types of ES services; X'_{t-1} is the expected quantity at year t-1; and X_t' is the expected quantity at year t.

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Future benefit flows: the value of depletion can be subtracted from the resource rent to yield an expression for the depletion-adjusted resource rent [5]. The "*depletion-adjusted resource rent*" represents the net income generated by the forest asset in the future depending on the closing period rate of change (Eq 9). Therefore, the future benefit flow of the different ES services was theorized as follows:

$$\boldsymbol{RR_t} = V'_{t-1}(1 + r_t)\text{-}V'_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

where RR_t is the depletion-adjusted resource rent (future benefit flows) for a single ES service; V'_{t-1} is the expected value of period t-1; 1 + r_t represents a rate of change; and V_t' represents the expected value of the asset at the end of the period.

The value of depletion for different types of stocks and flows from forest assets can be subtracted from the resource rent to yield an expression for the depletion-adjusted resource rent. The different types of stocks and flows, in this regard timber, litter/BLTs, and carbon from the plantation forests, were computed (Eq 10). It was theoretically formulated as follows:

$$RR_t = \sum_{i=1}^{z}(V'_{t-1}(1 + r_t) - V'_t) \ldots\ldots\ldots\ldots\ldots \quad (10)$$

where RR_t is the depletion-adjusted resource rent (expected benefit) for different types of ES services; V'_{t-1} is the expected value of period t-1; 1 + r_t represents a rate of change; V_t' represents the expected value of the asset at the end of the period; and z represents different types of stocks and flows from the plantation forests.

3. Results and Discussion

Physical Accounting

Area

Opening and closing period: The opening area of the plantation forest was accounted for using a field survey (Table 1), while the closing period of the same year was computed by adapting the closing period data of the Ethiopian plantation forests (Table 1), and there was no change [33]. Hence, the result of the plantation forests in the study catchment aligned with the Ethiopian government.

Table 1: The area changes of plantation forests between opening & closing periods of Ethiopia.

Plantation forest stocks	Area/ha	
	Ethiopian Gov't	Study area plantation
Opening area	909, 500	235.5
The net effect of afforestation and reforestation	-	-
Rehabilitation & reclassification	-	-
Conversion of plantation land	-	-
Forest fire	-	-
Pest damage	-	-
Disease	-	-
Net change	-	-
Closing stock	909, 500	235.5

Source: adapted from the forest database of Ethiopia, 2021.

Volume

Opening and closing periods: The volume account of plantation forests indicates that there was a slight change (Table 2). In other words, the opening period volume was 42,154 while the closing period was 41,915.2, and the difference was 238.8 m3 (negative). Similar investigation results of Ethiopian plantation forests indicate that there was a slight change in volume between the opening and closing periods [35]. For example, the opening and closing period volumes of Ethiopia were 162,800,500 and 161,876,250 m3, respectively, and this denotes that there was depletion in the plantation forests in the upper Hare-Baso river catchment [33].

Table 2: The volume and change rate of plantation forest in the catchment based on the change rate of Ethiopian government.

Annual change of plantation forests	Ethiopia	Surra	Plantation forest per tree species		
			E. globulus	C. lustanica	P. radiata
Opening volume	162,800,500	42,154	30,859.23	10,346.08	948.69
Mean annual increment (MAI) (-)	11,368,750	2,931.25	2,145.85	719.43	65.97
Timber (for furniture) (-)	-5,500,000	-1,418.09	-10,38.13	-348.05	-31.91
Wood fuel (-)	-6,793,000	-1,751.47	-1282.18	-429.78	-39.50
Rehabilitation and reclassification	0	0	0	0	0
Net change	-924,250	-238.80	-174.82	-58.61	-5.37
Closing volume (m3)	161,876,250	41,915.2	30,684.42	10,287.47	943.31

Sources: Computed field survey (2021) and annual volume change data of Ethiopia (FSR, 2017).

Volume of opening and closing periods (Carbon): The opening and closing period volumes of carbon storage from plantation forests of upper Hare-Baso river catchment were 9,487 t and 9317.94 t, respectively (Table 3). The decrease in wood biomass and corresponding carbon stock demonstrate that the reduction in plantation exceeds its increment.

Table 3: Total carbon/ton and average carbon storage (t/ha) capacity of aboveground (AG) and belowground (BG) biomass.

