FULL-LENGTH ARTICLE

Impacts of Land use and land cover changes on rural livelihood in the Bale Mountains Eco-Region, Southeast Ethiopia

Birhanu Ayana[1*], Feyera Senbeta[2] and Aseffa Seyoum[1]

[1]*Centre for Environment and Development, College of Development Studies, Addis Ababa University, Addis Ababa, Ethiopia*
[2]*Botswana University of Agriculture and Natural Resources, Gaborone, Botswana.*
*Corresponding author: *b.ayana2004@gmail.com*

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ABSTRACT
Land use and land cover (LULC) changes can adversely affect livelihood assets/resources impacting rural communities. This study assessed the livelihood impacts of LULC changes on rural livelihoods in Bale Mountains Eco-Region (BMER), Southeast Ethiopia. A sustainable livelihood framework was employed to assess the impact. A cross-sectional survey of 339 households, combined with field observations, was conducted to gather data on the effects of LULC changes between 1973 and 2021. Household heads served as the unit of analysis, and quantitative data were analyzed using descriptive statistics, while qualitative data were analyzed through content analysis. Results showed that 62.8%, 62.2%, and 85.3% of respondents reported expansion of cultivation into marginal areas, increased overgrazing, and excessive tree cutting, respectively, as significant indicators of change during the study period. As a result, local communities have experienced reduced crop yields, loss of grazing lands, declining soil fertility, and increased vulnerability to environmental risks. Furthermore, 99.7% of respondents perceived LULC changes as having a direct impact on their livelihood adversely affecting their livelihood assets, primarily natural resources. Livelihood patterns have transformed significantly, shifting from traditional pastoralism to agro-pastoralism and crop-based systems, with households diversifying into various income-generating activities. Adverse livelihood outcomes, including reduced well-being and increased food insecurity, were commonly perceived among respondents. The findings highlight an urgent need for sustainable management of natural resources to improve livelihoods across different LULC types. Moreover, diversifying livelihood strategies and assessing the community's coping and adaptive capacities are essential to mitigate the adverse impacts of LULC changes.

Keywords: Agricultural expansion; Deforestation**;** Livelihood; Livelihood Strategy; Mountains Eco Region; Sustainability

INTRODUCTION

A livelihood refers to assets-based activities people make (Anwa et al., 2024) in an attempt to meet various livelihood necessities (Gessese, 2018). Accordingly, livelihood assets (natural, physical, human, social and financial capital) are the basic resources for an individual or households to depend on for their livelihoods. A Livelihood strategy such as agricultural intensification, livelihood diversification and migration is an activity that people are undertaking for survival (Iddrisu et al., 2023). It incorporates both activities that generate income and other kinds of elements including social choices (Kamwi et al., 2015). The extent of livelihood assets and policies, institutions and processes determine the livelihood strategies/options people make (Gessese, 2018) to generate the necessary livelihood outcomes (Kamwi et al., 2015).

Land resources play a crucial role in determining rural livelihoods (Kamwi et al., 2015; Bashir, 2012); as land provides significant socio-economic benefits to human beings (Zotova & Cohen, 2016). The

interaction of land and livelihoods can be demonstrated through land uses (Gessese, 2018). Human beings modify their land surface hence changing LULCs when securing essential resources for their livelihoods (Daata et al., 2021a). In other words, LULC-based ecosystem services provide opportunities to derive a means of livelihood for rural communities (Gessese, 2018; Kamwi et al., 2015). However, changes in LULC have negatively impacted human livelihood system over the years (Daata et al., 2021; Zotova & Cohen, 2016; Bewket, 2002). According to Kamwi et al. (2015), rural livelihoods are highly susceptible to changes in LULC, particularly deforestation and agricultural expansion, have significantly undermined rural livelihoods by reducing access to fertile land, forest resources, and ecosystem services that communities rely on for subsistence.

LULC changes further significantly affect the capacity of an ecosystem to provide goods and services, as well as the functioning of the socioeconomic and ecological systems it supports (Anwa et al., 2024). For instance, forest cover change/deforestation has enormous negative impacts on rural livelihoods by accelerating land degradation, declining land productivity and exacerbating the loss of ecosystem services in the area where it occurs (Iwuji et al., 2022; Gifawesen, 2019). Moreover, Fikadu & Olika, (2023) also indicated the adverse rural livelihood impacts of LULC changes, mainly through the conversion of wetlands and swampy areas into water bodies by dam construction in the Nashe watershed of Ethiopia. A study by Bashir (2012) also demonstrated LULC change impacts on livelihood resources such as soil, forest production, agricultural production, livestock production and pastures. Agidew & Singh, (2017) also identified land degradation, farmland fragmentation, crop yield reduction, increased rate of soil erosion and climate change as some major implications of LULC changes on rural people's livelihood insecurity. Furthermore, a study by Garedew, (2010) also revealed the deterioration of livelihood and environmental security in the form of loss of woodlands, loss of biodiversity, soil degradation and food insecurity owing to LULC changes in the semi-arid areas of central Rift Valley of Ethiopia.

Previous studies (Ayana et al., 2024; Ayele et al., 2019; Legesse et al., 2019; Mezgebu & Workineh, 2017; Hailemariam et al., 2016) have shown considerable LULC changes in the study area. The majority of these studies have focused on analyzing LULC changes and their drivers using remote sensing satellite imagery, with limited attention given to examining the impacts of these changes on rural livelihoods. This study aims to analyze the perceptions of residents regarding historical LULC changes, and the impacts of these changes on their livelihoods, mainly on the livelihood resources/assets that were limited in the previous studies. It focuses on the biodiversity hotspot of the Bale Mountains Eco Region in Southeast Ethiopia. The goal is to promote effective and sustainable ecosystem management and enhance the provision of robust ecosystem services and functions to secure sustainable livelihood systems for the wider communities in the area. Therefore, this study aimed to answer the research question of how LULC changes impact rural livelihoods in the study area of BMER.

CONCEPTUAL FRAMEWORK

A sustainable Livelihood framework, developed by the Department for International Development (DFID, 1999), considers different factors determining the sustainability of people's livelihoods. According to UNDP (2017) the sustainable Livelihood framework is also an analytical framework that is used for the understanding of various factors affecting choices around subsistence, and examination of the interaction amongst themselves. Following this concept of the Sustainable Livelihood Framework the current study attempted to identify the factors that affect the local people's livelihoods and their relationships. The study variables include changes in LULCs and the associated shocks, livelihood assets, livelihood strategies, livelihood outcomes, and institutions, policies and processes (Figure 1). Assets (human, social, natural, physical and financial capital) are the key elements of the framework (Iddrisu et al., 2023) and livelihood resources that may be seen as the 'capital' base from which different productive streams are derived and from which livelihoods are constructed (Scoones, 1998).

