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Original article

Spatio-temporal variation on land use and land cover and its drivers under watershed management activities in Becho, Central Highlands of Ethiopia

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ABSTRACT

The study sought to understand the spatio-temporal variation of land use and land cover (LULC) and its drivers under watershed management activities in Becho district, in Ethiopia's Central Highlands. To gain a better comprehension of the subject, two micro watersheds were chosen to test the effectiveness of watershed management activities (treated-Shankur Tareqo and untreated-Mende Tufessa). LULC changes were detected using aerial photography (1973), and satellite images from Landsat 5 TM (1990), Spot 5 (2005), and Landsat 8 OLI (2021) obtained from the Ethiopian Geospatial Information Institute and the United States Geological Survey. In addition, key informant interviews (KII) and focus group discussions (FGD) were used to elicit LULC drivers. Between 1973 and 2021, the total area of woodland, and cultivated and rural settlement land LULC classes in the treated micro-watershed decreased by 24.65% (171.9 ha) and 7.34% (759 ha), respectively. Though, grassland, forestland, and barrenland increased by 30.83% (179.52 ha), 1% (3 ha), and 183.14% (755.28 ha), respectively. The overall area of LULC class for woodland, grassland, forestland, and cultivated and rural settlement decreased by 50.36% (316.16 ha), 41.23% (196.46 ha), 2.43% (11.85 ha), and 1.35% (138.6 ha), respectively, in the untreated micro-watershed, while barrenland increased by 175.86% (666.55 ha). According to KII and FGD, the drivers of LULC changes were identified as the expansion of cultivated land, population pressure, and government policy. According to the findings, local-scale watershed management activities was not as effective as expected. As a result, in order to achieve the desired outcome, the concerned stakeholders should reconsider how watershed management activities is undertaken.

KEY WORDS: land use, land cover**,** watershed management activities, spatio-temporal variation, supervised classification, detection

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1. Introduction

Land use and land cover dynamics are the main driving forces underlying local, regional, and global environmental changes (ABEBE ET AL., 2022). Almost 1.2 million km^2 of forests and woodlands and 5.6 million km^2 of grasslands and pastures have been converted into various types of land use over a long time period and on a worldwide scale (GUAN ET AL., 2008). The area of agriculture has expanded by 12 million km^2 during the same time frame. The majority of the conversion of forests and woodlands to other land use categories has taken place in South America, Africa, and Asia. Due to a number of factors, such as climate change and population growth (GAREDEW ET AL., 2009), East Africa has experienced the second-highest rate of transformation in Africa.

According to ASSEN & NIGUSSIE (2009), each region's specific physical and socioeconomic

conditions determine LULC changes and their effects. For instance, due to the growth of agricultural land, the Gubeta-Arjo peasant associations in central Ethiopia nearly completely lost all of their forest cover between 1973 and 2006 (GAREDEW ET AL., 2009). On the other hand, croplands increased by a net 51%, from 403 km^2 to 607 km^2, in the Fincha'a watershed between 1957 and 2001, at the expense of forests and grazing areas (TEFERA & STERK, 2010). Additionally, in the Chirokella micro-watershed in south eastern Ethiopia, the amount of dense forest cover declined by nearly 80% between 1966 and 1996, whereas the area of moderately forested land was totally transformed into other LULC categories. In the same micro-watershed, the number of cultivated and settlement lands increased by 62.8%, whereas the number of shrubs and degraded land cover increased by 49.9% and 100%, respectively (ASSEN & NIGUSSIE, 2009). Land degradation has inevitably resulted from this rapid change of grazing and forest land into cultivated and degraded land (HURNI, 1993).

Land degradation, prevalent in various agriculture-based developing countries, including Ethiopia, is manifested by soil nutrient depletion and loss of land productivity potential (TAMENE & VLEK, 2008). In Ethiopia, where more than 90% of the population depends on agriculture for food and a livelihood, soil erosion and soil fertility decline continue to be a significant problem (EBABU ET AL., 2020). In Ethiopia, a high rate of soil erosion, over-cultivation, improper land use, and poor soil management practices, among other things, are considered to be the causes of land degradation (AMEDE ET AL., 2001; BADEGE, 2001). In the Highlands, where inappropriate farming practices have been used for centuries and where about 87% of the nation's population lives, the problem of soil erosion and the associated reduction in soil fertility is worse (EBABU ET AL., 2020). For instance, according to BAI ET AL. (2008), about 26.33% (296,812 km^2) of Ethiopia's land area was affected by land degradation, majorly caused by water-induced soil erosion. About 23% of its soil erosion was contributed by cropland, which constituted about 50% of the country, with a mean soil erosion loss of 36.5 t ha^{-1} yr^{-1} (FENTA ET AL., 2021). Due to this, Ethiopia annually loses about one billion tonnes of topsoil, costing about 30% of its gross domestic product (KIRUI & MIRZABAEV, 2014).

To reverse the problem of land degradation and achieve the sustainable use of its resources, optimistic land management practises have been implemented in Ethiopia at a watershed scale, focusing on the Northern Highlands since the 1970s (AMEDE ET AL., 2001; BADEGE, 2001). As time passed and the problem intensified in different parts of the country, activities of natural resource conservation were primarily implemented in selected watershed sites of the Ethiopian Highlands, where land degradation was found to be severe (AMEDE ET AL., 2001; BADEGE, 2001). Implementation of watershed management activities (WMA) brought some positive outcomes in those parts of Ethiopia, especially after the adoption of integrated WMA in 2010 (GEBREHAWERIA ET AL., 2016; MELAKU ET AL., 2017). WMA induced at a watershed scale, for instance, caused a reduction of 25–38% in soil loss between 2011 and 2015 in the Gumara Maksegnit watershed (MELAKU ET AL., 2017), 64% of soil loss in the Agula watershed (between 1990 and 2012) (FENTA ET AL., 2017a), 47% of soil loss in the Central Highlands of Ethiopia (between 2007 and 2009) (ADIMASSU ET AL., 2012) and 65–70% (16.5t ha-1 yr-1) of soil loss at country level (FENTA ET AL., 2021). Moreover, watershed management induced coverage of dense forest (between 1965 and 2005) (ALEMAYEHU ET AL., 2009), and plantation and exclosure (between 2004 and 2009) (HAREGEWEYN ET AL., 2012) were significantly increased in the northern part of the country.