Tree Species	Area/ha	Total Carbon Stored (t)			Average Carbon Sink (t/ha)		
		AG	BG	AG+BG	AG	BG	AG+BG
E. globulus	172.4	5,115.7	1,023.1	6,138.8	29.7	5.9	35.6
C. lustanica	57.8	2,597.3	518.5	3,115.8	44.9	9.0	53.9
P. radiata	5.3	193.7	38.7	232.4	36.5	7.3	43.8
Overall	235.5	7,906.7	1,580.3	9,487.0	33.6	6.7	40.3

Source: field survey data, 2021 (Note: 1 ton = 1,000 kg)

Volume of opening and closing periods (Litter/BLTs): The opening and closing period volumes of litter/BLTs from the sampled eucalyptus plantation were 558576 kg/yr and 558323 kg/yr, respectively (Table 4). The change in the volume of litter is supposed to be due to anthropogenic factors, particularly, the preference of eucalyptus tree species by illegal loggers in the area in order to build houses [33].

Table 4: Dead litter of small plots (1 m*1 m) in two seasons (dry and wet seasons), mean weight of litter for two months/ha, and the weight of the entire eucalyptus forest.

Wet season kg/mon	Dry season kg/mon	Wet kg/ha/mon	Dry kg/ha/mon	Mean kg/ha/mon	Total kg/yr.	Ton/yr. (year)
0.73	0.89	243	279	270	558576	559

Source: obtained from the field (2021)

Some works have shown that there was litter production potential variation in eucalyptus plantations (Haile, 1992) and the upper Hare-Baso river catchment too. For example, the litter production/ha/month or #/annual of plantation forests was smaller than that of the Addis Ababa peri-urban eucalyptus plantation (Olsson, 2004). It was supposed that the plantation forests of the study catchment were more depleted than the others. For instance, the wood stand density of eucalyptus plantation/ha was 455, and was many fold less than other plantation forests in Ethiopia (Yirdaw, 2018; Tesfaye et al., 2020).

Monetary Value

Timber: The monetary value/m3 of timber varies based on the types of wood processing industries and types of timber [35]. The monetary value of timber from the plantation forests were accounted for using net present value (NPV) method (production cost method) based on the monetary value of timber for the wood industry in Ethiopia (Table 5) [33]. Hence, the opening value of the gross production value (GPV/m3) and gross value added (GVA/m3) of the upper Hare-Baso river catchment were USD130/m3 and USD11, respectively. Therefore, the summation of GVP and GVA of the plantation forests/USD/ha estimated was 5,910,043.2 (USD 5.9 million) (Table 5).

Table 5: The gross production value (GPV) and gross value added (GVA) of the timber production and wood processing industries of Ethiopia and the upper Hare-Baso river catchment

Closing volume/ m^3	Produced for utility	\$ GPV/m^3	\$GPV (million)	\$ GVA/m^3	\$ GVA (million)
Ethiopia 161,876,250	Production of logs	74/m^3	-	-	-
	Production poles	19/m^3	-	-	-
	Saw-milling and Panels	130/m^3	101	11	8
	Furniture industry	284/m^3	130	33	18
	Pulp and paper	143/m^3	79	95	44
Upper Hare-Baso 41,915.2	Production of logs	74/m^3	-	-	-
	Production poles	19/m^3	-	-	-
	Saw-milling and Panels	130/m^3	5.4	11	0.5
	Furniture industry	284/m^3	-	33	-
	Pulp and paper	143/m^3	-	95	-

Source: adopted from [33, 34].

The gross monetary value of the plantation forests in the upper Hare-Baso river catchment can vary and be embedded in the types of timber and wood industries [33]. For instance, in the wood, pulp and paper sector the GVA is declining in Ethiopia, while in the furniture sector increasing [34]. The accessibility of the plantation forests, distance from industries, and market (local and abroad) determine the monetary value of timber products, and likely to vary with these factors [51]. Hence, the timber value per cubic meter of plantation forests in the upper Hare-Baso rivers catchment varies depending on aforementioned factors.

Carbon: According to the petroleum fuels and kerosene tax of Ethiopia, carbon/ton was USD5 [45]. The USD5 was the mitigation cost for carbon released from petroleum and kerosene/ton in Ethiopia [46]. Hence, the monetary value of carbon stored /ton/ha was USD201.5 (Table 6).