Human capital represents the abilities, experience, work skills and physical state of good health which, when combined, allow populations to engage with different strategies and fulfill their objectives for their livelihoods. Regarding this human capital asset, the status of household heads' education and occupations was targeted for the study. Social capital refers to the social resources that populations will rely on when seeking their objectives relating to livelihoods (in the present study it refers specifically to

local social capital, including networks, associations and local institutions like financial cooperation, such as Busa Gonofa). Natural capitals refer to the stocks of naturally occurring resources (UNDP, 2017) and include land, forests, water and minerals that can support livelihoods (Iddrisu et al., 2023). For this study, LULC changes livelihood impacts in terms of changes in natural capitals such as soil, water and forest were considered. Physical capital refers to the basic infrastructure and production inputs needed to support livelihoods. Road infrastructure was considered in the current study. Financial capital refers to the financial resources such as personal savings, cash, credit/debit cards, remittances and pensions (Iddrisu et al., 2023) which populations employ to achieve their objectives regarding livelihoods. Crop and livestock economic properties were considered as the financial capital assets for this study.

While adapting a sustainable livelihood framework from (Kamwi et al., 2015) for this study, LULC changes and the associated impacts and shocks were considered as the vulnerability context impacting the livelihood resources under the influence of available institutions, policies and processes to result in possible livelihood outcomes in the study area of BMER.

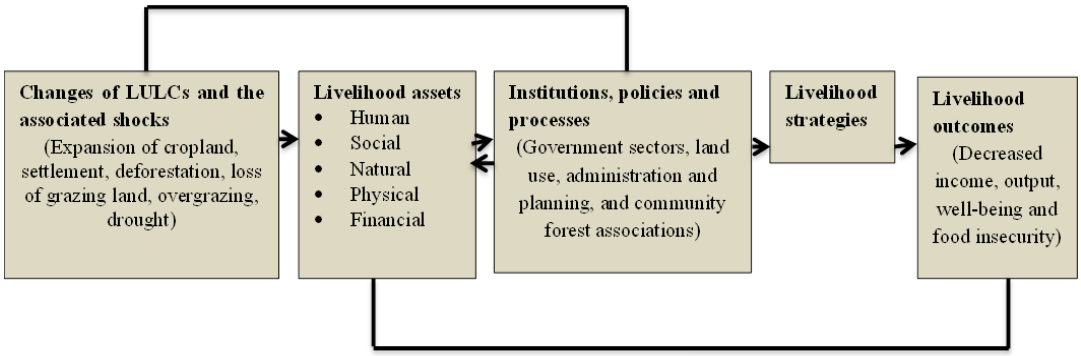

Figure 1: Conceptual sustainable livelihood framework (adapted from Kamwi et al., 2015)

MATERIALS AND METHODS

Study Area

The study was conducted in the Bale Mountains Eco-region (BMER) in southeast Ethiopia. The study area is characterized by its various mountainous landscapes that include Harenna Forest (the largest moist tropical forest remains in the study area), afro-alpine plateau (Sanette plateau), mountains peaks, valleys, grasslands, and agricultural land (Farm Africa et al., 2008). The second highest mountain peak in Ethiopia, namely Tullu Dimtu (4377m) is found in this area. The Bale Mountains National Park (BMNP) is also part of the BMER (Wakjira et al., 2015). Geographically, the current study area of the BMER ranges from 5°51′21.16″N -7°23′39.53″ N and 38°56′05.18″E - 40°29′23.20″ E (Ayana et al., 2024). Administratively, it covers six districts; four of them (Goba, Berbere, Dello Mena and Harenna Bulluk) are from the Bale zone, and the rest two districts (Adaba and Nensibo) are from the west Arsi zone (Figure 2). The projected population size for these six districts for 2021 was 787,167 (Ayana et al., 2024). BMER is characterized by its various climate conditions that vary with altitudes. Lowland areas receive annual rainfall between 600-1000mm while it is between 1000-1400mm for higher altitude areas. The BMER's mean annual minimum and maximum temperature are 1.4ºC and 18.4ºC, respectively (OFWE, 2014). As BMER is the largest area of Afro-alpine habitat on the African continent it is home to various species of fauna and flora. The common soil types of the area are: Cambisols, Vertisols, Luvisols, Lithosols and Nitosols (OFWE, 2014). livelihood strategies for most of the inhabitants in the BMER are small-scale subsistence agriculture (farming and livestock husbandry) and income generation from forest products (Mezgebu & Workineh, 2017; Hailemariam et al., 2015; Desta, 2007).

