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RESEARCH ARTICLE

An assessment of tangible community benefits from exclosures in Tigray, northern Ethiopia

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Abstract

In Tigray, northern Ethiopia, land degradation has generally undermined the environmental goods and services (EGS) those local communities depend on for their livelihoods. Massive sustainable land management programs (SLMP) to restore degraded land have temporarily ceased to be accessible free of charge to communities because human and animal interference were seen as the main drivers of the problem. The SLMP deals with agricultural productivity and land degradation through integrated watershed and landscape management where exclosures are key components. As a result, the expected translation of restoration outcomes into meaningful economic benefits for local communities is critical to the sustainability of the program. The current research deviated from previous studies by focusing on tangible benefits extracted by local communities from exclosures. A survey to understand the actual economic impacts of exclosures on the local communities was conducted in five villages of Tanqua-Abergele district of Tigray. We interviewed 331 households, 43 key informants and five focus groups each composed of 12–16 participants. Regression analysis revealed that the role of household heads in the village, governance and distance to the nearest exclosure were significantly associated with higher contribution of exclosure to household (CEHH) income. While gender showed positive but no significant effect on CEHH income, level of education was significantly against. A binary logistic regression showed that role of household heads in the village, governance system and gender had statistically significant association with higher benefit–cost ratio (BCR). While exposure to several sustainable land management training has positive but no significant effect, education levels were significantly against BCR. Discussions revealed that exclosures brought benefits to the local communities with increased water, enhancement of plant biodiversity and recovery of degraded lands. However, local communities are not making maximum tangible benefits and the contribution to household income is minimal which could counter exclosure expansion and sustainability. Maximizing benefits through designing of new irrigation sites to utilize the increment of water, planned harvest of grass for construction and animal feed, deployment of modern bee hives inside and near exclosures and creation of opportunities to collect wild fruits remain to be crucial.

Keywords Benefit–cost ratio · Exclosure · Household income · Socioeconomic · Village

1 Introduction

Land is vital for human well-being as it provides shelter, air, food and water. Globally, 45% of the Earth's land surface are drylands (Schimel 2010, p. 418). This is a very significant figure and the most sensitive segment of the earth that the world has to pay due attention. Studies indicate that 10–20% of global drylands are degraded (Bainbridge 2017, p. 175; United Nations 2011, p. 10), while up to 90 % is prone to degradation (Hulme and Kelly 1993, p. 9). Land degradation is the reduction or loss of the biological productivity resulting from climatic variations

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and human activities (Vogt et al. 2011, p. 150; Blaikie et al. 1988, p. 1). Although the drylands are less studied, Bai et al. (2008, p. 231) estimated that about 1.5 billion people depend on these degraded areas. This bears out that the livelihoods of the people who depend on drylands are severely affected. Degradation has been reported to threaten human well-being (Kasser 2009, p. 179) by reducing the productivity of land and those that depend on it including animals and plants. Therefore, restoration of the degraded areas to a productive state is more of compulsory action than a choice. This resulted in the deployment of different mechanisms of restoring the productivity of the degraded areas. Globally, the communal grazing areas of the drylands which suffer extra burden through overgrazing (Blaikie et al. 1988) and tree failing for multiple purposes (Vermeulen 1996, pp. 105–110) have been considered for restoration of ecological losses (Mekuria et al. 2018, pp. 14–16; Ashenafi 2017, pp. 29–30; Adams et al. 2016, p. 734; Tesfay 2016, pp. 113, 122). The afforestation and rehabilitation through exclosures contribute largely by limiting human activities of damaging the environment and mitigation of climate change impacts. In Ethiopia's Tigray Region, a typical arid and semi-arid area, rehabilitation of degraded lands through exclosures had been a practice for decades (Yayneshet et al. 2009, p. 542; Welemariam et al. 2018, pp. 1–11; Noulèkoun et al. 2021, pp. 1–3; Nedessa et al 2005; Gebremedhin and Pender 2001; TBNRDEP 1994). The region has been locally and internationally recognized for its successful restoration practices (Whiting 2017).

Communities and the communal lands co-evolved and sustained themselves to some degree for centuries. The local communities especially the poor depend on the communal lands for their survival. Any intervention on the management of these lands cannot sustain itself if the local communities are not entitled to some tangible and perceived economic and social benefits. After the communal lands were recruited into exclosures and managed under forest systems, new and tangible goods and services are compulsory expectations of the local communities. Local people rely on commonly owned lands for energy, building materials, traditional healing and food. Studies indicate that close to two billion people get significant livelihood benefits from forests (Chao 2012; Bhargava 2006, p. 14). In developing countries, the environmental resources render a share of up to 25 % of income (Vedeld et al. 2007, p. 876). Environmental resources were proved to enhance the resilience of the local communities during seasonal food shocks (Shackleton and Shackleton 2006, p. 565; Shackleton and hackleton 2004, p. 569) and other natural calamities.

According to Bainbridge (2017), exclosure was introduced as a feasible technology to halt land degradation and vigorously implemented in Tigray for more than three successive decades since 1991. Previous exercises on exclosures were scanty keeping forest cover to less than 9% of the land area in Tigray (Wisborg et al. 2000).

Exclosures improved soil health and vegetation cover, but their translation into actual benefits of the local people lacks quantifiable information. Studies indicate that socio-economic contributions of exclosures to local communities are highly required (Rossiter et al. 2017; Adem et al. 2020, to anticipate the sustainability of the program. Different theoretical methods were used to estimate the benefits of area closures established on communal grazing lands to the local communities in Tigray (Balana et al. 2012, pp. 29–30; Prabuddh & Suresh 2013, pp. 28, 32) with positive and encouraging predictions. However, to the best of our knowledge, limited research was conducted about actual benefits of exclosures to the local communities. Studies show that the government of Ethiopia established exclosures based on pure environmental orientation often with negative impacts on livelihoods of local communities (Lemenih and Kassa 2014, p. 1900). A review by Asmare (2021, p. 95) proposed further studies on how to sustainably and equitably share all benefits of exclosure land use to local communities and create a win–win situation. Notwithstanding the undergoing crucial experiments in the form of fees, credits or rewards for continuation and delivery of ecosystem services (Palmer and Filoso 2009, p. 576) and valuation methods (Prabuddh and Suresh 2013, pp. 28–29; Balana et al. 2012, p. 35; Birch et al. 2010, pp. 21,927–21,929), the tangible benefits the local communities receive from exclosures is more convincing and have more positive impact on sustainability. However, there is lack of empirical evidence on such evaluation approaches, despite the fact that it is decisive in its significance on feasibility and sustainability of the restoration efforts. Understanding the actual economic contributions of forest products to the people is important to policymakers, stakeholders, and practitioners (Gurung et al. 2021, p. 447). This paper departs from the hypothetical valuation approaches and presents the actual benefits of exclosures to the livelihoods of the local communities using benefit–cost ratios and percent shares on total household incomes. Moreover, the qualitative impacts as perceived by local communities are included as indicators.