Table 6: The monetary value of carbon per ton (t) of the Surra plantation and tree species

Tree Species	Area/ha	Total carbon/ton and monetary price		Mean carbon/ton/ha and price	
		AG+BG	Price/total/USD5	AG+BG	Price/ha/USD
E. globulus	172.4	6,138.8	30694	35.6	178
C. Lustanica	57.8	3,115.8	15579	53.9	269.5
P. radiate	5.3	232.4	1162	43.8	219
Overall	235.5	9,487.0	47435	40.3	201.5

Source: field survey data (2021). Note: 1 ton = 1,000 kg

The results in Table 6 demonstrate that the average monetary value per hectare of carbon from the upper Hare-Baso river catchment plantation forests is less than that of other plantation forests in Ethiopia that better managed [52]. This might be due to variation in wood density, accounting methodologies, management disparities, and other growth determinant factors [47, 50, 53, 54]. In particular, the mean carbon stored per hectare was less than that in the other plantations because of the lower wood stand density (455/ha), common illegal cutting, frequent grazing, and encroachments of people. Indeed, the monetary value of carbon during the opening/closing period was lower (Table 6).

Litter/BLTs: The average market price surveyed for a kilo of litter/BLTs was ETB 1.60; therefore, the total annual monetary value was ETB 893,721.60, while the monetary value/ha/annual was ETB5184 (Table 7). The monetary price of litter/kg of the plantation forests varies based on the season. The supposed reasons are: during the dry season the wood biomass-dependent people acquire fuelwood from different sources such as cattle dung and crop residues [55, 56].

Table 7: Litter/BLT production and its corresponding monetary value/month, per/annual

The production potential of BLTs/kg				The monetary equivalent/ETB			
Total area/ha	kg/ha/mon	T/kg/yr	kg/ha/yr	ETB/kg	ha/mon	T/kg/yr	T/yr.
172.4	270	558,576	3240	1.60	432	5184	893,721.60

Source: field survey data, 2021. Note: 'mon' represents month

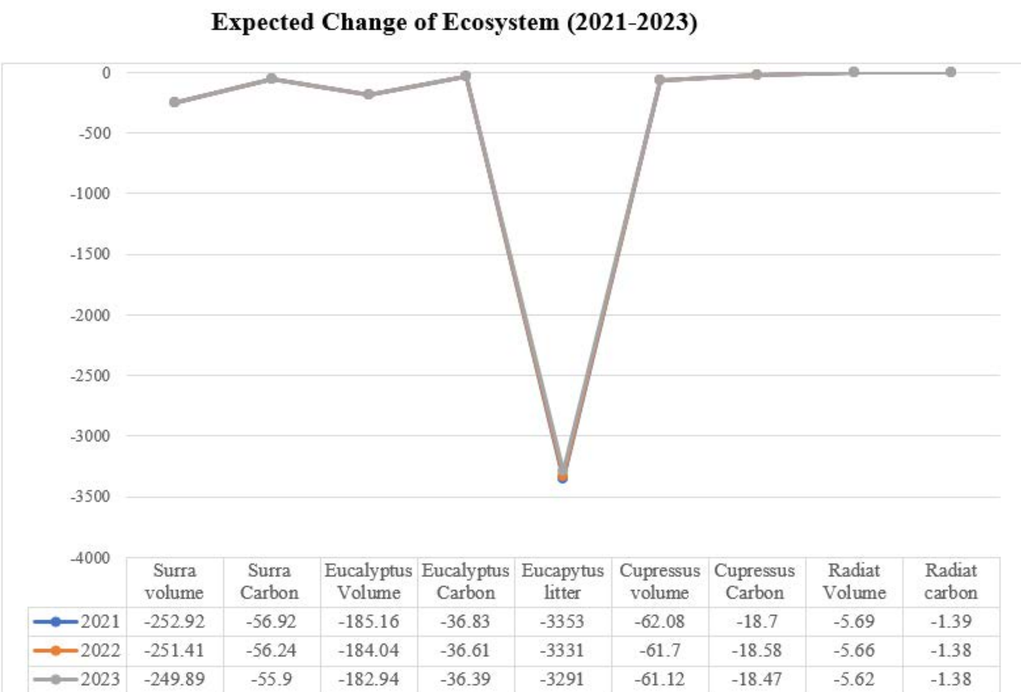
Similar studies conducted on the plantation forests state that women who depended on the raking of litter stored during the dry season and sell during the wet season [49]. Similarly, the field observations and some informal interview data indicate that some women who raked BLTs/litter from the plantation forests were stored during the dry season and sell in the wet seasons. However, the monetary production potential of BLTs/litter/ha from the eucalyptus plantation forests of upper Hare-Baso rivers catchment was lower than others, and is because of high degradation [48, 49].