These and other success stories caused the introduction of WMA in different parts of the country through a top-down approach (GEBREHAWERIA ET AL., 2016). In line with this, Oromia regional state announced WMA in 2010/2011 in all parts of the region including the study area (OROMIA REGIONAL NATIONAL STATE BUREAU OF AGRICULTURE AND NATURAL RESOURCES, 2017). The specific place of Kiro in the Shankur Tareqo micro-watershed, was selected as a model area to implement different soil and water conservation measures as it represents the hilly and gully areas of the district, which have suffered serious soil erosion for a long period (BECHO WOREDA NATURAL RESOURCES DEPARTMENT (BWNRD), 2021). With the start of WMA, in Kiro and the Shankur Tareqo micro-watershed as a whole, a better achievement has been observed on soil and water conservation activities even though different obstacles were found. As a result, the Shankur Tareqo micro-watershed has been considered the subject of different forms of soil and water conservation activities since 2010/2011.

Thus, in addition to the aforementioned factors (population growth and density, over-intensification of land use, farm size, land tenure status, and lack of land use policies), LULC change-induced land degradation and land degradation-induced WMA are two sides of the same coin that have an impact on the LULC structure in the study area and elsewhere. However, it is hard to find an

article that was written on LULC change of the district unlike that of the northern part of Ethiopia. Even the few existing articles about LULC changes (SHAWUL & CHAKMA, 2019; TEFFERA ET AL., 2018) covering the watersheds were performed at the macroscale. However, the contribution of LULC change studies at such a large scale to land management options is less (GEBRELIBANOS & ASSEN, 2013). But studies at the micro-scale watershed, which were uncommon in the study area, are more effective. In order to devise suitable land management practises, strategies, and policies, a thorough analysis of LULC change brought on by WMA and other driving variables within the micro-watershed is thus urgent and essential. Hence, this study aimed to detect the spatio-temporal variations of LULC and its driving factors under watershed management in the Becho district of central Ethiopia between 1973 and 2021.

2. Materials and methods

2.1. Study area

The study was conducted in two adjacent micro-watersheds, named Shankur Tareqo (treated) and Mende Tufessa (untreated) in the Becho District, of the Central Highlands of Ethiopia (Fig. 1). The treated micro-watershed covers 12,327 ha and is located between 8°29′44.33″ and 8°40′00″N latitude and 38°07′14.55″ to 38°20′15″E longitude. Its elevation ranges between 2101 m. a.s.l. in the lower part, and 2795 m a.s.l. in the upper part, with a slope gradient reaching 69%. It encompasses the specific place of Kiro where a government-led WMA was implemented in collaboration with Shankur village residents on previously degraded communal land. The Kiro specific place covers approximately 32 ha. It was viewed as a model site to disseminate technologies and experiences in natural resource conservation to the nearby watersheds. In this specific place and the Shankur Tareqo watershed, about 606 m of gully rehabilitation with trees, 5 m^3 of gully rehabilitation with stones, 3.72 km of soil bund, 1.5 km of the stone bund, and 20 micro-basins were constructed between 2018 and 2019 (BWNRD, 2021). The adjacent Mende Tufessa micro-watershed located between 8°33′57.71″ and 8°40′00.13″N latitude, and 38°07′13.98″and 38°19′2.00″E longitude, covering an area of 12,272 ha, was used as a control to check the effectiveness of the introduced WMA, due to the absence of government-led WMA implemented in this micro-watershed. Thus, it was considered to be untreated.

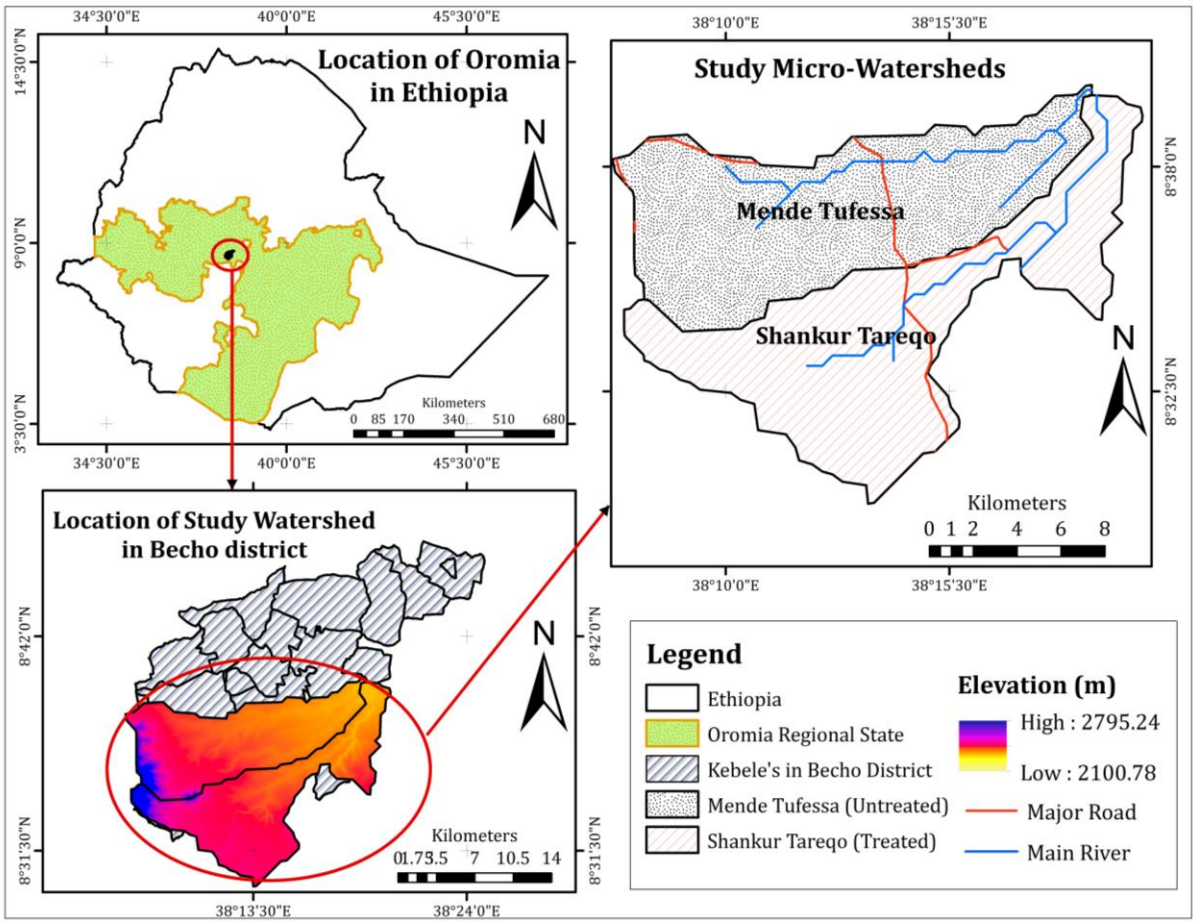


Fig. 1. Location map of Shankur Tareqo and Mende Tufessa watersheds, in Becho district

The underlying geology in each micro-watershed consists of Nazareth series volcanoes, forming parent materials for the vertisols that dominate the landscape of the watersheds. About 90% of the soils in the watersheds are vertisols, while the remaining are occupied by luvisols, nitisols, and leptosols (ELIAS, 2016).