2 Methodology

2.1 The study area

The study was conducted in Tanqua-Abergele district, central zone of the Tigray National Regional State (Fig. 1). Tanqua-Abergele is organized into 20 administrative villages wherein agricultural extension offices that are gradually evolving to Farmers Training Centers (FTC's) are well

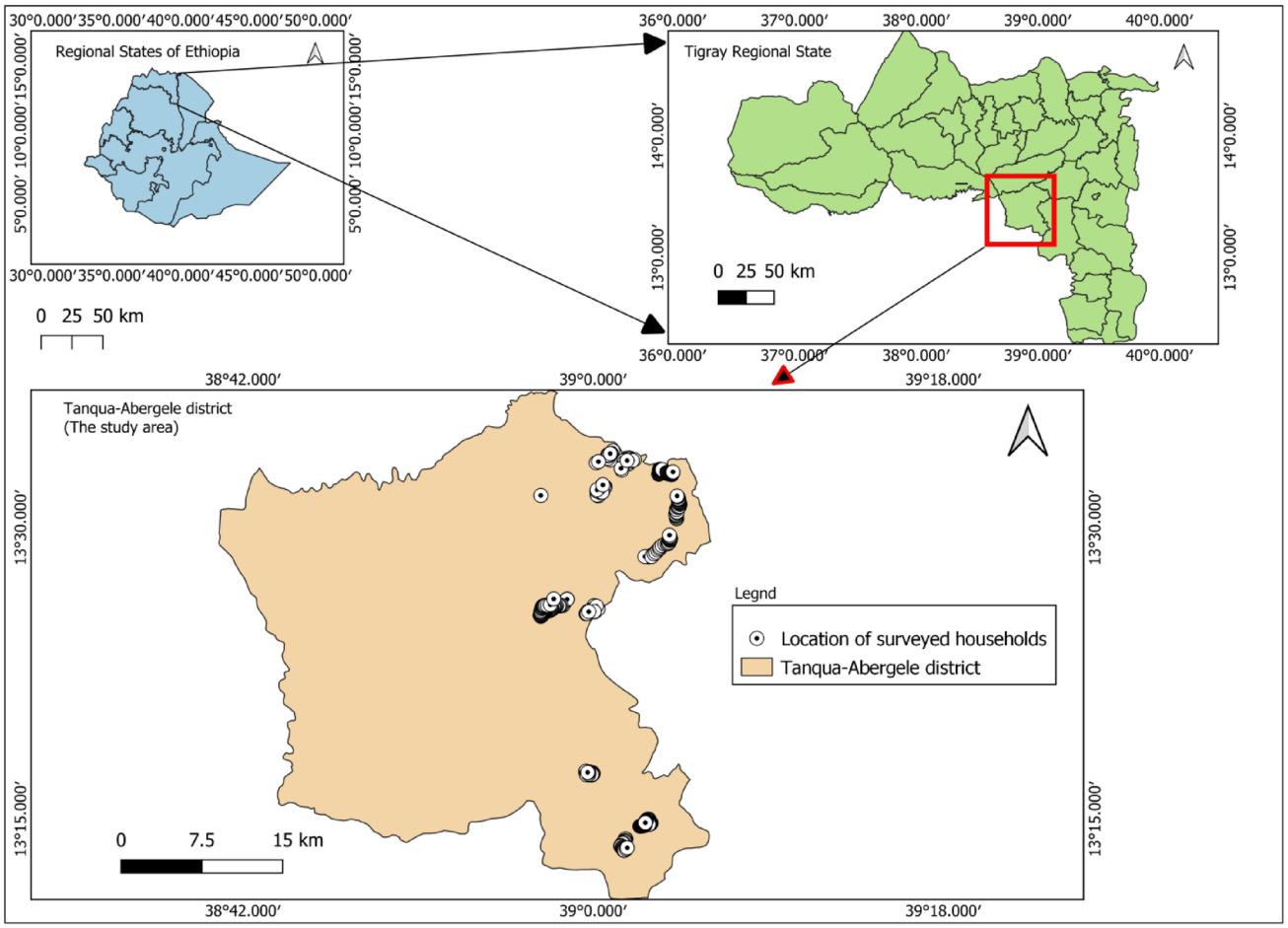

Fig. 1 Map of the study area developed using QGIS; data sourced www.diva-gis.org, and the field

established. The FTC's can own demonstration lands with the objective of establishing integrated natural resources, crop production and animal management practices to help farmers appreciate new technologies. The district is prone to recurring drought as it characteristically belongs to hot warm sub-moist low lands (SM1-4b) agro-ecology and is largely exposed to long dry periods of semi-arid climate (Tsegay et al. 2018).

The altitude of the district shows extreme variability between 937 and 2370 m above sea level. The rainfall, which is largely uneven in temporal and spatial distribution, ranges between an average minimum and maximum of 580–750 mm per annum. Similarly, mean minimum and maximum temperatures vary between 18 and 26 °C, although extreme temperatures are recorded in low-lying areas.

Sustainable Land Management Programmes (SLMP) are introduced as demonstration models based on which villages can align their large scale soil and water conservation campaigns. As a result 113 exclosures were established with the intentions of reducing food security risks through overcoming moisture deficit and soil degradation. Direct socioeconomic gains from exclosure products were not well thought at the point of their inception but their sustainability will always depend on tangible local benefits from the same. The district is rich in different local breeds of cattle and shoats (Endowment Fund For the Rehabilitation of Tigrai 2012). Tekeze Hydropower dam, the tallest arch dam in Africa, is located in this district (Welde and Gebremariam 2017, p. 3) giving it a hope for intensive conservation programs to curtail siltation and downstream irrigation.

The overall land area is estimated at 144,564 hectares. Land use and land cover categories in the district include irrigated agriculture (5466 ha), rain-fed agriculture (39,740 ha), pasture (2433 ha), and exclosures (32,986 ha). Other areas (63,939 ha) is composed of uncategorized mountains, communal grazing land and settlement areas (Araya et al. 2023). The average annual total household income from all income sources ranged from US$1,584 to US$2,078. Exclosures render some augmenting benefits to local communities, but there is a lot to be done as indicated by a typical schematic diagram in Fig. 2.