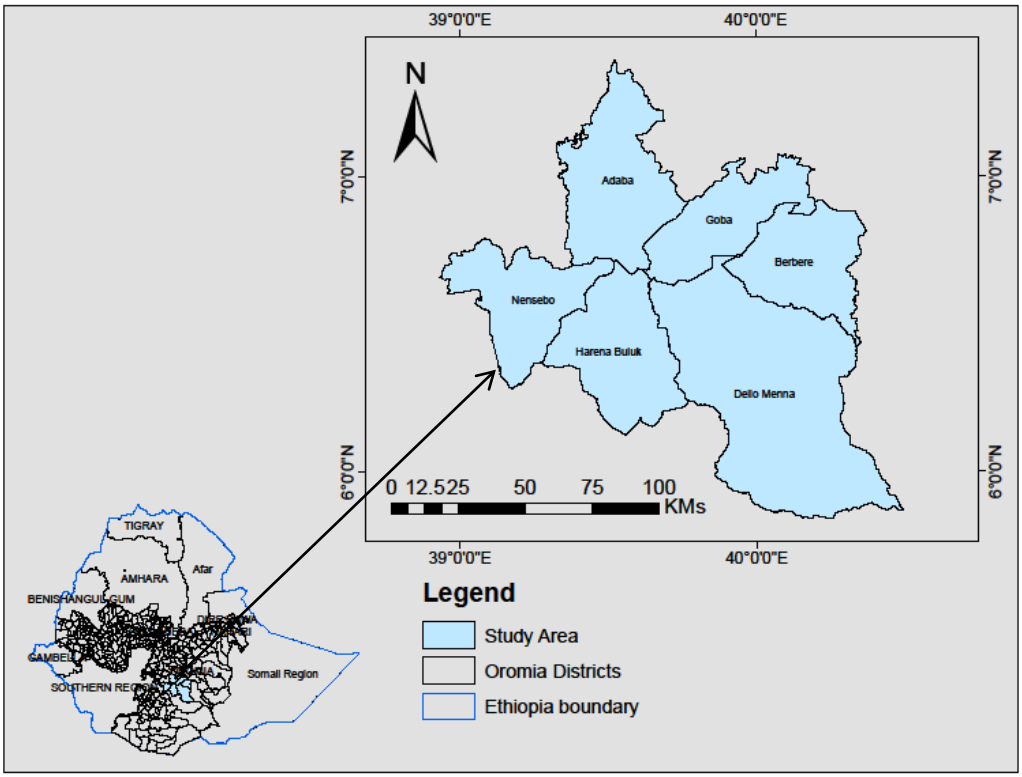

Figure 2: Map of study area in the BMER

Study design

The study employed a descriptive cross-sectional survey design involving 339 households, along with field observations conducted in the study area of BMER. A cross-sectional survey is cost-effective and easy to implement at a single point in time (Wang & Cheng, 2020). In this study, this cross-sectional survey was preferred to gather data on farmers' perception (describing current attitudes and experiences) of LULC change and its impacts on livelihoods at a specific period (1973-2021) without requiring long-term follow-up as in the time-series survey.

Sampling technique and sample size determination

Agro-ecologically stratified technique (Mezgebu & Workineh 2017) and a reconnaissance survey by the researcher were used to select study site, comprising of six districts in the BMER. The study site was stratified agro-ecologically into three, namely highland, midland and lowland districts where two districts were categorized into each category. This was meant to get comprehensive data from all agro-ecological zones in the study area. Accordingly, Goba and Adaba, Harenna Bulluk and Nensebo, and Berbere and Dello Menna districts were categorized into highland, midland, and lowland districts, respectively. In consultation with relevant zonal and district experts during the reconnaissance survey, the following criteria were set and used to select study districts and kebeles: (1) relative distance against forested land; (2) livelihood strategies of the local communities (their relatively high dependency on forest resources and expansion of agriculture, livestock and crops, means of production); and (3) their accessibility. Accordingly, three districts, one from each agro-ecology, were purposely selected to represent the three agro-ecologies. The selected districts were: Goba, Harenna Bulluk and Dello Mena. Then, three representative kebeles, the smallest local administrative units (One from each district) were purposively selected based on the above criteria. The selected kebeles were: Rira from Goba, Hawo from Harenna Bulluk and Wabaro from Dello Mena.

From the total number of 2,879 households registered in the selected three kebeles, the size of the sample household farmers selected for interviews was determined using the formula developed by Kothari (2004). The exact number of household heads to be interviewed in each kebele was proportionally (Table 1) determined and simple random probability sampling was used for the determined sample size.

$$n = \frac{Z^2.p.q.N}{e^2\,(N-1) + Z^2 p.q} \text{----------1}$$

Where: n= sample size; Z = 95% confidence limit (interval) under normal curve that is 1.96;P = proportion of the population to be included in the sample; assumed to be 0.5 since this would provide the maximum sample size (Legesse, 2015); q = None occurrence of event =1-0.5 that is (0.5); N = Size of population (2879); e = Margin of error or degree of accuracy (acceptable error term) (0.05).

Following the formula, 339 respondents were used for data collection through a semi-structured questionnaire. These respondents were all rural people and the heads of households living in the study area of BMER.

Table 1: Total sample size determination from total population of the study area

District	Selected Kebele	Agro-ecology	Total household head number	Sample size
Goba	Rira	Highland	569	67
Harenna Bulluk	Hawo	Midland	1230	145
Dello Mena	Wabaro	Lowland	1080	127
Total			2879	339

Data source and collection method

For household surveys, a semi-structured questionnaire was used to collect both quantitative and qualitative data on demographics, livelihood assets, strategies and outcomes, as well as on different aspects of LULC changes and their rural livelihood impacts. Triangulation method of data collection through multiple methods was used for collected data validation and examination of the problem under study. As a data source for remote sensing imagery-based LULC change analysis, the current study builds on the findings of a previous study (Ayana et al., 2024); from which the classified Landsat image maps of the years 1973 and 2021 were used.

Demographic characteristics (such as sex, age, marital status, family size, land holding and education status), LULC types (such as agriculture, settlement. forest, grassland, bushland, woodland, bare land and water bodies), LULC changes and their associated shocks, livelihood assets (human, social, physical, natural and financial capital), livelihood strategies, livelihood outcomes and institutions, policies and processes were the study variables employed for the assessment of livelihood impacts of LULC changes in the study area.

Data analysis

Demographic data were summarized through the computation of central tendency (average) and dispersion (range), to describe household characteristics across the study area. Quantitative data obtained from the household questionnaire surveys were carefully processed, coded and analyzed using the Statistical Package for Social Sciences (SPSS) software version 25. This analysis involved computing frequencies, percentages and cross-tabulations to analyze variables relevant to LULC change and its local livelihood impacts in the study area of BMER. On the other hand, qualitative data obtained through open-ended questions from individual interview and field observations were analyzed through content analysis. This allowed for the identification of key themes related to perceived causes, patterns and consequences of LULC changes, substantiating the interpretation of quantitative findings.

For the remote sensing-based LULC change analysis, the supervised image classification method was applied using the maximum likelihood classification algorithm. This method is used to categorize satellite imagery into eight LULC classes, namely: agriculture, settlement, grassland, bushland, woodland, forest, bare land, and water bodies. Following classification, a post-classification comparison technique was employed to detect and quantify LULC changes over time, enabling accurate assessment of both spatial and temporal LULC dynamics across the study area.

RESULTS

Household characteristics

The interviewed respondents were all the heads of households. All of them were married and about 46.9% of them had a family size between 4 and 8 children. Eighty-five percent (85%) of the respondents were male. 54.9% of the respondents' age category fell within the range of 61 and above years. The largest proportion of the respondents (40.1%) had attended only 1-4 schools, and a significant proportion of them (32.7%) had land holding sizes between 1 and 2 hectares (

Table **2**).When compared to the past 48 years ago, many of the respondents 198 (58.4%) indicated that their land holding size has declined as they have given land to their married children.