Both micro-watersheds are predominately grouped into the mid-altitude zone (ELIAS, 2016). According to long-term meteorological data (1990–2019), these micro-watersheds were characterised by mean maximum and minimum annual temperatures of 22.67°C and 9.09°C, respectively. The mean annual temperature and average annual rainfall are 16°C and 1127 mm, respectively (Fig. 2). The subsistence rain-fed farming system forms the main economic activity in both micro-watersheds. Locally, maize (*Zea mays*), teff (*Eragrostis tef*), wheat (*Triticum aestivum*), and chickpea (*Cicer arietinum*) are the major cultivated crops. Furthermore, oxen, cows, goats, sheep, hens, horses, mules, and donkeys are the most common animals found in the micro-watersheds (BWNRD, 2021).

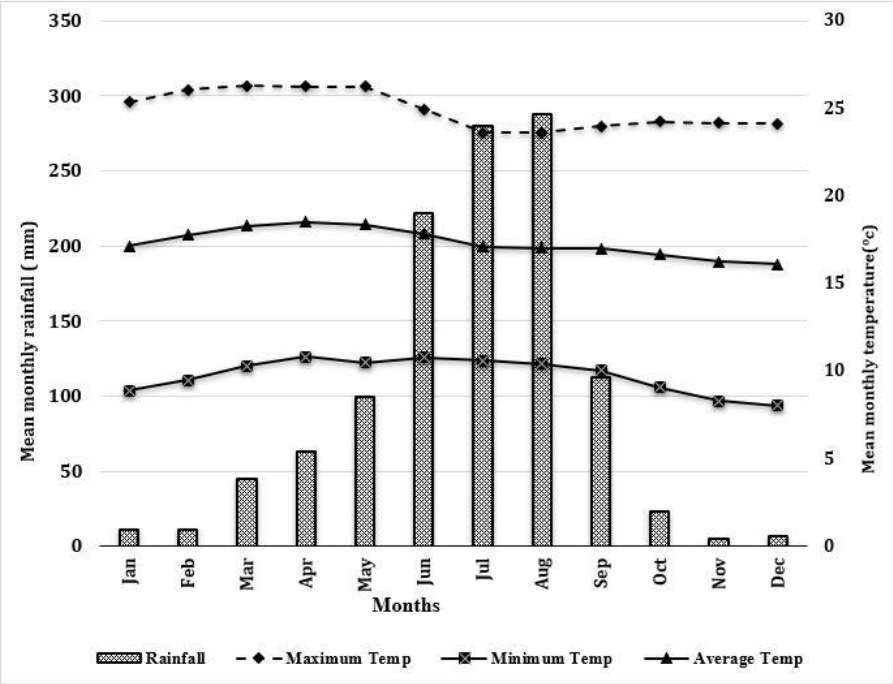


Fig. 2. Rainfall and temperature records of the study area based on the records of nearby Tulu Bolo station (1990–2019) from the national meteorological service agency, Ethiopia

2.2. Data acquisition, sources and processing

The LULC change analysis of the study area was carried out using a collection of aerial photos and various satellite imagery. Accordingly, the Ethiopian Geospatial Information Institute (EGII) provided seven aerial photos for 1973 and a Spot 5 image for 2005, as well as two sets of topographic maps at 1:50000 scale. The remaining Landsat Collection 1 level-1 data product images of 1990 and 2021, and digital elevation model were freely downloaded from the USGS website in December, 2021 (https://earthexplorer.usgs.gov). Furthermore, the watershed boundaries were delineated using digital elevation model. The images were chosen based on data availability (1973 aerial photos), anticipated major changes (1990), introduced watershed management (2005) and year consistency (2021).

Scanned aerial photos with a photogrammetric scanner at 1200 dots per inch (DPI) in tagged image file (TIF) format were independently orthorectified and registered to a coordinate system of WGS 1984 UTM Zone 37N using the Transverse Mercator projection system with less than 0.85 root mean square error (RMSE) by the data providers, that is EGII. These rectified pieces of aerial photos were mosaicked using Erdas Imagine 2014. After calibrating at sensor radiance, radiometric correction of Landsat 5 TM and Landsat 8 OLI was carried out using the methods described by ZADBAGHER ET AL. (2018) and PRIETO-AMPARÁN ET AL. (2016), respectively, in Erdas Imagine 2014. All of these images were reprojected to a WGS 84 into a UTM Zone 37N coordinate system using a 1:50,000 topographic map as the base map to avoid any projection distortion and displacement that might occur among those images.

Finally, the study area was extracted using the boundary of watersheds on the mosaicked geo-referenced aerial photos of 1973 and the satellite images. Investigation of shape, size, pattern, tone, texture, shadow, and site association were used to identify LULC classes in mosaicked aerial photos of 1973. However, in order to improve delineation objectivity, interpretation repeatability, and processing efficiency, locally available LULC types from satellite images were identified through supervised classification (maximum likelihood techniques) algorithms with the aid of Erdas Imagine 2014 and ArcGIS 10.7. The indistinguishability of rural settlements and cultivated land, as well as natural forest and plantation, was recognised during this process because they had the same tonal value on the image. Therefore, rural settlements and cultivated land were amalgamated and called "cultivated and rural settlement land", while plantation and natural forest, which are commonly found along riversides, were simply called "forestland". Using the existence of vegetation, edaphic conditions and artificiality of cover as explained in the Land Cover Classification system (Di Gregorio, 2005), five LULC types–barren land (BL), forestland (FL), cultivated and rural settlement land (CRSL), grassland (GL) and woodland (WL)–were identified in the studied micro-watersheds (Table 1).