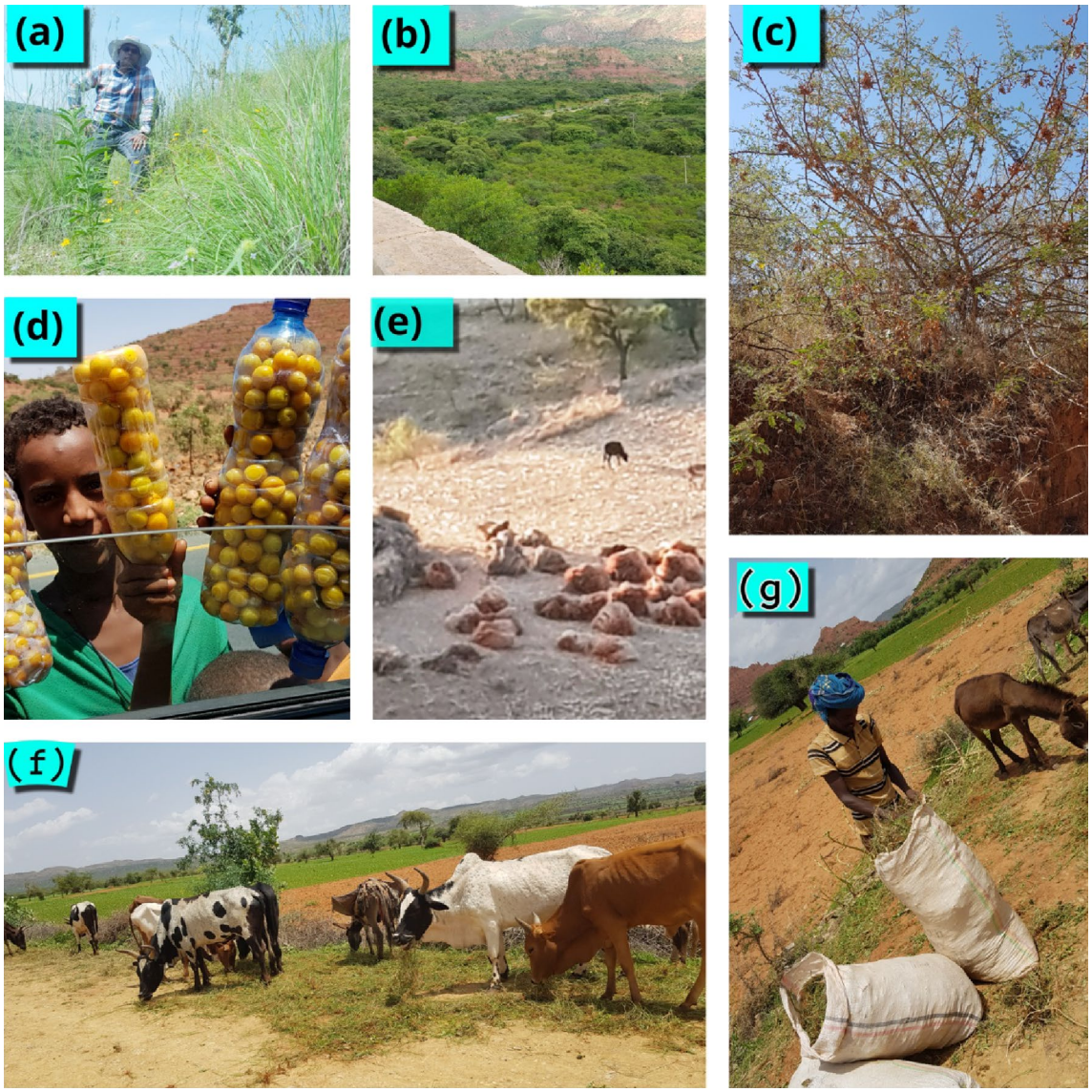

Fig. 2 An example of availability, utility and utility gaps of exclosure products in Tanqua-Abergele district. There are some reasonably utilizable goods and services produced within exclosures. Typical examples include animal feed (**a**), browse leaf and bee forage (**b**), browse pods (**c**) and edible wild fruits (**d**). Some locals earn good money by selling edible wild fruits along the roadside adjacent to exclosures (**d**) and utilize grass produced in exclosures for thatches during the construction of houses (**e**). In another scenario, farmers could not find enough area and biomass on communal grazing lands and thus feed their animals on weeds removed from farmlands (**f**) and package and carry the leftovers for later feeding at homes to the same or other animals (**g**). This is a typical example which reveals that exclosure products are not being transferred into actual benefits while demands are high. All pictures were taken by the authors during data collection in Lemlem, Gera, Shekatekli and Mearey villages

2.2 Data collection

Five villages were selected for this study. Socioeconomic survey was conducted to understand the economic contribution of exclosures to households. Interviews were held with a total of 331 household heads calculated using formulas in Cochran (1977) and proportionately distributed based on household size of each village. Systematic random sampling was used to pick individuals from a farmers list which was collected from the local administration (Fig. 3). Sampled households were inclusive of age and gender. Individual interviews were conducted to gather information on clarifying types of benefits, benefit sharing, type of products available and collected and household income generated, effect of exclosures on crop and livestock production and other inside and offsite effect of exclosures on households. Household interviews also documented household basic information (names, gender, age, education, location, household size and

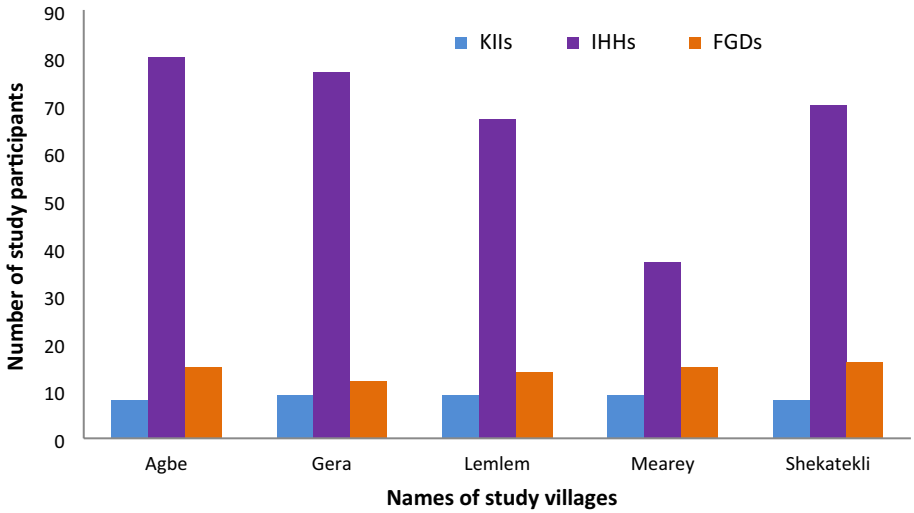

Fig. 3 Sample size distribution of Key Informant Interviews (KIIs), Individual Households Interviews (IHHs) and Focus Group Discussion (FGDs) in each selected study village of Tanqua-Abergele district

similar demographic data) and all sources of income. Then, contribution of exclosures to household income, cost–benefit ratio and negative consequences of exclosures was derived from the data gathered.

Five Focus Group Discussions (FGDs) each composed of 12–16 participants comprising females and males, out of which 43 were youth and 29 elders were held. FGDs provided background information and broad understanding of the Sustainable Land Management Programme (SLMP) prior to the key informant and individual interviews. The FGDs were used to particularly triangulate the information related to exclosure contribution to community livelihoods.

A total of 43 (Fig. 3) key informants (KIs) were interviewed to acquire in-depth understanding of information gathered during the FGDs. Specifically, KIIs were used to collect information on investment costs, exclosure benefits, price estimation of exclosure products, quantity of conservation structures and norms, utilization of exclosure products, metric equivalents of main local units used and price per unit which is necessary in valuing exclosure products. The KII respondents were professionals, village administration, technicians, experts, development agents (DA's) and people engaged in land administration, social justice and knowledgeable people about exclosures and available products. The KIIs complimented information from individual interview on the economic contribution of the exclosures and other related issues.

Exclosure sustainability is directly linked to their actual and potential economic contribution to local communities. This could be more plausible if there are immediately saleable and/or utilizable exclosure products at community levels. Monetary estimates of utility of exclosure products can help practitioners and decision makers focus on tangible transfer of benefits that communities can appreciate. The major credible environmental benefits and costs in each of the five locations were collected using well designed list of variables.

2.3 Data analysis

All income benefits earned from and the costs incurred by the households on exclosures were captured. During the interviews, households were asked to quantify the annual benefits they earned in a specified year. All costs of exclosure establishment, maintenance and annual costs were majorly obtained from KIs. Contributions of Exclosures to Household Income (CEHH) were calculated by dividing the total annual values of benefits from exclosures to the total household income, while the benefit–cost ratio (BCR) was computed by dividing the total discounted values of the exclosure benefits to the total discounted value of the costs. BCRs were calculated for the first five years. Benefits and costs were calculated on an individual (per person year^{-1}) basis so that comparisons were possible.

Regression analysis was used to determine the effect of education, gender, exclosure distance, age group, administrative roles of respondents, governance and training in sustainable soil and water conservation (Table 1) on benefit–cost ratio and contribution of exclosures to household income (Table 2). Villages differ in their capacity to deliver good governance and thus we took village as an indicator variable for governance. Moreover, the actual benefits were analyzed separately for monetary values of timber and non-timber products. A paired t-test was used to compare forest product incomes per person from communal land, own land and exclosures.