Social Welfare

Expected losses

Area: The rate of change for the area of plantation forests during the opening and closing periods was zero (no change in area). The current change rate of area for the Ethiopian plantation forests is zero [33, 35]. Therefore, the expected change rate of area for the plantation forests in the study catchment should become zero for the three consecutive years (2021, 2022, and 2023). In other terms, if the present change rate proceeds for the three consecutive years there will sustainable human illbeing.

Volume: The volume of opening and closing periods for the plantation forests of the Ethiopian government was negative, and the volume of plantation forests of the study area were adapted from Ethiopia, and therefore, negatived (reduced) [33]. Hence, the volume change rate of the plantation forests in the upper Hare-Baso river catchment was 0.6% (Fig 2). Consequently, the expected changes per year for three consecutive years were -252.92, -251.41, and -249.89 for 2021, 2022, and 2023, respectively (Fig 2). Irrespective changes in the volume rather than area on the plantation forests imply that there was depletion [14]. For example, demonstrated that illegal loggers were preferred by Cupressus lusitanica and Pinus radiata tree species in plantation forests [50]. The field survey data also showed that the Surra government plantation was highly degraded because of illegal logging, encroachments, and overgrazing.



Source: field data, 2021 and literature.

Figure 2: The expected ecosystem services volume changes within three consecutive years.

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(c) Litter/BLTs:

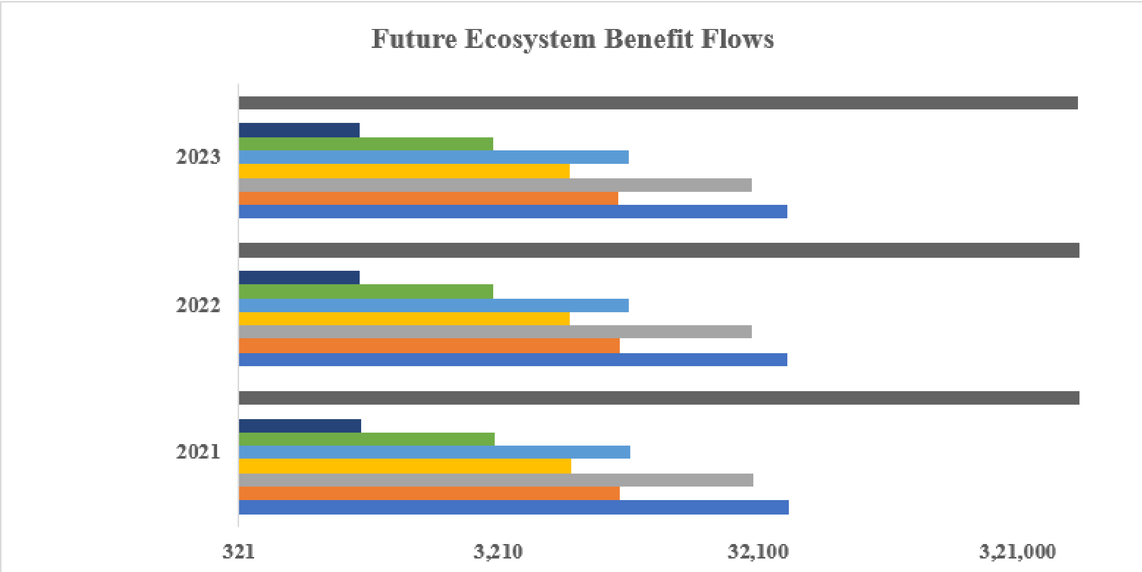
The opening volume of litter/BLTs from the Surra sub-Eucalyptus plantation was acquired via field survey and was 558,576 kg/year (Fig 2 above). Its closing volume data were adapted from opening–closing volume data of Ethiopia plantation (FSR, 2017). Consequently, the expected change in litter/BLT volume for three consecutive years was -305.67, -303.83, and -302.01 kg for 2021, 2022, and 2023, respectively (Fig 2 above). It is true that if there is a reduction in the area and volume of forest assets, there will be a negative change in ecosystem services and vice versa (UN, 2014). The practical situation of the plantation forests aligned with the findings. For instance, the average wood stand density was 455 and many-fold less than that of other plantations in the central highlands of Ethiopia (Yirdaw, 2019; Tesfaye, et al., 2020).