Table 1. LULC types identified in the treated and untreated micro-watersheds

LULC types	Description
BL	Refers to areas of exposed stone, sand and soil or area with no vegetation or dominated by rock-out crops, eroded and degraded lands found along the flooding area of the local stream valleys, over gentle and steep mountain slopes
CRSL	Refers to areas covered with annual rainfed crops and scattered rural dwelling
FL	Refers to plantations, the disturbed natural patchy forest cover of mature trees and riparian vegetation
GL	Refers to areas covered with grasses
WL	Areas covered with sparse woody plants mixed with shrubs, bushes, and grasses. It also incorporates perennial cropland with 30-50% moderately stocked tree crown cover

NB: WL=Woodland, GL=Grassland, FL=Forestland, CRSL=Cultivated and Rural Settlement land and BL=Barren land

Furthermore, information that is not possible to extract from aerial photos or satellite images was obtained through open-ended guided questions used for focus group discussion (FGD) and key informant interview (KII) as well as from personal field observations. A total of three FGDs were held in both watersheds, comprising of 5 to 8 participants selected from local elders, community leaders, and development agents. KII were also conducted with 12 (6 from each watershed) purposefully selected local residents aged between 30 and 65 to gain further insight into issues related to LULC changes perceived throughout their lives.

2.3. LULC spatio-temporal change detection methods

Post classification change detection techniques, which reduced the possible effects of spectral resolution and sensor differences between the multi-temporal image (Abera et al., 2018) were used to analyse the change in LULC for the periods 1973–1990, 1990–2005, 2005–2021, and 1973–2021. This method enabled an assessment of the temporal changes of the LULC types and computed the extent of LULC conversion induced by WMA and physical, socio-economic and policy related factors. Thus, the rate of absolute variation of a single LULC category between two time points was quantitatively determined using the equations 1 and 2. Additionally, to have a complete picture of the conversion between various LULC types, transition matrices were made for the different periods of analysis.

$$S = U_b - U_a \quad (1)$$

$$K = \frac{U_b - U_a}{U_a} \times 100\% \quad (2)$$

where S is the absolute variation in the area of a certain land type in the study period; K is the change rate of a land type with a positive value representing an increasing rate and a negative value representing a decreasing rate; Ua and U_b is the area of a land type at the beginning and the end of the study period in hectares.

3. Results and discussion

The LULC types and their spatial distribution for Shankur Tareqo and Mende Tufessa micro-watersheds are shown in Figs. 3 and 4 as well as Table 2. Cultivated and rural settlement, woodland, grassland, forestland, and barren land were the common LULC types identified in the watersheds. Furthermore, the LULC transition matrix determined for the years between 1973 and 2021 are presented in Table 3.

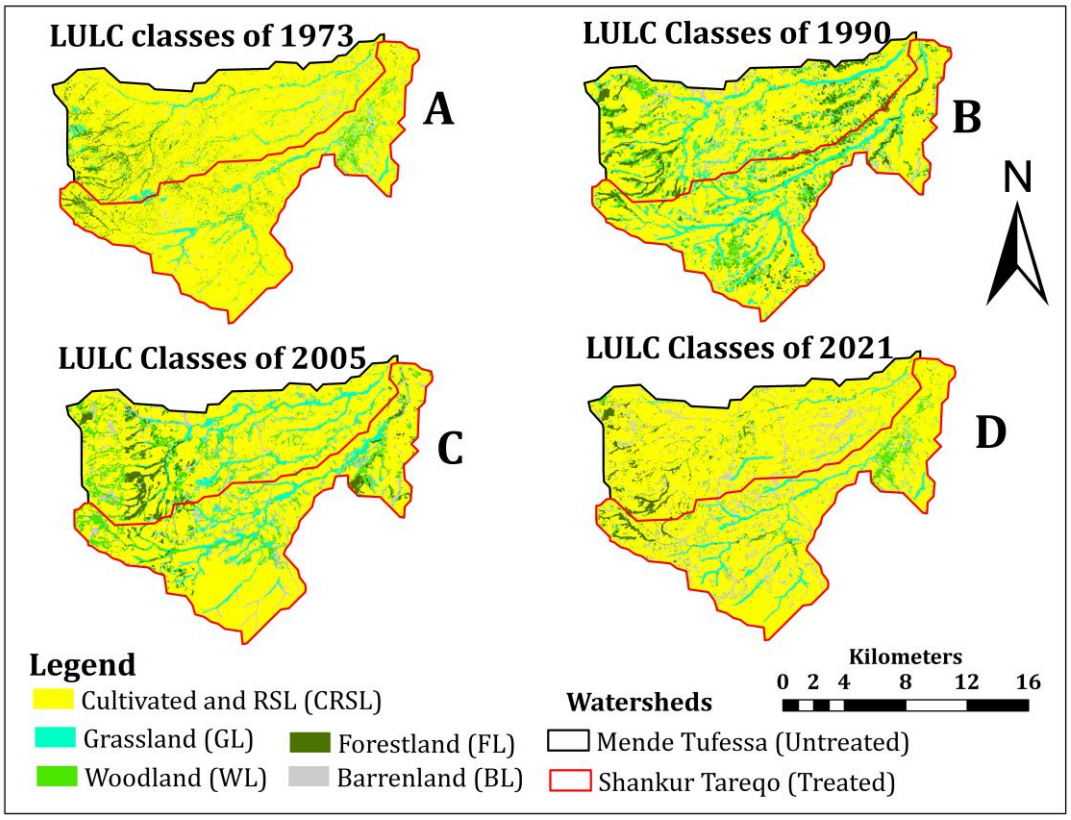


Fig. 3. LULC distribution of Shankur Tareqo and Mende Tufessa micro-watershed for each year from 1973 to 2021

3.1. Cultivated and rural settlement land (CRSL) LULC pattern from 1973–2021

CRSL comprises the largest share of the watersheds throughout the study period (1973–2021). The share of this LULC category in the treated micro-watershed accounted for 84%, 69%, 72%, and 78% for the years 1973, 1990, 2005, and 2021, respectively (Fig. 4). Except for the years 1973–1990, CRSL LULC types increased continuously (Table 2). In the first period of analysis (1973–1990), a considerable reduction, by 17.48%, of this LULC category was recorded due to rural-urban migration and *Beherawi Witidrina*[1], as per KII and FGD. This was in line with the study of YESUPH & DAGNEW (2019), who found that between 1973 and 1986, there was a major rural out-migration in the Gedalas watershed of the north-eastern Highlands of Ethiopia, which resulted in a decline in CRSL. MEKUYIE ET AL. (2018) also noted a decrease in farmland between 1985 and 1995 as a result of the movement of pastoralists in response to climate change. In the later periods of analysis (1990–2005 and 2005–2021), CRSL LULC classes showed an increasing trend. The highest increment of 7.89%, with a rate of 43.8 ha yr^{-1}, was observed in the years between 2005 and 2021 (Table 2). This increment is the result of 753.5 ha of WL, 565.8 ha of BL, 469.9 ha of GL, and 206.5 ha of FL conversion to CRSL between 2005 and 2021 (Table 3). In general, the CRSL LULC classes decreased by ~7% over the study period, between 1973 and 2021, in the treated micro-watershed.