For a qualitative evaluation on the perception of local communities on the contribution of exclosures to their well-being, information was gathered from KIs, FGDs and individuals in each village. The results were aggregated and calculated to rate the perceived effects (positive and negative) of exclosures in order of importance from highest to the least. Also, individual interview participants were asked to list and rank the key goods and services available within the exclosures. We

Table 1 Description of predictor variables

Characteristics	Description
Formal education of HH	Education level of the household head is a categorical variable; 'None' being the base, to which grades 1–8, 9–10 and Preparatory + (Including grades 11–12, diploma and university degrees) were compared
Age of HH head	Age is a dummy variable where '0' is the base indicating ≤ 35 years and the comparison group is > 35 years of age
Gender of HH head	Gender is a dummy variable where '0' is base representing 'Female household head' and the comparison group 'Male household head'
Training of HH about SLMP	Training in SLMP is categorical variable; '0' is a base when the household head never got training, '1' if he/she was trained 1–3 rounds and '2' if the HH got frequent training exceeding 'three rounds'
Distance to nearest exclosure	The distance of the household residence home to the nearest exclosure in kilometers
Effect of village governance	Village is a categorical variable and was taken as a proxy measurement for variation in governance that would affect benefit sharing, protection of exclosures; 'Agbe' is taken as a base to which Gera, Lemlem, Mearey and Shekatekli villages were compared
Role of HH in the village	Role of household head in the village is a categorical variable with four groups and the base is 'None' coded with '0' when household head holds no any position in the village. General admin is if the HH head holds one of the village cabinet positions. Exclosure guard formally employed individual of exclosure, land admin committee is membership of the three village land administration committees, and SWC technician is if the household head has been leading landscape restoration technically, mobilization of labor and coordination

Table 2 Description of outcome variables

Characteristics	Description
Benefit–cost ratio (BCR)	The BCR was evaluated using dummy variables (0 and 1) with a binary outcome of '0' which designates a ≤ 1 BCR values (profit has not being made) while BCR > 1, coded as '1' showing the investment is worthwhile. Model used *Logit* $\left(P\left(Y=1\middle\vert x_1,\ldots,x_k\right)\right)=\beta_0+\beta_1x_1+\cdots+\beta_nx_n$ where P is the probability of the response variable 'Y' is equal to '1' designating profitable. β_0 is the value of the constant, while $\beta_1, \ldots\beta_n$ are Odds Ratio (OR) for explanatory variables $x_1 \ldots x_n$ in which x_n stands for a predictor variable education of HH head, age group, distance between residence of HH head and exclosure, role of the HH head in the village, training in SLMP, village of residence or gender
Contribution of exclosures to household income (CEHH)	CEHH income is continuous dependent variable expressed in percent of all estimated benefits over the total HH income. Model used $y=\beta_0+\beta_1x_1+\cdots+\beta_nx_n+\epsilon$; 'y' is the predicted value of the dependent variable; β_0= the y-intercept; β_1x_1 = regression coefficient (β_1) of the first independent variable (x_1) β_n = the regression coefficient of the last independent variable (x_n); ϵ = the model error

Table 3 Multiple and binary regression models for contribution of exclosures to household income (CEHH) and benefit–cost ratios (BCR), respectively, in Tanqua-Abergele district of Tigray, northern Ethiopia

Characteristics	CEHH income				BCR	
	Coefficient	*t*	*P*	Odds ratio (OR)	*z*	*p*
Role						
Admin	2.306	1.16	0.246	26.958	7.14	0.000
Guard	23.969	4.61	0.000	27.848	3.46	0.001
Land admin	2.086	0.30	0.762	6.986	1.70	0.089
SWC Tech	9.283	3.05	0.002	4.116	2.49	0.013
Distance NE	−0.681	−1.97	0.050	0.920	−1.14	0.254
Effect VG						
Gera	3.483	1.58	0.115	17.104	5.36	0.000
Lemlem	−4.079	−1.72	0.086	8.121	3.69	0.000
Mearey	−3.721	−1.34	0.182	11.991	3.69	0.000
Shekatekli	7.783	3.52	0.001	1.420	0.63	0.532
Age HH	3.737	2.01	0.045	1.011	0.03	0.977
Gender HH	3.230	1.44	0.151	5.821	2.93	0.003
Train-SLMP						
1-3x	−3.217	−0.95	0.341	0.255	−1.76	0.078
4+	−1.842	−0.53	0.595	1.139	0.18	0.855
Level FEHH						
E (1–8)	−12.806	−3.19	0.002	0.224	−2.10	0.035
S (9–10)	−11.763	−2.84	0.005	0.153	−2.53	0.012
P+	−9.254	−2.08	0.038	0.162	−2.22	0.027
b_0	14.305	2.39	0.0217	0.007	−3.33	0.001

Role (Role of household head in the village); Admin (Member of village cabinet); Guard (Exclosure guard); Land admin (Land administration committee member); SWC tech (Soil and Water Conservation technician); Distance NE (Distance to nearest exclosure); Effect VG (Effect of Village Governance); Age HH (Age of Household Head); Gender HH (Gender of Household Head); Train-SLMP (Training of Household Head in Sustainable Land Management Programme); 1-3*x* (Trained one to 3 times); 4+(Trained more than four times); Level FEHH (Level of Formal Education of Household Head); E (Elementary education), S(Secondary education), P+(Preparatory education and above); b_0 (Constant)

asked individuals about how they use forest products in their daily lives and different remedies in times of need for human and animals and analyzed using frequencies.

3 Results

3.1 Contribution of exclosures to household income (CEHH)

As detailed in Table 3, of a regression model ($F(16, 314) = 5.79$, $R = 0.2277$, R-MSE = 13.371, $p = 0.000$) several factors were significantly associated with higher CEHH income including role of households heads in the village (being a member of village cabinet, Coef = 2.31, exclosure guard, Coef = 23.97, soil and water conservation technician, Coef = 9.28), governance system (residing in Gera Coef = 3.48, Lemlem, Coef = −4.08, Mearey, Coef = −3.72) and distance to the nearest exclosure, Coef = −0.68. However, being a male (Coef = 3.23) has positive but no significant effect on CEHH income, while reaching grade level 1–8 (Coef = −12.81), 9–10 (Coef. = −11.76) and 11 + (Coef. = −9.25) were significantly against CEHH income.

3.2 Benefit–cost ratio (BCR) of exclosures

As clearly stated in Table 3, of binary logistic regression ($x^2(129.15)$, $R = 0.3198$, $p = 0.000$), several factors showed statistically significant association with higher BCR. These include the role of the households heads in the village (being a member of village cabinet OR = 26.96, exclosure guard OR = 27.85, soil and water conservation technique lead OR = 4.12), belonging to a particular village with variable governance system (residing in Gera OR = 17.10, Lemlem, OR = 8.12, Mearey OR = 11.99) and gender (being a male OR = 5.82). Unexpectedly, exposure to SLMP training for 1–3 rounds (OR = 0.26)