Table 2: Respondents educational status and land holding patterns

Variable	Levels	Frequency	Percent
Educational status	Never attended school	117	34.5
	1-4	136	40.1
	5-8	74	21.8
	9-10	11	3.3
	Higher education	1	0.3
	Total	339	100.0
Size of land holding (in ha)	<1ha	78	23.0
	1<2ha	111	32.7
	2<3ha	37	10.9
	3≤4ha	46	13.6
	>4ha	67	19.8
	Total	339	100.0

Historical LULC changes in BMER

The results of LULC change analysis for this study build on the findings of previous remote sensing imagery-based LULC change analysis by Ayana et al. (2024) in the BMER. LULC Classification accuracies for the generated LULC maps of both 1973 and 2021 years were with overall accuracies of more than 80% and kappa values in the range of 0.80-1.00. These have met the accepted and recommended standard of above 80% for the overall accuracy (Turan & Günlü, 2010) and kappa coefficients that fall in the recommended range (0.80-1.00) of almost perfect strength of agreement (Rwanga & Ndambuki, 2017). Through the application of the post-classification comparison method for LULC change detections, the study was possible to obtain an increment in areal extent for agriculture, settlement and bare land classes, and a reduction for the other LULC classes, namely: grassland, bushland, woodland, forest and water bodies in the period between 1973 and 2021(Table). Figure 3 shows the spatial changes of these LULC classes over the mentioned period.

Table 3: LULC changes for the period of 1973 to 2021

LULC Class	1973	2021	LULC Changes from 1973 to 2021	
	Area (km^2)	Area (km^2)	Area (km^2)	%
Agriculture	1099.5	2783.2	1683.7	153.13
Bare Land	131	518.2	387.2	295.57
Bush Land	1837.4	1320	-517.4	-28.16
Forest	4398.2	3080.1	-1318.1	-29.97
Grass Land	1453.3	1327.9	-125.4	-8.63
Settlement	195.4	291.2	95.8	49.03
Water	174.5	27.3	-147.2	-84.36
Wood Land	4321.5	4262.9	-58.6	-1.36

Source: From Previous LULC change analysis (Ayana et al., 2024)

The results of the current household survey on the f LULC changes in the study area of BMER also indicated that forest (98.2%), grassland (85.3%), bushland (64%) and woodland (63.7%) were perceived (multiple responses) to be the dominant LULC types in 1973. In 2021, respondents perceived that they were the agricultural land (97.6%), forests (93.5%), settlement (82.9%), woodland (60.8%) and grassland (51.9%) types of LULC that dominated the study area in the BMER (Table). Almost the majority of them (99.7%) responded that there were obvious LULC changes in land use land cover patterns in the area between the period 1973 and 2021 which were characterized in the form of expansion of cultivation to the marginalized areas (62.8%), overgrazing (62.2%), cutting of trees (85.3%) and others (3%). This shows that the natural resource bases of the area, mainly forests, woodlands, bushes and grassland are highly exploited for the sake of expansion of agriculture and settlement. These results complement the imagery-based LULC change results that showed the expansion of anthropogenic practices that contributed to the net reduction of mainly, forests, woodland, bushland and grassland types of LULC for the favor of the expansion of, mainly agriculture and settlements (A B

Figure 4) in the study area of BMER.

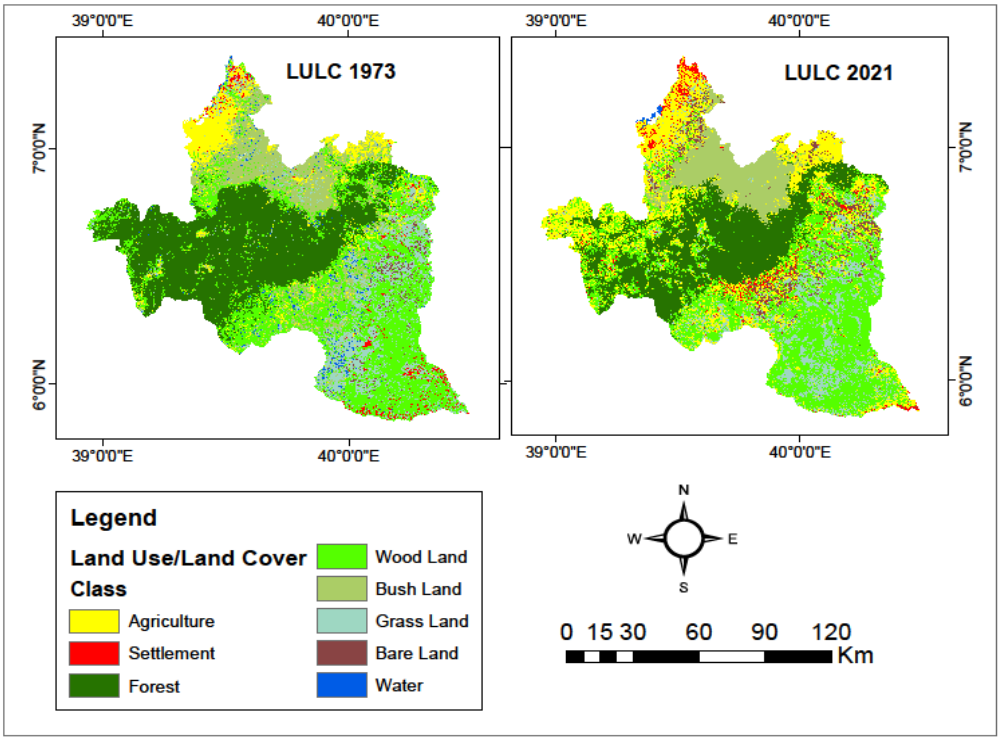

Figure 3: LULC Geospatial Maps for 1973 and 2021

Table 4: Perception of households on the changes of LULC patterns overtime in their area (n=339).

LULC type	What are the common types of land use land cover in the area in			
	1973?		2021?	
	% "Yes" HHs	% "No" HHs	% "Yes" HHs	% "No" HHs
Agriculture	27.7	72.3	97.6	2.4
Settlement	20.1	79.9	82.9	17.1
Grassland	85.3	14.7	51.9	48.1
Bushland	64	36	12.1	87.9
Woodland	63.7	36.3	60.8	39.2
Forests	98.2	1.8	93.5	6.5
Bareland	0.9	99.1	19.8	80.2
Water	30.4	69.6	3.5	96.5

A B

Figure 4: An example of dominant agricultural land use practice (A) and rural settlements encroaching grasslands (B) in the BMER

Perceived impacts of LULC changes on household livelihoods

A detailed investigation was conducted on the impacts of LULC changes on the households' livelihood assets, strategies and outcomes over the past 48 years (1973-2021) in the study area of BMER. In the investigation, livelihood impacts of LULC changes in different socioeconomics and environmental conditions were targeted and assessed.