In the untreated micro-watershed, after a decline from 83.93% in 1973 to 68.34% in 1990, CRSL showed a significant expansion from 69.35% in 2005 to 82.78% in 2021 (Fig. 4). Between 2005 and 2021, the highest increment of 19.38%, with

[1] It was the Derg regime's forced conscription of young male working-age groups into its wars with the Tigray People's Liberation Front, the Eritrean People's Liberation Front, and the Ogaden War.

a rate of 103.07 ha yr^{-1}, was observed (Table 2). CRSL expanded at the expense of 1023.1 ha of WL, 631.7 ha of GL, 501.7 ha of BL, and 420.1 ha of FL (Table 3). The primary reason for this increment, as mentioned by the stakeholders, was population pressure. During the study period, CRSL in this micro-watershed decreased by 1.35%. The result of this study was in agreement with the findings of those who found a decline of CRSL by ~7% throughout their study periods between 2000 and 2017 in north west Ethiopia (WORKU ET AL., 2021), ~1% between 1985 and 2017 in south west Ethiopia (FASIKA ET AL., 2019), ~14% between 1985 and 2010 in the Abaya-Chamo basin (WOLDEYOHANNES ET AL., 2018), and ~24% between 1985–2015 in the Afar region (MEKUYIE ET AL., 2018).

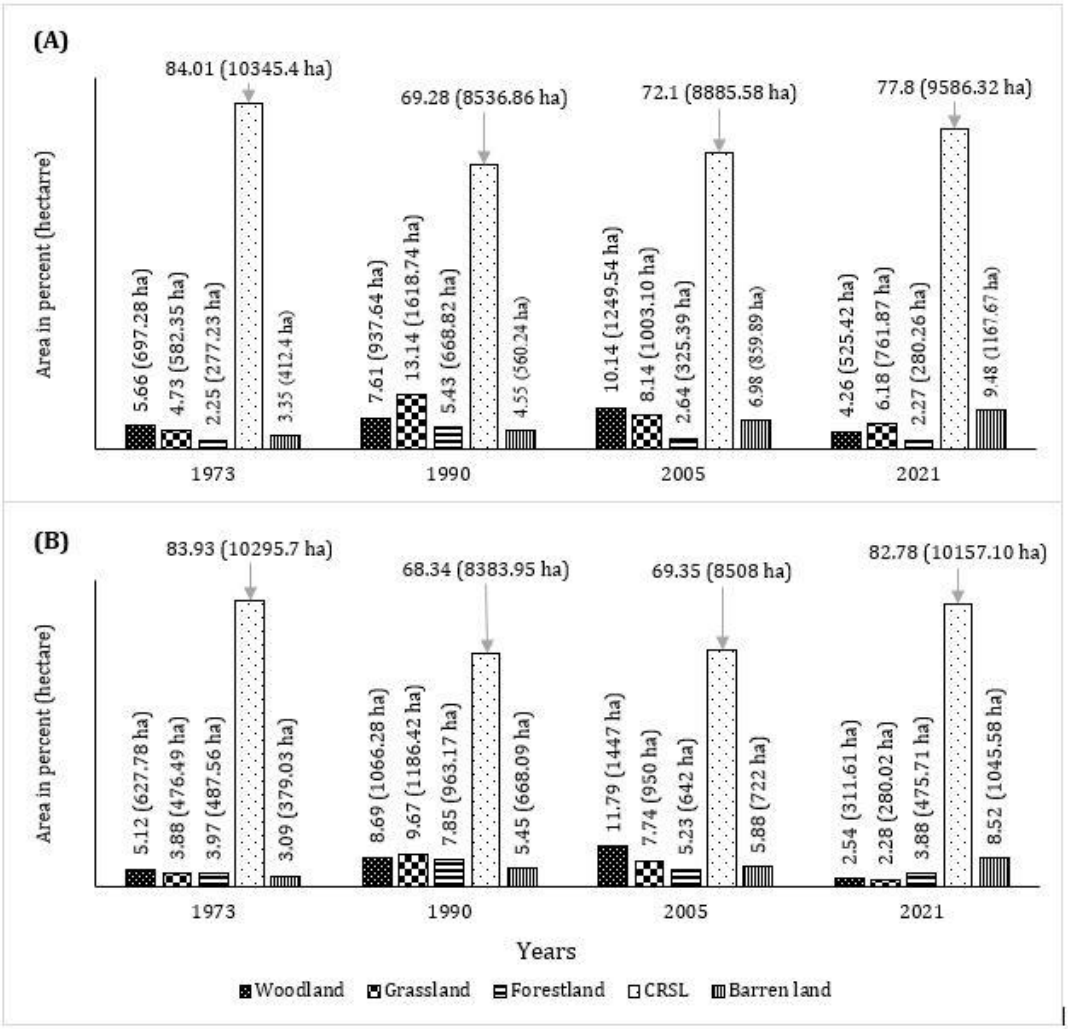


Fig. 4. Aerial coverage of LULC change in the Shankur Tareqo (A) and Mende Tufessa (B) micro-watersheds in 1973, 1990, 2005 and 2021

3.2. Grassland (GL) LULC pattern from 1973–2021

In 1973, GL covered approximately 5% of the treated micro-watershed, which increased to 13.14% in 1990. After that, GL showed continuous decline. It declined from 8.14% in 2005 to 6.18% in 2021 (Fig. 4). Between 1973 and 1990, the GL LULC class increased by 177.97% at a rate of 60.96 ha yr^{-1} (Table 2). This is the opposite side of a decline in CRSL in which ~1293 ha of CRSL was converted to GL (Table 3). Thus, the source of shrinkage in CRSL was probably due to its part being taken over by GL that, over time, transformed into WL, hence causing an increase in GL and WL LULC types during this time period. In contrast to this period of analysis (1973–1990), aerial coverage of the GL LULC class decreased by 38.03% and 24.05% in the second (1990–2005) and third (2005–2021) periods of analysis, respectively. The highest decline was recorded in the second period (1990–2005) of analysis, which was attributed to a conversion of 758.3 ha, 298.7 ha, 115.6 ha, and 72.9 ha of GL to CRSL, WL, BL, and FL, respectively (Table 3). Throughout the study period (1973–2021), a total of 312.6 ha (53.7%) of GL was converted to CRSL LULC types.