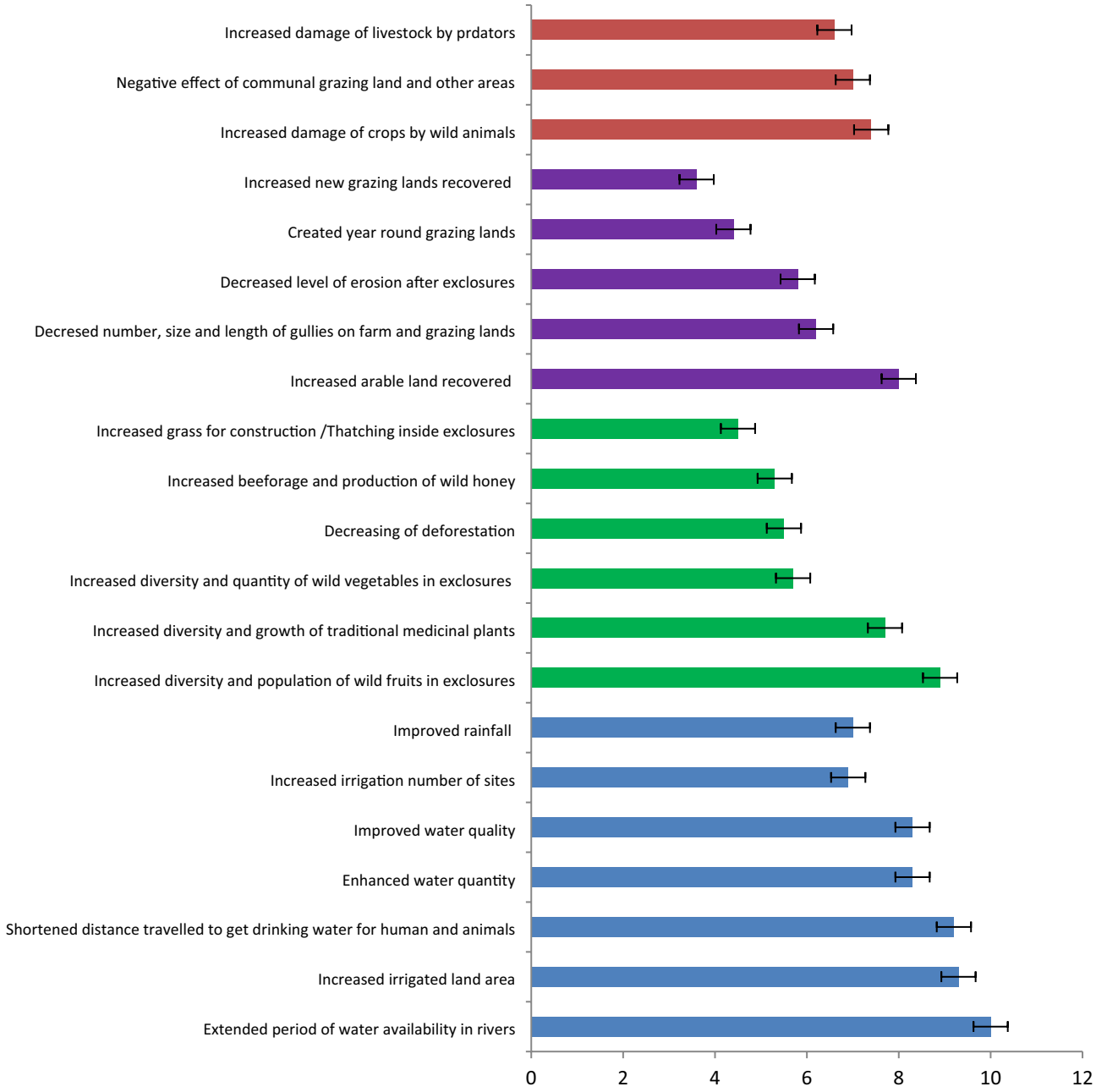

Fig. 4 Perception of local community members on effect of exclosure on their well-being, evidence from FGD response, rating 1–10 (1 being low and 10 the highest)

and 4 + (OR = 1.14) has positive but no significant effect on BCR. To our surprise, being educated to grades 9–10 (OR = 0.153) or 11 + (OR = 0.16) was significantly against BCR.

3.3 Other potential and actual benefits of exclosures to local communities

A thorough discussion with FGDs to list the major exclosure effects on different livelihood components and environmental issues is indicated in Fig. 4. The exclosure impacts as rated by FGD were water improvement and increment (8.43), enhancement of biodiversity and related (6.27) and recovery of degraded lands (5.6). The main goods and services within the exclosures (Fig. 5), ranked in order of their importance were bee forage (57.4%), animal feed (49.55%), firewood (40.79%), farm tools (35.65%), sand and stone for construction (10.57%), bee colony (6.95%), medicinal plants (2.42%), timber for construction (1.51%) and wild honey (0.91%). Out of the 331 respondents 89.12%

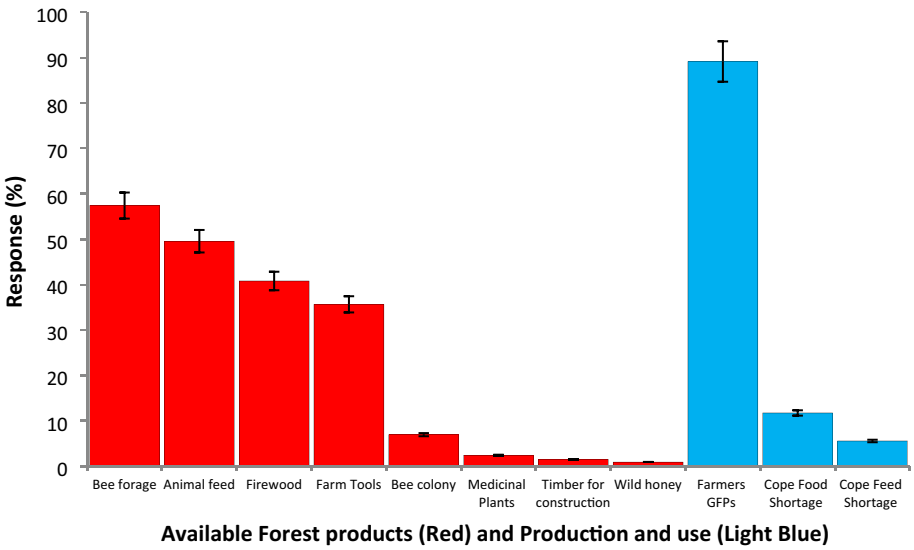

Fig. 5 Community beneficial goods and services available in exclosures and their utilization. (*Note* Farmers GFPs, farmers who grow forest products in their farm lands, Cope Food/Feed Shortage, Farmers who sold or collected forest products from exclosures to cope feed or food shortage)

deliberately nurtured and produced forest products in their farmlands. Out of the respondents who reported they face animal feed shortage, 5.56% took collection of leaves and pods from browses in the exclosures as an immediate remedy to feed their animals. In a severe drought, KIIs, FGDs and individuals confirmed that they had an opportunity to avert looming animal losses due to feed shortage through grazing exclosures for a specified period scheduled by the local administration. Similarly, 12.1% of the households who faced human food shortage collected forest products for consumption and income to purchase food grain, while 67.2% of them worked for food for work in exclosures.

In general, the most appreciated positive impact of exclosures was found to be related to water enhancement. In this regard, FGDs confirmed that exclosures improved water quantity, quality, availability and accessibility throughout the year. In our discussion with FGDs in Agbe, they indicated that they observed water increment along the downstream of the main rivers during the dry season as a result of improved underground water.

Exhaustive FGDs in Gera village elucidated that exclosures enhanced availability of water. Previously, water scarcity was the source of conflict in the village. Inhabitants had to travel long distances for an average of three hours and stay overnight queuing to fetch drinking water. They specified that currently they have two months extended availability of water as an outcome of exclosures establishments. FGDs in Lemlem village stated that previously they had to travel long distance to public shallow wells to fetch drinking water. However, nowadays the numbers of water points have increased with an even distribution along the river stream and many springs at short intervals. Presently, clean and safe water for human and animal consumption is modestly available from September to June.

The quality of water has been improved due to the physical structures of soil and water conservation built along the upper catchments and their positive effect on vegetation. Moreover, top-down construction of soil and water conservation structures showed an immediate impact on the degraded mountainous areas, protection of flooding and gully formation on farmlands. As a result, decreasing gully formation, conversion of gullies to farmlands and recovering eroded grazing lands are exclosure impacts appreciated by respondents. Interviewees recognized four most potential exclosure products vis-a-vis bee forage, animal feed, firewood and farm tools (Fig. 5). These are mainly potential benefits and not necessarily accessible by the local communities due to constraints linked to governance and rules (bylaws).

3.4 Negative impacts of exclosures

Some negative impacts of exclosures as perceived by local communities (Fig. 4) were underlined. In Gera, the FGDs indicated that there was rather a net decrease of grazing lands due to exclosures. Coupled with a relatively higher livestock population, it affected their land resources through repeated grazing and frequent tree cutting which aggravated the severity of soil erosion and exposing lands degradation. In Agbe, there was increased damage of field crops by wild animals. After the introduction of exclosure and a criminalization of wild animal hunting, the population of porcupine, grivet monkey and leopard has increased. In Lemlem, they indicated that they had similar challenges from wild animals. A worst case was a killing of more than 50 dogs by the predators indicating the severity of such incidents.