Impacts on natural capital (soil, water, and forest)

Soil degradation, especially soil erosion and soil fertility loss, is one of the impacts of LULC changes perceived that reduced crop productivity in the study area. Respondents explained that forest cover reduction has accelerated such land degradation in the study area. Almost all respondents claimed that soil erosion has become one of the environmental problems in their area. The dominant type of erosion perceived was by water runoff (83.2%) even though the rest respondents (16.8%) noticed the existence of soil erosions by both water runoff and wind sand dunes. Furthermore, 97.9% of respondents perceived that the current status of the soil fertility of their plot of land has decreased when compared to the past decades. Consequently, most of them (98.2%) indicated the decline in their crop yield per unit area in recent years. This decline in agricultural production and productivity has had profound adverse effects on household livelihoods, particularly in a region heavily dependent on subsistent farming.

Similarly, about 99.4% of the respondents perceived the existence of water-related problems in the BMER. Water shortage was perceived by 77.3% of respondents in the study area. Furthermore, about 41.9%, 56.6% and 50.4% of respondents noticed the existence of the problem of water pollution, increased runoff and varied and erratic rainfall in the study area of BMER, respectively. For instance, regarding the problem of water shortage resulting from LULC change-induced nearby streams drying up, more than half (53.4%) of the total respondents indicated that they had to travel more than one kilometer to access river water in the study area of BMER. Table shows the perception of respondents on the relative accessibility to river water now compared to the past 48 years ago. The results in the table indicate that the majority (83.8%) of the respondents perceived a decrease in accessibility to river water within the past 48 years. Respondents also indicated that owing to LULC changes the seasonal water volume in rivers/streams has been decreased, crop productions and productivities have been affected by rainfall variability and the effects of runoff have been increased over time; all these have subsequently impacted their livelihoods.

Table 5: Percentage of respondents perception on the patterns of accessibility of river water over the past 48 years ago

Response	Frequency	Percent
Increased	12	3.5
Decreased	284	83.8
Not changed	43	12.7
Total	339	100.0

Source: Households field survey in 2021

Communities in BMER have depended on several forms of forest products for their livelihoods. The results of the household survey indicated that all of the respondents replied that there were forests in their area and used them to support their sustenance such as the provision of poles and other materials for construction and agricultural implements (64.9%), grass and reeds (64%), firewood (86.7%), charcoal (10%), wild coffee and other fruits/flowers/leaves (51%) and tubers and roots (42.2%). However, most of the respondents (97.9%) noticed that these forest resources were encroached by agricultural land expansion, which reduces forest ecosystem services and functions. This shows that continuously deforestation is the main problem in the study area of BMER. Table shows respondents perceptions on the rate of deforestation and reasons accounted for the decreased collection of forest products in the BMER. Large proportions of them (40.4%) indicated the existence of a fast rate of deforestation in the BMER. In this regard, most respondents (95.3%) indicated a decrease in forest products over the years. The main reasons for the reduction of forest products are also presented in the the table. A considerable proportion (73.2%) of the respondents attributed the reduction of forest products owing to LULC change/deforestation in the area. Respondents also explained that deforestation is responsible for climate change that could adversely impact agricultural production through increased temperature, rainfall variability, and increased frequency and intensity of extreme weather events such as droughts and floods.

Table 6: Respondents perceptions on the rate of deforestation and reasons accounted for the decreased collection of forest products in the BMER

Questions presented to HHs	Response	Frequency	Percent
How do you view the current rate of deforestation?	Fast	137	40.4
	Moderate	121	36.7
	Slight	81	23.9
	Total	339	100.0
What factors are believed to contribute to the decline in forest product collection?	Owing to reduced forests in the area	248	73.2
	Due to enforced laws limiting forest accessibility	78	23
	Other reasons for reduced collection of forest products	13	3.8
	Total	339	100.0

Impacts on crop and livestock (financial capitals) production-based livelihoods

In this current study area of BMER, subsistence agriculture has been practiced by all respondents. Table shows the major crops and other farm produces and reasons for the reduction of their harvests as perceived by respondents in the study area of BMER. It was reported that Maize was dominant crop (79.9%) followed by Wheat (57.2%) and Barely (38.3%). Other crops produced in the BMER include Teff, Mongbean and coffee. Respondents perceived that the productions/harvests of their crops have shown variation over time owing to the impact of LULC change-based soil fertility loss, soil erosion and land degradation. The majority of them (98.2%) perceived that their crops' harvests have decreased over the past few decades. On the other hand, only (1.8%) of respondents perceived the increment in the harvests of their crops. They attributed the reduction of the harvests of their crops primarily to LULC

change-based soil and land degradation (82.9%) followed by shortage and variability of rainfall (68.4%) in the BMER. **Error! Reference source not found.** also shows the perception of respondents on the reasons for the reduction of their crop harvests over the past few decades. Generally, the overall perceived severity of the impacts of LULC changes on crop production and productivity is summarized in Figure. The result indicates that a considerable number of respondents (88.2%) perceived that the overall severity of LULC impacts on crop production and productivity has increased over time.

Table 7: Major crops and other farm produces and reasons for the reduction of their harvests perceived by respondents in the study area of BMER

Questions presented to HHs	Response	Frequency	Percent
Could you describe the major crops you cultivate?	Maize	271	79.9
	Sorghum	58	17.1
	Wheat	194	57.2
	Barely	130	38.3
	Oat	21	6.2
	Bean	2	0.6
	Pea	1	0.3
	Lentil	2	0.6
	Linseed	14	4.1
	Others	97	28.6
What other farm products do you produce?	Fruits	187	55.2
	Vegetables	176	51.9
	Coffee	219	64.6
	Others	7	2.1
What factors have contributed to the decline in your crop harvests?	Rainfall shortage and variability	232	68.4
	Soil and land degradation	281	82.9
	A lack of extension services	156	46
	Others	6	1.8

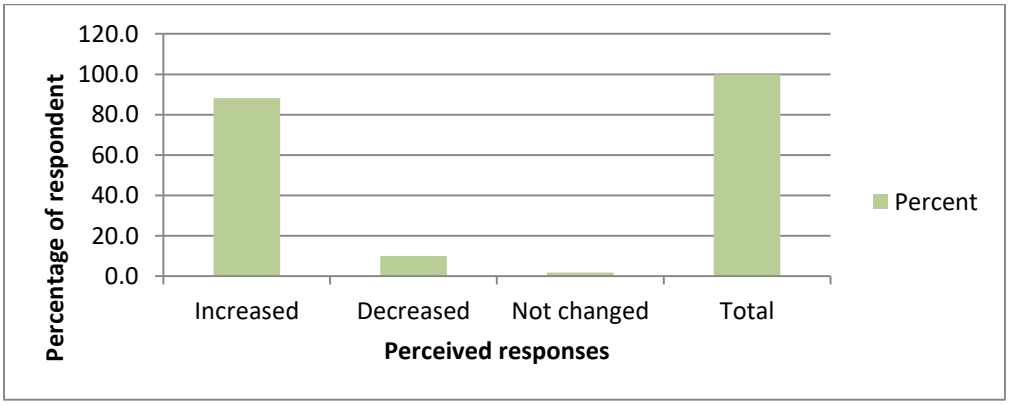

Figure 5: Perceived status of severity of impacts of LULC changes on crop production and productivity over time.