Similarly, in an untreated micro-watershed, the GL LULC class accounts for nearly 3.88% of the total area in 1973 and 9.67% in 1990 (Fig. 4). This showed an increment of GL which was attributed to a decline in CRSL following rural–urban migration and *Beherawi Witidrina* as mentioned by the elders. However, in the later years, it gradually declined from 7.74% in 2005 to 2.28% in 2021. The primary contraction took place from 2005 to 2021 by 70.52%, with a rate of 41.87 ha yr^{-1} (Table 2). Much of this LULC class was changed into CRSL (631.7 ha, ~67%) due to the high demand for agricultural land resulting from population pressure (Table 2). The results of GAREDEW ET AL. (2009) and YESUPH & DAGNEW (2019), found an increase in GL from 1973 to 1986 and subsequent continuous reductions were perfectly in agreement with this study. Similar findings were also reported by DEGIFE ET AL., (2019) for the period of 1972–1992 in the Lake Hawassa watershed. This LULC class decreased by 41% throughout the study period. This was in line with the results of ASMAMAW ET AL. (2011) and GEBRELIBANOS & ASSEN (2013) in the Gerado and Hirmi Watersheds of the north-eastern and northern highlands of Ethiopia, respectively.

Table 2. Absolute variation in the area (S) and change rate (K) of LULC in the treated and untreated micro-watershed in different periods; increase (+) and decrease (-)

Shankur Tareqo (Treated) micro-watershed								
LULC Classes	1973-1990		1990-2005		2005-2021		1973-2021	
	S (ha)	K (%)	S (ha)	K (%)	S (ha)	K (%)	S (ha)	K (%)
WL	240.36	34.47	311.9	33.26	-724.12	-57.95	-171.86	-24.65
GL	1036.39	177.97	-615.64	-38.03	-241.23	-24.05	179.52	30.83
FL	391.59	141.25	-343.43	-51.35	-45.13	-13.87	3.03	1.09
CRSL	-1808.54	-17.48	348.72	4.08	700.74	7.89	-759.08	-7.34
BL	147.85	35.85	299.65	53.49	307.78	35.79	755.28	183.14
Mende Tufessa (Untreated) micro-watershed								
LULC Classes	1973-1990		1990-2005		2005-2021		1973-2021	
	S (ha)	K (%)	S (ha)	K (%)	S (ha)	K (%)	S (ha)	K (%)
WL	438.51	69.85	380.72	35.71	-1135.39	-78.46	-316.16	-50.36
GL	709.94	148.99	-236.42	-19.93	-669.98	-70.52	-196.46	-41.23
FL	475.61	97.55	-321.17	-33.35	-166.29	-25.9	-11.85	-2.43
CRSL	-1911.75	-18.57	124.05	1.48	1649.1	19.38	-138.6	-1.35
BL	289.07	76.27	53.91	8.07	323.58	44.82	666.55	175.86

NB: WL=Woodland, GL=Grassland, FL=Forestland, CRSL=Cultivated and Rural Settlement land and BL=Barren land

3.3. Woodland (WL) LULC pattern from 1973–2021

The area of the WL class in the treated micro-watershed was comprised of 5.66%, 7.61%, 10.14%, and 4.26% in the years 1973, 1990, 2005, and 2021, respectively (Fig. 4). This showed a gain of WL in the first (1973–1990) and second (1990–2005) periods of analysis, but a decline in the third period of analysis (2005–2021) (Table 2). The highest (34.47%) rise of the WL LULC class was detected in the first period of analysis (1973–1990) with a rate of 14.14 ha yr^{-1} due to the conversion of CRSL (806 ha, 7.8%) to WL. Thus, the increase in WL area is presumably attributed to gains from CRSL due to the reasons mentioned below. In contrast, from 2005 to 2021, WL area coverage decreased by 57.95% at a rate of 45.26 ha yr^{-1}. However, throughout the study period (1973–2021), this LULC class exhibited a net loss of 24.65% (171.86 ha) in which the majority was transformed into CRSL (45.7%, 318.2 ha) (Table 3).

In the untreated micro-watershed, GL LULC accounted for 5.12%, 8.69%, 11.79%, and 2.54% of the total area in 1973, 1990, 2005, and 2021, respectively (Fig. 4). The WL LULC class in this watershed increased by 69.85% and 35.71% in the periods of analysis from 1973 to 1990 and from 1990 to 2005, respectively. According to KII and FGD participants, the socialist regime's policy of rehabilitating degraded land in the 1980s through exclosure of hillsides and tree-planting efforts led to an increase in the WL class in both micro-watersheds throughout the first and second periods of analysis. In contrast, it declined

by 78.46% in the third period (2005–2021) of analysis (Table 2). In the overall study period (1973–2021), WL LULC dwindled by 50.36% in the untreated micro-watershed. This loss was largely associated with its conversion to a CRSL (467 ha, 74.5%) (Table 3).

The need for more firewood due to population growth, the redistribution of land to ex-soldiers who have returned since the military regime in Ethiopia was overthrown in 1991, and the expansion of CRSL, as mentioned by KII and FGD, may all be responsible for the overall decline in WL in both micro-watersheds. This is consistent with research done in other regions of Ethiopia (YESUPH & DAGNEW, 2019). However, the overall decline in the treated micro-watershed was significantly lower, which may have been caused by the government's adoption of WMA.