4 Discussion

4.1 Contribution of exclosures to household (CEHH) income

In the current study, the CEHH income was classified as low with an average value of 11.81%. Other study reports on the contribution of forest products to household income in Ethiopia also showed high variability. Some estimations were 17% (Teshome et al. 2015, p. 334), 21.4% (Fikir et al. 2016, p. 4) and 27% (Babulo et al. 2009, p. 114) in different places. Kalaba et al (2013, p. 159) in Zambia and Teshome et al. (2015, p. 331) in Ethiopia reported that forest products contribute 44.4% and 16.1% to male and 41.4% and 23.5% to females households' total income, respectively. Mamo et al. (2007, p. 921) calculated 39% contribution of forest products to the household total income in Dendi district of Ethiopia. Suleiman et al. (2017, p. 1) found that income from NTFPs accounts for 20–60% of the total income of most (68%) of study participants. A meta-analysis of 51 case studies in 17 countries by Vedeld et al. (2007, p. 869) revealed that forest products contribute an average 22% of the total household income. Therefore, it was found out that the calculated values of actual benefits from exclosures are low in the current study area. Role of household head in the village, distance from exclosure, governance, age of household head, gender, SLMP training and level of formal education affect CEHH income scores. CEHH income varies from 6.5 to 19.3%, with the large variability between villages being attributed to several determinants. The status of the administrative position of head of household in the village played a key role in the extraction of forest products. Zhu and Lo (2021, p. 1) found that opportunities to reap benefits from NTFP projects are not evenly distributed between workers and non-workers in state forest enterprises. Consistent with our results, Musyoki et al. (2016, p. 209) in their study in Kenya found a significant association between the role of head of household and benefits extracted from forest products. CEHH income and distance between household residence and location of exclosures show a negative and significant relationship. This is related to the longer time spent collecting forest products and the opportunity cost of the labor (Robinson and Lokina 2011, p. 85). Other researchers (Gebregziabher and Soltani 2019, p. 11; Shimelse et al. 2017, p. 450) reported that remote farmers perceived or collected significantly fewer forest products than nearby ones.

Our study results showed that male-headed households received twice the percentage income contribution from the forest compared to female-headed households. Consistent with our findings, Adhikari et al. (2004, p. 251) reported that female-headed households collected almost half as many of these products as male-headed households, reflecting the lack of productive assets owned by women and the lower ability of women to negotiate and influence forest management decisions on their behalf. We agree with previous studies (Teshome et al. 2015, p. 335; Asfaw et al. 2013, p. 4) who indicated that the relative importance of exclosure products to females is significantly higher in Ethiopia. However, our results suggest male dominance in eligibility for access to forest products. In line to our study, Coulibaly-Lingani et al. (2009, p. 521) reported that women in Burkina Faso had less access to NTFPs than men. Similarly, Mushi et al. (2020, p. 702) found that men collected some types of NTFPs more than women did. Teshome et al. (2015, p. 335) observed that access to forest products vary across gender in Ethiopia. As reported by Suleiman et al. (2017, p. 13) the utilization of NTFPs was significantly influenced by gender. According to Kassa (2015, p. 101) NTFPs account for 53.76% of the annual income for women in Ethiopia. In their study, male headed households made more use of forest products such as honey and gum Arabic than their female counterparts around Falgore Game Reserve in Kano, Nigeria.

Acquiring benefits from exclosures in Tanqua-Abergele identified two extreme cases. On the one hand, benefits were obtained from exclosures under a weak governance system that did not have strict rules and regulations, in which case income would be forcibly derived and its sustainability is questionable. On the other hand, administrative measures served only to protect, without clearly establishing benefit-sharing modalities that would compel community members to prevent benefit-sharing. Discussions confirmed that they obtained benefits, particularly from firewood, wild fruits, farm implements and pastures, not in an organized and legal manner, but rather as theft. Thus, where protectionist statutes such as Lemlem village were implemented immediately, the overall economic benefits from exclosures were small, and where rules and regulations that were not as strict were implemented, the temporary benefits could be increased. A recent exclosure governance analysis by Araya et al. (2023) concluded that exclosure governance system is suffering from weak rules. Comparing the highest and lowest income drivers in governance system, the outcome was the opposite (Lemlem was stricter to protect exclosures than Shekatekli). Mushi et al. (2020, p. 695) in their study of determinants of access to NTFPs in Mt. Kilimanjaro, Tanzania reported that there were inter-village variations indicating effect of governance. Teshome et al. (2015, p. 336) studied that contribution of forest products to households varied with regions in Ethiopia due to restrictions imposed by Tigray and Amara administrative bodies.

Heads of households under the age of 35 years had a significantly low percentage of exclosure income. This was related to the attitude of the younger households to get better income from other jobs and daily chores. Consistent with our study, a positive association was found between age

and income from forests (Abebaw et al. 2012, p. 78). However, our research results are inconsistent with the results of Asfaw et al. (2013, p. 5) who reported that age does not have a significant impact on income from forests.

Although training households in SLMP up to four times had no significant effect on CEHH income, a positive but non-significant association was calculated compared to those who were not trained. In partial agreement with the current study, Zande and Mzuza (2022, p. 84) reported a significantly positive association between community awareness, involvement in forest management and economic benefit.

Surprisingly, CEHH income was negative and significant as head of household education increased. In agreement with our studies, collection of forest products decreased with increasing educational level in Botswana (Garekae et al. 2017, p. 7) and Tanzania (Mushi et al. 2020, p. 704) as education provides opportunity for other income sources. This might be also linked to higher opportunity costs of labor which was corroborated by Adhikari et al. (2004, p. 253). Contrary to the current results, Coulibaly-Lingani et al. (2009, p. 520) in their study in Burkina Faso confirmed that educational level is a key determinant to access NTFPs. Zande and Mzuza (2022, p. 92) in Malawi revealed no association between education and economic benefits from forests. Ahammad et al. (2021, p. 235) from Bangladesh, however, reported that the association between economic benefits and household head education level depends on the type of the forest product utilized. In their study the head of household education level significantly influenced forest and tree product use but not the use of bamboo.

4.2 Benefit–cost ratio (BCR) of exclosures

Benefit–cost ratio is a decision-making tool in which figures exceeding one are taken as indicators of profitability and less than or equal to one otherwise (Mills 2016, p. 2; Chichilnisky 1997, p. 199). When using the cost–benefit analysis as a supplemental regulatory decision-making, some principles should be followed, such as political implications, economic analysis, not being tied only to benefit–cost analyses, description of uncertainties, external verification, assumptions and distributional consequences (Chichilnisky 1997). Therefore, the current analysis depends on the actual benefits being reaped by local communities. The higher benefits of household heads who are members of the village cabinet might be related to their influence of programs and schedules for extraction of forest products. A study by Musyoki et al. (2016, p. 214) in Kenya revealed a significant association between role of household head and benefits withdrawn from forest products. Apart from better access to on-time information, the enforcement of rules against influential village leaders when benefits were acquired violently is also minimal. Moreover, exclosures remain to be profitable for exclosure guards as they directly collect products and secure employment (Mekuria 2013; Yirdaw et al. 2007). Similarly, individuals involved in technical support of exclosure establishment, construction of physical soil and water conservation structure, plantation and maintenance got more benefits which elevated their benefit–cost ratios. In line to this, Tadesse et al. (2017, p. 171) reported that respondents who had benefited more from the forest products were active participants in program implementation.