The major types of livestock reared and perceived reasons for the reduction of their livestock harvests over time are summarized in Table . The result indicates that the largest proportion of the respondents (98.5%) owned cattle. They also had Goats (52.8%) and Donkeys (62.5%). Most of the respondents (98.8%) perceived that their livestock productions/harvests have been decreased over time. The highest

proportion of respondents (93.8%) attributed the reduction of livestock harvests over time to the shrinkage of grazing lands followed by a shortage of water resources (69.9%) in the study area of the BMER. In general, Figure shows the respondents' perception of the overall severity of LULC change impacts on their livestock productions/harvests over the past few decades; the result shows that a considerable number of the respondents (89.1%) have perceived the increased impacts LULC change on their livestock productions/harvests.

Table 8: Percentage of respondents rearing a typical livestock and perceptions of reasons for the reduction of their livestock harvests in the study area of BMER (Multiple response)

Questions presented to HHs	Response	Frequency	Percent
What types of livestock do you primarily raise?	Cattle	334	98.5
	Goats	179	52.8
	Sheep	146	43.1
	Camels	3	0.9
	Horses	124	36.6
	Donkeys	212	62.5
	Chickens	129	38.1
	Others	3	0.9
What factors have contributed to the decline in your livestock harvests over time?	Shortage of water resources	237	69.9
	Grazing land shrinkage	318	93.8
	A lack of extension services	111	32.7
	Others	6	1.8

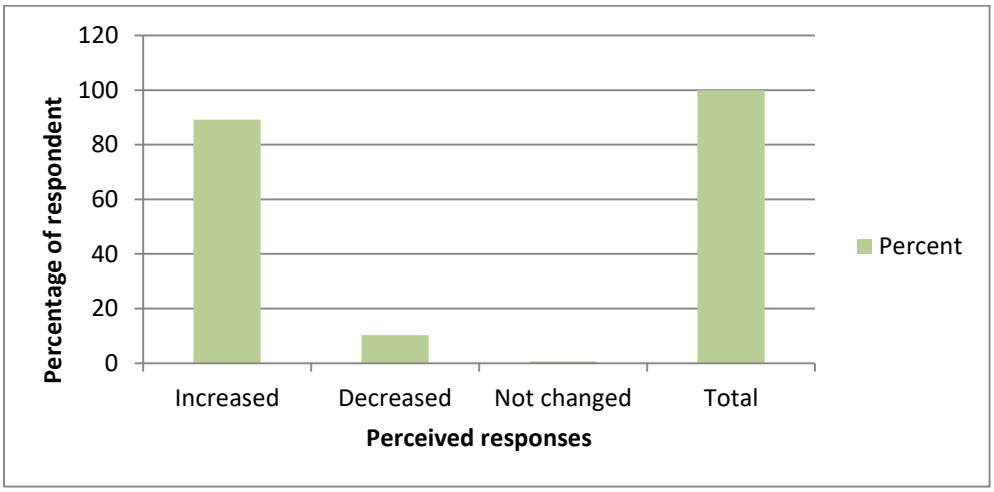

Figure 6: Perceived status of severity of impacts of LULC changes on livestock production and productivity over time

Impacts on physical asset- based livelihoods

According to all respondents, both types of all-weather and dry-season roads are found in the study area of BMER. Most of the respondents (97.9%) responded that they have access to these roads. Table shows the perceived response of respondents on the distances to access the nearest road from their houses, where more than half of them (59.3%) had to travel more than 1km to access the nearest road.

Table 9: Perceptions of respondents on the distances to access the nearest road from their houses

Distance to access the nearest road	Frequency	Percent
Within 1km	138	40.7
Between 1km-2km	98	28.9
More than 2km	103	30.4

Conversion of natural land covers mainly forests, woodlands, bushlands and grasslands to anthropogenic land uses (agriculture, grazing through overgrazing, etc.) is responsible for the generation of devastating runoffs. This makes the transportation system difficult and costly hence harming their livelihoods, especially during the rainy season in the study area of BMER. Accordingly, a large proportion of respondents (48.1%) perceived that the severity of LULC change impacts on the functionality of the rural roads has been increasing in the study area (Table).

Table 10: Perceptions of respondents on the relative severity of LULC change impacts on rural roads now compared to the past few decades in the study area of BMER

Response	Frequency	Percent
Increased	163	48.1
Decreased	18	5.3
Not changed	158	46.6

Impacts on social asset- based livelihoods

In the current study, all respondents indicated that LULC change-based hazards such as drought, floods, irregular rainfall and the associated crop failures have been increased in the study area of BMER. Buusa Gonofaa[1] is one of the social assets perceived by respondents for protecting community members during such hazard-hit times. However, the practicability of this social asset has been eroded over time owing to the increasing LULC change-based hazards and the affected households to be supported accordingly. As a result, only few of the respondents 33 (9.7%) showed their accessibility to the benefits of this social asset. Moreover, Most respondents (87.6%) perceived that the degree of the LULC change impacts on the practicability of this social asset has been increasing now compared to the past few decades (Table 3).

Table 3: Perceptions of respondents on the relative severity of LULC change impacts on the practicability of social asset of Busa Gonofa overtime in the BMER

Response	Frequency	Percent
Increased	297	87.6
Decreased	21	6.2
Not changed	21	6.2

[1] Buusaa Gonofaa is a traditional Oromo practice of community-based mutual support, where people contribute resources to help those in need, especially in times of hardship.

Impacts on human asset- based livelihoods

For this current study, the statuses of human resources in terms of education and occupation were considered whether they have been adversely impacted or not by LULC changes in the study area of BMER. According to all respondents, their education was perceived not to be adversely impacted by LULC changes; however, their occupations were perceived to be impacted with the consequent impacts on their livelihoods. Respondents indicated that their main occupations within the past 48 years were crop production, livestock rearing and both crop and livestock production. However, owing to the reduction of the productivity of these occupations throughout the study period respondents have engaged in other income generation activities such as home construction (0.4%), guarding (16.8%), weaving (0.6%), wood crafting (2.4%), fishing (1.2%), traditional medicine collection (7.7%) and sewing (0.3%). Generally, considering all of the assets-based livelihood impacts of LULC changes, respondents perceived the following rates of impacts (Table 4); where the highest percentage of them perceived a moderate rate (46.6%) followed by the high rate of impacts (41.9%).