Table 3. LULC conversion matrices in different periods in each watershed (area in ha)

Changed from	Changed to	Shankur Tareqo (Treated)				Mende Tufessa (Untreated)			
		1973-1990	1990-2005	2005-2021	1973-2021	1973-1990	1990-2005	2005-2021	1973-2021
		ha	ha	ha	ha	ha	ha	ha	ha
Woodland (WL)	WL	51.9	125.7	147.7	284.1	82.7	184.9	90.3	57
	GL	114.5	29.1	91.8	29.6	72.9	22.3	33.5	11.5
	FL	79.2	76.2	125.2	19.8	69.1	240.9	170.7	47.1
	CRSL	427.2	681.9	753.5	318.2	375.4	589.9	1023.1	467
	BL	23.6	23.1	127.5	44.5	27.1	27.4	127.3	44.5
	Total	696.4	936	1245.7	696.2	627.1	1065.4	1444.9	627.1
Grassland (GL)	WL	26.2	298.7	67.5	16.5	36.3	229	35	12.2
	GL	114	370.3	313.1	205.9	111.4	275.1	128.5	76
	FL	19.6	72.9	19.7	8	49.9	86.3	19.6	34.7
	CRSL	380.7	758.3	469.9	312.6	254.7	542.5	631.7	309.6
	BL	41.4	115.6	132	39	23.6	52.1	134.7	43.5
	Total	581.9	1616	1002.1	582	475.9	1185	949.5	476
Forestland (FL)	WL	23.7	149.5	58.3	10	78.1	182.2	34.5	17.2
	GL	35.9	9.8	17.9	11.8	48.3	9.3	7.9	6.6
	FL	23.9	81.6	17.6	29.9	89.4	232	136.1	52.1
	CRSL	185.1	413.3	206.5	198.4	255.4	525.9	420.1	378.7
	BL	8.2	13.1	23.8	26.7	16	12.4	43.4	32.6
	Total	276.8	667.3	324.1	276.8	487.1	961.7	642	487.2
CRSL	WL	806	622.7	196.6	202.5	841.7	786.4	126.9	214.9
	GL	1293	516.8	252	496.6	920.1	563.6	94.7	180
	FL	524.7	81	98.3	216.3	725.7	78.5	123.5	331.3
	CRSL	7240	6680	7576	8523.7	7216.9	6423.5	7569.2	8729.2
	BL	464.5	620.9	749	892.3	575.9	522.2	583.8	828.4
	Total	10329	8521	8872	10331.4	10280.3	8374.1	8498.2	10283.9
Barren land (BL)	WL	27.7	49.1	54.9	11.6	26.1	62.5	24.4	9.6
	GL	58.1	76.1	86.4	17.4	31.5	79.1	15.3	5.5
	FL	19.1	12.7	19	5.1	27	4.4	25.2	9.4
	CRSL	285.7	335.7	565.8	215.7	269.7	414.5	501.7	259.1
	BL	20.7	84.7	131.2	161.8	23.9	106	153.5	94.9
	Total	411.4	558.3	857.3	411.7	378.2	666.5	720.1	378.5

NB: CRSL=Cultivated and Rural Settlement land

3.4. Forestland (FL) LULC pattern from 1973–2021

In 1973 and 1990, around 2.25% and 5.43% of treated micro-watershed were classified as FL, respectively (Fig. 4). This indicates a 141.25% increase in FL cover class over 17 years, with a rate of 23.03 ha yr^{-1} in the first period of analysis (1973–1990), compared to a decrease in the second (1990–2005) and third (2005–2021) periods of analysis (Table 2). The increment in the first period of analysis was ascribed to the replantation programme announced and implemented by the socialist regime that preserved the remnant indigenous trees and expanded forest cover. Moreover, politically affiliated rural-urban migration, which abandoned CRSL and served to regenerate remnant trees, was also mentioned as a cause by the elders. This was similar to the result of a reported increment of forestland cover between 1970 and 1980 in the Rib watershed (MOGES & BHAT, 2017). Conversely, in the second (1990–2005) and third (2005–2021) periods of analysis, the FL class exhibited a reduction of 51.35% and 13.85%, respectively, as a consequence of its conversion to CRSL (61.9%, 413.3 ha and 63.7%, 206.5 ha) (Table 3). The increased demand for cropland and the use of trees for construction purposes were the apparent causes of reduction of the FL cover.

In the untreated micro-watershed, FL increased from 3.97% in 1973 to 7.85% by 1990. In the latter period, it gradually declined from 5.23% in 2005 to 3.88% by 2021 (Fig. 4). In the overall study period (1973–2021) of analysis, FL class in the treated micro-watershed showed an increment of 1.09% with a rate of 0.06 ha yr^{-1} while it decreased by 2.43% in the untreated one. This shows an improvement of FL LULC class in the treated micro-watershed, owing primarily to replantation activities in the Kiro specific location and the expansion of eucalyptus plantation, as revealed by KII and FGD participants. Thus, this would be a small benefit detected in the treated micro-watershed due to the introduction of WMA. Similar findings were also observed in north-eastern Ethiopia (ASMAMAW ET AL., 2011) and northern Ethiopia (GEBRELIBANOS & ASSEN, 2013).

3.5. Barren land (BL) LULC pattern from 1973–2021

In the treated micro-watershed, BL accounts for 3.35%, 4.55%, 6.98%, and 9.48% of the total area in 1973, 1990, 2005, and 2021, respectively (Fig. 4). The percentage of each increment was 35.85%, 53.49%, and 35.79% in the first (1973–1990), second (1990–2005), and third (2005–2021) periods of analysis, respectively (Table 2). This revealed a declining rate of increase in the treated micro-watershed after the implementation of WMA, which was also affirmed through FGD. It increased by 183.14% over the entire study period (1973–2021), much of which came from CRSL classes (892.3 ha, 8.6%) (Table 3).

The spatial coverage of the BL class in the untreated micro-watershed comprised of 3.09%, 5.45%, 5.88%, and 8.52% in 1973, 1990, 2005, and 2021 respectively (Fig. 4). The rate of increment of the BL LULC class in the first (1973–1990) and third (2005–2021) periods of analysis was higher for the untreated compared to the treated micro-watershed (Table 2). However, in the overall period (1973–2021) of analysis, the rate of BL increment was higher for the treated micro-watershed. As shown in (Table 3), the treated micro-watershed still had the highest conversion rate of CRSL to BL (8.6%), compared to 8.06% in the untreated one. This confirms that, in the treated micro-watersheds, further efforts will be needed to rehabilitate the degraded land through soil and water conservation activities. According to the discussion with the KII, this was one of the factors that led to the selection of the treated micro- watershed for rehabilitation activities.

3.6. Major drivers of LULC change

3.6.1. Expansion of cultivated and rural settlement land

Except for the first period of analysis (1973–1990), the CRSL class was shown to have significant expansion at the expense of WL, GL, and FL in both watersheds. In the first period of analysis (1973–1990), CRSL classes surprisingly declined in both micro-watersheds from where they were in 1973. This finding sharply contrasts with that of REID ET AL. (2000), who reported a significant decrease in cultivated land in Gullele (27%), in Gerangera (50%) and in Kumbi (67%) between 1973 and 1987 in the Gibe valley (south western Ethiopia). BEWKET & STERK (2002) also reported a shrinking of farmland by 2% between 1982 and 1998 in the Chemoga Watershed, Ethiopia. According to KII and FGD participants, the socialist regime's shift of land ownership from landlord to peasant association (which prevented some farmers from cultivating land previously owned by the landlord due to widespread fear), *Beherawi Witidrina*, and rural-urban migration were mentioned as reasons for change.