In the current study, exclosure profitability relied on village governance systems. This is related to capacity of village leadership to maximize community benefits, put in place fair benefit sharing mechanisms and control of illegal product harvesting. Governors play an important role in regulating ecosystem services because public goods and benefits are involved (de Koning et al. 2011). Trainings on capacity building regarding SLMP have positive but no significant effect of benefit–cost ratio. This is largely linked to inefficient content of the trainings attributed to benefit extraction of exclosure products. However, Meijaard et al. (2021, p. 11) noted that each new community forest program requires a certain amount of training, capacity building, and planning for effective implementation without which communities may fail to attain overall environmental and social objectives. As education could have provided more options of income generation, education level above grade nine was associated with significantly lower benefit–cost ratio. Similar findings were reported by Mushi et al.(2020, p. 704) in Tanzania and Garekae et al. (2017, pp. 8–10) in Chobe district of Botswana. Other studies (Fonta and Ayuk 2013, pp. 98–99; Masozera & Alavalapati 2004, pp. 89–90) reported an inverse relationship among education levels and extraction of forest products confirming low benefit–cost ratio. Contrarily, Tadesse et al. (2017, p. 171) and Obadire et al. (2014, p. 325) demonstrated that education catalyzes flow of information and significantly associated with participation in exclosure management and extraction of forest products.

4.3 Other potential and actual benefits of exclosures to local communities

In agreement with the current study (Fig. 4), Mekuria et al. (2020, pp. 11–12) reported that exclosures can contribute to recharging groundwater. In another way, increment of the potential irrigable sites and shortening of distance to fetching animal and human drinking water are immediate outcomes of Sustainable Land Management Programmes in which exclosure is the main. More water flows in rivers after the rainy season ceases were reported to exist following the implementation of SLMP. As a result, both potential and actual irrigation sites and areas increased.

The quality of water available in rivers and shallow wells were also improved. Previously, water for human and animal drinking and household utilities used to be critical problems in almost all villages. Exclosures had positive effects by reducing the distance to fetch water, the waiting time for drinking water, the quality and quantity of the water, and increasing the area and number of irrigation points. This happened mainly through groundwater recharge, spring water development and improved soil water content. In line with our findings, many studies on the impact of exclosures on water development in Ethiopia (Mezgebo et al. 2022, pp. 2598, 2607; Damene et al. 2020, p. 2; Crossland et al. 2018, p. 50; Balana et al. 2012, pp. 32, 35; Girmay et al. 2009, p. 79; Nyssen et al. 2008, pp. 300, 308; Naudtsayb et al. 2004, p. 624) proved that exclosures were effective in water enhancement. Moreover, Kitalyi et al. (2002, p. 1) in their study of several years of work in West Pokot District in Kenya reported that exclosures increased water.

Additionally, it was noted that there was a change in rainfall pattern after the establishment of exclosures. Unlike the previous late July rain-onset patterns, it begun raining no later than June each year, helping farmers plant crops with more productive traits that require a longer growing season. FGDs linked this to the improvement of the overall environmental conditions. They noted that it was not the case before the large-scale exclosures establishment and massive soil and water conservation campaigns. Therefore, exclosures are playing significant roles to correct the erratic nature of the rainfall in the study area. Mekuria et al. (2021, p. 17) and Mekuria and Yami (2013) in their study in Tigray reported that exclosures contributed to regulating rainfall. Mezgebo et al. (2022, p. 2598) highlighted the importance of exclosures in enhancing crop production. The quality and quantity of water were improved due to the positive effect of the physical structures of soil and water conservation built along the upper catchments and vegetation. Previous study (Zhu et al. 2016, p. 115) in China proved that sediment capping and re-vegetation improved water quality. Yibeltal et al. (2022) in their study in the Ethiopian highlands provided evidences that exclosures enhanced water quality. Exclosures and massive soil and water conservation projects are perceived reasons for the availability of water near their homes. Yibeltal et al. (2022) in their study in the Ethiopian highlands attested that exclosures enhanced water levels.

Exclosures are promising in restoring economically valuable plants that were on the verge of disappearing. Previous studies (Birhane et al. 2006, p. 138; Mengistu et al. 2005) showed that species that disappeared a long time ago have been restored following the establishment of exclosures. Knapp (2005) revealed that Island rush-rose, a federally listed threatened species, and being rare on Catalina, was recovered in exclosure areas. Volis (2016, p. 1) reviewed that restoration ecology has a great potential to recover plants in a verge of disappearance. Similarly, Sinore and Doboch (2021, p. 7) in their analysis of data collected for ten years confirmed that exclosures have improved vegetation. Other reports confirmed that exclosures enhance vegetation (Mekuria and Veldkamp 2012; Mengistu et al. 2005).

In the current study, bee forage, animal feed, firewood and farm tools were potentially available in exclosures. Mekuria et al (2020, p. 28) highlighted that ecological degradation of natural resources threatens honey production and exclosures in high lands of Ethiopia played a significant role in restoring these limitations. However, they indicated that planned and systematic utilization of these goods and services was a key constraint. Balana et al. (2012, p. 30) conducted cost benefit analysis of exclosures in Tigray and found out that exclosures can produce firewood from the sixth year after establishment, but are not readily usable by the local communities. Mezgebo et al. (2022, p. 2598) indicated that farmers draw benefits such as fuel wood from exclosures established on open grazing lands in Tigray. FGD and KIIs confirmed a relatively better utilization of bee forage and animal feed. However, no systems were in place to use firewood and farm tools. The latter in particular was badly needed by the local peasants since farming tools were needed to fulfill special structures that could be used as farming implements. Farm implements with special structures and unique dimensions were rarely available in communal lands. According to FGDs, a wooden agricultural tool can provide service for several years, and cutting down some of these may not seriously affect the exclosures to be considered tree destruction. Several years of work in West Pokot district in Kenya proved that exclosures increased fuel wood, land value and livestock production (Kitalyi et al. 2002, p. 1). Mekuria et al. (2021, p. 40) reported that farmers perceived the effectiveness of exclosures by their production of farm implements. Tesfay (2018, p. 486) also summarized that local communities harvested timber and grasses for construction, animal feed, fuel wood, farm implements, honey bee forage, health care, and to protect farmland from clogging with silt and mud from the upper catchment areas of the Gra-Kahsu Exclosure in the south of Tigray. Moreover, Mezgebo et al. (2022) reported communities benefited getting construction materials from exclosures in Tigray. In line with our studies, many researchers emphasized that exclosures served as diverse sources of economic and ecological benefits to the local communities (Crossland et al. 2018, p. 53; Shiferaw et al. 2018, p. 1574; Birhane et al. 2017, p. 44; Mekuria et al. 2017; Abera et al; 2016; Mureithi et al. 2015, pp. 537–540; Tefera et al. 2005, pp. 46–49). In order to achieve these goals, however, suitable redevelopment, protection and use concepts proved to be absolutely necessary.

Another significant benefit of enclosures was the improvement in the qualities of eroded soils. Inline to our studies, soil qualities improved on eroded and communally

owned hilly areas of Tigray (Jacob et al 2019, p. 253). Similarly, a ten-year study by Sinore and Doboch (2021) verified that exclosures improved physical and chemical properties of soils when compared to adjacent grazed lands. Many researchers confirmed that exclosures have enhanced soil fertility (Mekuria et al. 2021; Adem et al. 2020, p. 1; Yimer et al. 2015, pp. 4–9), reduced soil erosion (Mezgebo et al. 2022, p. 2598; Asmare 2021, p. 105; Ashenafi 2017, p. 28; Girmay et al. 2009) and improved productivity of farmlands within the respective landscapes (Noulèkoun et al. 2021, p. 9; Baudron et al. 2015, pp. 113–118). This was largely achieved through protection from run-off and sedimentation (Adem et al. 2020, p. 7; Descheemaeker et al. 2009, p. 246; Naudtsayb et al. 2004, p. 624).