Table 4: Respondents' perceived rate of impacts of LULC changes on their livelihoods

Rate of impacts	Frequency	Percent
Very low	6	1.8
Low	14	4.1
Moderate	158	46.6
High	142	41.9
Very high	19	5.6
Total	339	100.0

Livelihood transformation, diversification and outcomes

Livestock rearing was practiced by 38.6% of respondents in 1973 as a main livelihood source. The dependency of people on this source of livelihood has decreased owing to grazing land shrinkage over time in this study area. This resulted in very few (0.9%) respondents' dependencies on only livestock sources in 2021. On the contrary, dependency on crop production only as a livelihood strategy was very low in 1973 as only 3.8% of respondents were engaged. However, to meet the increased food requirements for the increased population from 131,150 in 1973 to 787,167 in 2021 (Ayana et al., 2024), this crop production livelihood strategy has increased resulting in 38.9% of respondents' engagement in this type of livelihood strategy in 2021. The dependency of respondents on agro-pastoralism (production of both crops and livestock) type of livelihood strategy was 56% and 59.3% in 1973 and 2021, respectively. This shows that agro-pastoralism remains the dominant means of economic activities in the study area of BMER. Moreover, the percentage of respondents who engaged in wild resource use (such as various forest products) as a means of livelihood strategy has decreased from 1.5% in 1973 to 0.9% in 2021 in the study area.

Generally, owing to impacts from LULC changes substantial transformations of livelihood from pastoralism into agro-pastoralism and pure crop production systems have occurred in the study area of BMER. Furthermore, respondents have shown their diversifications of livelihood strategies into other income generation activities such as beekeeping, fattening, petty trading, guarding, and into skills such as home construction, weaving, wood crafting, fishing, sewing and motor biking. All these transformations and diversifications of livelihood mechanisms have been perceived by the majority (68.1%) of the total respondents.

Regarding the livelihood outcomes in the changing conditions of LULCs in the study area, respondents perceived the reduction of yields/outputs per unit area of their crop and livestock productions in the past 48 years. Moreover, deforestation has led to reduced income and benefits from the forest products. Regarding these economic activities, many household heads perceived the adverse reduction of their well-being and the existence of food insecurity problems in the study area.

Major shocks affecting communities' livelihoods

Respondents in the current study area have experienced several shocks in the past 48 years, which were directly or indirectly related to the impacts of LULC changes. Table 5 presents the major shocks that have been experienced by local communities in the study area. The results of the household interview revealed that drought was the most serious shock experienced by most respondents followed by food shortage, irregular rainfall and fire shocks. Drought and erratic rainfall problems were mentioned as LULC change-induced climate change impacts by respondents from Wabaro kebele of Delo Mena Woreda. However, fire-related shock was reported by respondents from Rira kebele of Goba Woreda and Hawo kebele of Harenna Bulluk Woreda.

All respondents perceived that government institutions/sectors, policies and processes have played their major roles in reversing such shocks and associated households' vulnerabilities by enabling the adoption of measures and approaches such as integrated watershed management, community forest management, livestock and pasture management and promotion of agro-ecologically suitable various alternative income generation activities to achieve sustainable livelihood outcomes. However, they have also their drawbacks. For instance, government-led resettlement programs and promotion of agriculture-led industrialization policies implemented by previous governments have contributed to the degradation of natural resources (such as forest, grazing land, etc.) and hence to the adverse livelihood outcomes in the study area of BMER. Respondents also mentioned the existence of weak law/bylaw enforcement in forest protection and management in this study area of BMER.

Table 5: Major shocks experienced by communities in study area of BMER

Major shocks	Frequency	Percent
Erratic rainfall	234	69.0
Drought	272	80.2
Fire	170	50.1
Food shortage	270	79.6
Flood	63	18.6
Other	54	15.9

DISCUSSION

The results of both satellite imagery and household survey analyses indicate that LULCs had undergone changes in the period between 1973 and 2021 with the noticeable expansion of agriculture, settlement and bare land LULC classes, and reduction of forest, woodland, bushland, grassland and water bodies LULC class types in the study area. The findings of this study corroborate the results of several previous LULC studies in Ethiopia (Mulaw et al., 2023; Anteneh, 2022; Abebe et al., 2022; Negassa et al., 2020; Ayele et al., 2019; Legesse et al., 2019; Mezgebu & Workineh, 2017) and elsewhere outside the country (Mwanga et al., 2024; Balaka Opiyo et al., 2022; Daata et al., 2021b).

Furthermore, in accordance with other studies (eg., Fikadu & Olika, 2023; Iddrisu et al., 2023; Lahai et al., 2022; Daata et al., 2021b; Gessese, 2018; Zotova & Cohen, 2016; Kamwi et al., 2015; Bashir, 2012), the current study also identified that the observed and perceived changes in LULCs have tremendous impacts on rural livelihoods in the study area. For instance, one of the livelihood impacts of LULC changes perceived by respondents was soil degradation, especially in soil erosion and soil fertility to ultimately reduce crop productivity in the study area. In line with this finding, a study by Anwa et al., (2024) reported a decrease in soil fertility status owing to LULC changes in the Abbottabad District of Pakistan. Another study (Gessese, 2018) in Ethiopia also confirmed the impact of LULC changes on

land productivity especially in agricultural land by threatening food production and rural livelihoods. Water-related problems such as water shortage, water pollution from agricultural land uses, and runoff responses are also other LULC change-based impacts that have subsequently affected the livelihoods of communities in the BMER. The finding of the LULC change impacts on water availability and consequently on local livelihoods corroborate previous studies (Anwa et al., 2024; Anteneh, 2022; Gessese, 2018). Furthermore, most respondents (95.3%) indicated the decrease in forest products over the years owing to LULC changes/deforestation in the study area; and this problem was reported to be a long-time problem in the area. Respondents also explained that deforestation is responsible for climate change that could adversely impact agricultural production through increased temperature, rainfall variability, and increased frequency and intensity of extreme weather events such as droughts and floods. In line with these findings, Iwuji et al., (2022) indicated the impact of LULC changes especially deforestation on people through the reduction of earnings from forest resources and loss of their farmland exposed to erosion. A similar study (Gifawesen, 2019) in the Yabello District of Borena reported that deforestation was the main problem and responsible for soil erosion and land degradation with the subsequent effect on the rural livelihoods in the area. Furthermore, the current results of LULC change impacts on forest-based livelihoods confirm previous results (Mulaw et al., 2023; Gessese, 2018; Bashir, 2012). In general, LULC changes have considerable impacts on natural capital such as soil, water and forest resources to subsequently affect the livelihoods of the rural communities in the study area of BMER.