(d) Carbon:

Based on the change rate of opening–closing periods, the expected changes for the three consecutive years were -56.92, -56.24, and -55.9 for 2021, 2022, and 2023, respectively (fig. 10 above). These results imply that the expected change in carbon is negative. Because 50% of the dry biomass of a plantation is carbon (Macías et al., 2017), and a decrease in dry biomass reduces carbon volume (Henry et al., 2010).

3.3.2. Expected gains

The future benefit flows (net flows) of forest assets are measured by summing the negative and positive changes by considering different factors (Hamilton & Ruta, 2009), and the results will be negative, positive, or no change (DeGroot et al., 2012). The future benefit flows from the plantation forests in the catchment are expected to decrease within three consecutive study years (Fig 3). If the depletion rate is greater than the replacement rate and the rate of change becomes permanent for the upcoming periods, the future benefit flows become fragile, and implies that sustainable human wellbeing becomes fragile (Bartelmus et al., 1993; Lang, 2007).



	2021	2022	2023
Eucalyptus (Litter)	558576	5,55,223	5,51,892
Radiata (carbon)	231.01	229.63	228.25
Radiata (Vol.)	943	937.34	931.72
Cupressus (carbon)	3097.1	3078.52	3060.05
Cupressus (Vol.)	10284	10222.3	10161.18
Eucalpytus (Carbon)	6101.97	6065.36	6028.97
Eucalpytus (Vol.)	30674.07	30490.03	30307.09
Total Carbon (Sur)	9430.08	9373.84	9317.94
Total Vol. (Sur)	41,915.20	41662.28	41410.87

Source: field data, 2021; and adapted from the literature [33].

Figure 3: Future ecosystem benefit flows for the three consecutive years.

The overall volume of plantation forests in Ethiopia makes a negative change based on the results of opening and closing periods [33]. In contrast, if the rate of change information of the present value is greater than the expected future benefit flows, there will be a shrinking of ES services [5]. Thus, according to figure 3, the future benefit flows of the upper Hare-Baso River catchment plantation forests become diminishing in all services, particularly timber, carbon, and litter/BLTs productions. To conclude that the expected benefits flows are determined by the growth rate, whether increment or reduction of productions per year. In this regard, the expected change and future benefit flows of monetary values of timber (plantation), carbon, and BLTs/litter of the plantation forests of the Upper Hare-Baso River catchment were indirectly assessed by assessing their physical and monetary values (Fig 2 and 3) and determined the unsustainable human wellbeing.

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4. Findings and Conclusion

The opening and closing period change of ecosystem services were negative. For instance, the opening area of sample plantation forest was 235.5ha with no change whereas its volume was 42,154 and 41,915.2 with slight change respectively. The opening and closing period volumes of carbon storage were 9,487 t and 9317.94 t, respectively while the litter/BLTs of eucalyptus were 558576 kg/yr and 558323 kg, respectively. The future expected change of volume for three consecutive years were -252.92, -251.41, and -249.89 for 2021, 2022, and 2023, respectively by the current change rate of 0.06%. These results imply that the opening-closing period volume of all ecosystem services and their corresponding monetary prices are decreasing for the plantation forests of upper Hare-Baso rivers catchment. The expected losses will be increasing while the expected gains will be decreasing. To conclude that the sustainable human wellbeing of the study area and beyond is questionable if the current degradation rate continues.

Recommendations

Based on the current change rates it is recommended to the regional, zonal, woreda, and NGOs to apply the community-based forest management to reduce change rates/yr, afforestation for surrounded communal grazing lands to enhance grazing land benefits and indirectly to reduce the consumption pressures. Moreover, introducing the renewable energy sources is recommended to detach the fuel wood sole energy source dependent users.

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