In the second (1990–2005) and third (2005–2021) periods of analysis, the CRSL LULC class increased at the expense of other LULC classes

due to a high demand for cereal crops resulting from population pressure within both micro-watersheds (Table 3). This increment in CRSL was similar to the findings of SHIFERAW ET AL. (2001) and TEFERA (2011), who reported an increment of cropland in Borena Woreda (South Wollo) and Nono Woreda (Central Ethiopia) due to rapid population growth. However, the lower rate of increment in CRSL class was recorded for the treated micro-watershed for the third period (2005–2021) of analysis (Table 2). This was due to the introduction of WMA. Besides, as per the information gained from KII and FGD participants, the low-rate of increment of CRSL in the treated micro-watershed was due to a lack of additional farmland, rural-urban migration of the young working age group, and resettlement programmes undertaken by Oromia regional state in 2005. Therefore, CRSL change caused LULC change in the studied micro-watersheds.

3.6.2. Demographic related factors

Demographic factors are one of the underlying causes that brought LULC change in different parts of the country (ABERA ET AL., 2018; GEBRELIBANOS & ASSEN, 2013), which is implicated in the study area also. According to the CSA's population census and projection (CENTRAL STATISTICAL AGENCY, 2007, 2013, 2021), the rural population of the district increased rapidly from a total of 44,382 in 1994 to 82,737 in 2021. This showed an increase in the rural population of more than 86.6% between 1994 and 2021. To some extent, an increase in the human population in the Highlands has also caused an increase in the population of livestock (DUBALE, 2001). Such rapid population growth, combined with an increase in the livestock population in the area, has put pressure on the area's limited land resources by increasing demand for food, fuel, construction materials, grazing land, and permanent settlement land. These issues were also confirmed through KII and FGD participants as well as the quantitative data presented in Fig. 3, suggesting a positive relationship between population growth and expansion of the cultivation land at the expense of other land use types. This was in line with a finding by ZELEKE & HURNI (2001), who reported a decline in forest cover in central Gojjam from 27% to 0.3% between 1957 and 1995 due to population pressure. Forest cover declined from 34% to 3% in the country between 1950 and 1980 due to population pressure-induced factors (ASSEN & NIGUSSIE, 2009). Moreover, GAREDEW ET AL. (2009) reported that population-induced lack of livelihood security had forced farmers to use the woodlands to cope with recurrent household shocks in the Central highlands of Ethiopia, which further modified the LULC of the area. Therefore, it can be concluded that population growth has driven the expansion of CRSL in the studied watersheds at the expense of other LULC classes, which have ended up being degraded, as observed in other parts of the country.

3.6.3. Policy changes related factor

A change in policy is a perceptible departure from the intended path of action that had been put in place to solve a perceived societal issue (MICHAELS ET AL., 2006). Policy change follows a predetermined process that involves problem identification, adoption of a specific policy, implementation of the policy, and evaluation of the policy (MICHAELS ET AL., 2006). The last step is crucial in identifying the effect of the policy on the environment. In line with this, long-term residents of the area were requested to explain the policy-related factors responsible for the change in LULC. Accordingly, the informants cited the policy changes of 1974 and 1991 as the main drivers of LULC transformation in the study area. In accordance with the well-known motto "Land to the Tiller," which was elicited by KII and FGD participants, the first policy change nationalized the land and the natural resources on it, resulting in FL and WL being owned by the government. The second policy change resulted in the extensive destruction of vegetated areas as portions of formerly government-owned tracts of land were given to private investors and distributed among smallholder farmers. In order to bring about LULC change in the watersheds under research, the second policy modification has the biggest influence.

According to KII and FGD, much of the expansion of CRSL, BL, and loss of FL LULC classes were found after the downfall of the socialist regime. Before the downfall, the number of people residing in the watershed was low due to rural–urban migration and *Beherawi Witidrina*, which created surplus land. Moreover, they also stated that the socialist government planted trees in a mountainous area that extended from the hilly areas of Shankur and Mende kebeles[2] to Dilella towns on the land taken from the previous landlord. This was partly responsible for the slight increase in GL, WL, and FL in the first period of analysis (1973–1990).

[2] It is the lowest administrative unit in Ethiopia

The Ethiopian People's Revolutionary Democratic Front government that succeeded the socialist regime in 1991 subsequently advocated state ownership of land whereby only usufruct rights are bestowed upon landholders. According to FGD participants, this policy shift encourages the private sector and individual farmers to engage in free and uncontrolled exploitation of FL in order to have more cultivated land, particularly by clearing previously planted trees. It can, therefore, be concluded that government policy has played a significant role in LULC change in the study area. The results from ABERA ET AL. (2018), ASMAMAW ET AL. (2011), and GEBRELIBANOS & ASSEN (2013) in the Wanka, Gerado, and Hirmi Watersheds of the northwest, north-eastern, and northern highlands of Ethiopia, respectively, were similar to these.

4. Conclusions

Based on mosaicked aerial photos and Landsat images, LULC changes were calculated for the treated and untreated micro-watersheds of the central highlands of Ethiopia using in-depth analysis. The result indicated that CRSL in both watersheds declined between 1973 and 1990, and they experienced upsurges later. From 1973 to 1990, WL, GL, and FL grew in both watersheds, whereas CRSL decreased. Due to the growth of BL in the chosen micro-watersheds, FL, WL, and GL decreased in the following years. These LULC types declined at a slower rate in the treated micro-watershed. This lower rate of decline was attributed to the WMA performed there. However, significant variation between the two micro-watersheds was not observed. Thus, this implicates the ineffectiveness of the WMA. Because of this, as the land loses its protective natural cover as a result of the growth of agricultural land, population pressure, and other government policy-induced causes, the examined watersheds become more and more vulnerable to land degradation. Thus, the patterns of LULC changes in the examined micro-watersheds have nevertheless been greatly influenced by an interaction of physical, socio-economic, and policy issues. In order to identify observed impediments, previously deployed WMA should be reviewed. Furthermore, the chosen micro-watersheds should adopt a suitable additional watershed management plan based on the knowledge gained from the prior WMA. Reforestation of the watershed's degraded areas, protection and enhancement of the current FL cover, and other successful soil and water conservation techniques should be included in this effort to prevent additional land degradation.

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