In the study area, LULC changes have adversely impacted crop production and productivity and hence the dependent livelihoods of the communities by affecting soil resources and weather conditions. In line with these findings, Anwa et al., (2024) also reported a reduction of crop production owing to LULC change-based soil infertility and unreliable rainfall patterns. Similarly, LULC changes, mainly conversion of grazing, bush and forest lands to cultivated land have also strongly affected the number of livestock and their products in the BMER. This has drastically impacted the livelihoods of pastoralists and agro-pastoralists in the study area of BMER. In agreement with these findings Gifawesen, (2019) reported LULC change-induced drought impacts on pasture and water natural resources as well as on farmland production with consequent reduction of crop and livestock productions and productivity in the Yabello District of Borena Zone. In addition, Gessese, (2018) also reported a reduction of livestock production and productivity owing to reduced fodder resources due to population growth-induced traditional grazing lands conversion mainly to croplands. Hence, crop and livestock properties that are considered financial assets in this study are vulnerable to LULC changes in the study area.

One of the physical assets considered to be influenced by the changing condition of LULC changes in the study area was road infrastructure. According to respondents, the perceived damages to the roads owing to LULC changes were mainly caused by runoff amounts reaching the roads. Similarly, one of the social assets perceived by respondents for protecting community members during hardship in the study area of BMER was Buusaa Gonofaa. It is an indigenous social protection mechanism when a community member encounters a serious economic, cultural, political and psychological problem among the Borena people of Oromia (Wako et al., 2023). According to (Gifawesen, 2019), it is also one of the social assets known among Oromo communities, especially among lowland pastoral communities and commonly supports poor and hazard-affected households. The result of this study shows that the practicability of this social asset has been eroded over time owing to the increasing LULC change-based hazards and the number of affected households to be supported accordingly in the study area. This finding corroborates the result of a previous study (Gifawesen, 2019). Furthermore, LULC change-induced impact on human-asset such as on respondents' occupations was the main problem mentioned in the study area. A similar finding of LULC change-induced adverse impact on the productivity of human resources such as occupation, education and human labor was reported by a previous study (Gifawesen, 2019; Riché et al., 2009).

The shifting of livelihood strategies has happened as a response to the impacts of LULC changes within the study period (1973 to 2021) in the study area. Explicit livelihood transformations have occurred from pastoralism into prevalent agro-pastoralism and pure crop production systems in the study area of BMER. These shifts have been influenced by the increasing transformation of socio-ecological systems in the form of LULC changes; which in turn are driven by various driving factors such as population

growth, climate change, the prevalence of poverty and government institutions and policies (Ayana et al., 2024) in the study area. This current finding of the dominancy of agro-pastoralism as a means of livelihood was also reported by a previous similar study (Gifawesen, 2019) in the Yabello District of the Borena Zone. Similar findings of reduced dependency on livestock production (pastoralism) and wild resources uses due to LULC changes were reported by a previous study (Anwa et al., 2024). The shifts of livelihood strategies in the study area have occurred alongside livelihood diversifications into various income-generating activities such as beekeeping, fattening, petty trading, and guarding. In line with this finding, a previous study by Gifawesen, (2019) also indicated the existence of households' livelihood diversifications into petty trade, charcoal selling, handcraft, labor work and employment as guard besides their main economic activities owing to climate change-induced LULC changes.

Associated with the adverse impacts of LULC changes on livelihood resources, many household heads perceived the adverse reduction of their well-being and the existence of food insecurity problems in the study area. In line with this finding, a previous study by the same authors (Ayana et al., 2024) indicated that most of the local people in the low- and mid-land woredas (Delo Mena, Berbere and Harena Buluk) of the study area of BMER are beneficiaries of the Productive Safety Net Programme (PSNP) and hence reported to be food insecure. Similarly, regarding the various LULC change-related shocks mentioned in this study, similar results of wildfires, floods, and drought shocks that are associated with LULC changes were also reported by (Lahai et al., 2022). Furthermore, irregular rainfall, drought, fire and food shortage identified as the main LULC change attendant shocks in this study confirm the previous result (Kamwi et al., 2015).

In a nutshell, the study area of BMER has been subjected to LULC changes that, consequently have threatened the sustainability of communities' livelihoods by adversely impacting the livelihood resources/assets and the dependent livelihood strategies and outcomes. Although the current study and its findings were interpreted with the important limitation of its consideration of only the potential adverse impacts of LULC changes on rural livelihoods in the study area of BMER, its results and recommendations still have valuable contributions in providing information to decision-makers and planners for sustainable development and management of LULC diversities to ensure sustainable human livelihoods.

CONCLUSION AND RECOMMENDATIONS

This study aimed to assess the perceived LULC changes and their livelihood impacts in the period between 1973 and 2021 in the study area. The finding shows that the study area has experienced considerable changes in land use land cover patterns during the study period which were characterized as the expansion of cultivation to the marginal areas (62.8%), the expansion of overgrazing (62.2%) and cutting of trees (85.3%). These show a considerable expansion of agriculture and settlement lands at the expense of natural forests, woodlands, bushes and grassland in the study area. These changes have adversely impacted the livelihood resources such as natural resource bases (soil, water and vegetation such as grass, bushes and forests), livelihood strategies and the socio-economic well-being of rural households in the BMER. For instance, LULC dynamics reduced social networks such as Busa Gonofa, as well as accelerating the damage of physical assets (road infrastructure). Moreover, transformations of livelihoods mainly from pastoralism into agro-pastoralism and pure crop production system and diversifications of livelihood strategies into other income generation activities have occurred owing to LULC changes in the study area. Furthermore, many household heads perceived the existence of adverse livelihood outcomes explained through the reduction of their well-being and the prevalence of food insecurity problems in the study area of BMER. Although this research study is limited to analyzing only the negative impacts of LULC changes, it has valuable contributions in informing decision-makers and planners for sustainable development and management of LULC diversities to ensure sustainable human livelihoods.

Hence, it necessitates sustainable participatory conservation and management of natural resources for sustainable human livelihoods and environmental health as well. Furthermore, there is a need for further diversification of livelihoods that are sustainable, resilient, nature-positive and regenerative to reduce LULC changes and their associated adverse livelihood impacts in the study area of BMER. Moreover,

further study is required to assess the potential communities' coping and adaptive mechanisms for the adverse livelihood impacts of LULC changes in the study area of BMER.

Declaration of competing interest

The authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors. All ethical responsibilities of authors are maintained.

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