In the current study, partially meeting demand for forest products from farmland is becoming a trend as it was not possible to source them entirely from exclosures and communal grazing lands. It was proved that farmers grew selected plants targeting farm tools, wild fruits for cash and home consumptions, animal feed and soil nutrient improvement within their farm lands. The push factor for farm production of the aforementioned goods was the refutation to get them from current exclosures and open communal lands as there were governance constraints and overexploitation through free riding. Babalola (2009, p. 222) in Nigeria and Chilalo and Wiersum (2011, p. 56) in Ethiopia reported that farmers produce enough forest products in their farmlands with a significant income contribution to the households. Pandit and Kumar (2010, p. 671) confirmed that integrating NTFPs providing plant species was more profitable than cultivated crops in their study in Nepal. In Ethiopia farmers produce forest products as a diversification, specialization and coping strategy (Chilalo & Wiersum 2011, p. 57). However, for the new intervention to sustain as an integral element of the system, a new steady state has to reveal in which the three components should balance. In this regard exclosures, grazing lands and farmlands need to co-exist by contributing basic forest products and related livelihood components that were previously derived solely from communal grazing lands. There is an intension, however, to recruit additional exclosures and engulf the free grazing areas in which a new state of zero-grazing is expected to prevail. The end target of zero-grazing will depend on the new benefits the exclosures are currently providing to the local community in a highly acceptable quality and sustainable manner. Therefore, lower supply of forest products can be improved by technologies that are capable of enhancing the different forest products to fulfill the demands of the local communities. Turner (1988) emphasized that sustainable development implies maximization of net economic benefits in which the quality of the natural resources and the services provided by them are enabled and maintained through time. The study gave convincing outlook by stating that technology can enable improvements to be achieved in the quality of the environment and the level of the services that it affords. Brack (2018)'s recommendation is in agreement with this view which emphasized the importance of technological support for sustainable forest production and utilization.

Legal restrictions on free access to the forest products and awareness on the significance of growing trees were indirect impacts of exclosures on driving ecosystem goods and services from farm lands. Due to alterations related to environment, social and economic conditions in the last 30 years, it is compulsory to treat exclosure in harmony with the aforementioned changes. The risk of losing forest products can be minimized by sourcing them from exclosures, farmlands and communal grazing areas in a balanced approach. Participation of the local communities through design, governance and strict rules can guide the success of exclosure in coexistence with other land uses. Chilalo and Wiersum (2011) demonstrated that farmers in Ethiopia diversified forest products by collecting them from forests and producing them on their farms. This in turn diversifies sources of income for farmers (Chilalo & Wiersum 2011) and livelihood diversification has the potential to avoid risks (Wiggins et al. 2011).

Efforts are required to enable farmers to fulfill their basic needs for forest products from their own farmlands while comprehensive plans are also imperative to maximize benefits from exclosures and ensure sustainability. Araya et al. (2023) demonstrated that maximizing community benefits from exclosures has to be accentuated as one of the key inputs to sustainability of exclosures. Mekuria et al (2020) in their report about the business model of exclosure emphasized the mechanisms to maximize ecological and economic benefits. The amount of forest products derived by farmers as a coping mechanism was low. But, due to their importance as source of food, coping for food and feed shortage, resilience during drought and employment have the potential to sustain themselves. However, driving exclosure benefits is usually illegal and stands as a key challenge. Exclosures provide resilience to drought shocks as indicated in the communities' grazing of exclosures to surpass drought and related problems. Exclosures helped communities to cope with feed shortage during droughts in Kenya (Wairore et al. 2015) and Ethiopia (Mezgebo et al.2022). Like elsewhere, extraction of forest products from exclosures was proved in this study. Forest products, especially the NTFPs, are reported to play significant roles in coping mechanisms during crisis in different angles of the world (Tieminie et al. 2021; Paumgarten and Shackleton 2011).

4.4 Pitfalls of exclosures

In agreement to the current study, a review by Napier and Desta (2011) in Southern Ethiopia concluded that exclosures

shadow a risk of shrinking of other resources for common use. An increasing pressure on remaining communal grazing lands was identified as a negative impact of exclosures by Mekuria et al. (2011). As a result it was emphasized that the deforestation increased in non-protected areas as options for collecting forest products especially fuel wood and farm tools became limited. Establishment of exclosures harbors more predators and attacks particular areas sometimes in a gregarious state. A report by Nelson & Sandbrook (2000) confirmed that local communities can sometimes become victims of their own success in managing natural resources. He stated that where wildlife numbers increase, there are often adverse outcomes including personal injury (and in extreme cases death), crop damage and livestock killings. Crop damage was also reported by 16% of farmers living near exclosures interviewed in Tigray (Birhane et al. 2017).

5 Conclusion

The focus of this study was to identify the exploitable and appreciable goods and services obtained by local communities, perceived benefits and monetary values in terms of profitability and contribution to household income. Exclosures provided tangible benefits and goods to local communities as well as enhancing crop and livestock production. The combined promising effects enabled local communities to have a positive attitude towards exclosures, despite their low level. Surprisingly, it was proved that despite the negative aspect associated with predators, farmers appreciated the positive aspect of coexistence between wildlife and agriculture and the overall health of the environment. However, using quantification of tangible benefits and analysis of BCRs, we have clearly demonstrated that exclosures are not profitable and CEHH incomes are marginal. Rethinking of measures to upgrade BCR to a significantly profitable level and enhance CEHH income, entail maximization of benefits by a factor of three. Even worse is the significant discrepancy between household characteristics, including age, gender, education level, and governance systems. Also, we made it very evident that exclosures pushed farmers to drive some necessities from farmlands. Increasing the intentional removal of forest products from farmlands creates a solid foundation for exclosure programs to be effective. Before exclosure is scaled up, the most efficient and sustainable way to use the areas that have already been hired must be reconsidered. In addition, technological tools for diversified forest product sources are disregarded.

The demand for forest goods in a community varies depending on their level of awareness, the scarcity of the products, and individual livelihood plans, which necessitates local government partitioning benefits in accordance with fundamental requirements. To close the gaps of benefit variance among community features, it is crucial to raise awareness of the available exclosure products, provide legal access to and use of forest products, and conduct periodic needs assessments of community members. Rules and regulations need to be strictly adhered to in order to prevent habitual illegal sourcing. Also, encouraging farmers to source their basic needs for forest products from plants produced on their own lands can aid in preventing them from engaging in damaging activities within exclosures. On the other hand, enabling local communities to extract more non-timber forest products from exclosures can contribute to the sustainability of the program. For communities to participate in projects that have numerous advantages, strong institutional structures and technical support are needed. Beekeeping in and around exclosures, dairying, and cattle farming with feed cultivated in exclosures are particularly simple to apply. Also, it seems reasonable to permit poor households to access, harvest, and sell wild foods that are available in exclosures. Above all, the inventory of farms and grazing grounds as exclosure command areas and their recruitment into various irrigation plans can be done in concert with exclosure development and overall landscape management. The findings and conclusions reached in this study can be taken as crucial inputs to the global concept of land degradation neutrality (Chasek 2022; Cowie et al. 2018; Safriel 2017) to help ensure food security, energy needs, land tenure, gender equality, access to clean water, and biodiversity are considered—and addressed—together (Chasek 2022).

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Declarations

Conflict of interest Oliver Vivian Wasonga is an editorial board member of Socio-Ecological Practice Research. He was not involved in the peer-review or handling of the manuscript, and has no other competing interests to disclose. All coauthors have no conflict of interests to declare that are relevant to the content of this article.

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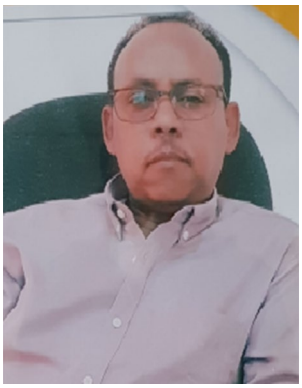

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