Spatio-temporal land use/cover dynamics and its implication for sustainable land use in Wanka Watershed, Northwestern highlands of Ethiopia

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Abstract

Land use and land cover (LULC) change has become a key research priority for years. Understanding long-term trends of environmental changes is essential for making suitable interventions for land use planning and natural resources management, such as in the Ethiopian highlands. This study focuses on the analysis of six decades of LULC dynamics in the Wanka watershed of the Northwestern highlands in Ethiopia. Two sets of aerial photographs (1957 and 2017), SPOT 5 and sentinel satellite imageries were analyzed. In addition, data from key informant interviews, focus group discussions and field observations were used to identify the drivers and impact of LULC change. It was found that cultivated and rural settlement land (CRSL), bare land, and urban built up area have been continuously expanded at the expenses of mainly forest and shrub lands. Over the entire study period (1957-2017) while the bare land and CRSL have increased by about 59% and 20 % respectively, forest and shrub lands have declined by 59% and 57% respectively. Urban built up area has also expanded. On the other hand, the impact of population pressure and expansion of CRSL land were considerable. The trend of LULC dynamics in the study watershed implies adverse impact on the quality and quantity of the land resource. Hence, we recommend that appropriate land use planning and strategies that reduce expansion of cultivated land need to be practiced.

Key words: sustainable land use; cultivated land; trends; land use; land cover

Introduction

Land use and land cover (LULC) change has become a key research priority for years. Understanding long-term trends of environmental changes is essential for making suitable interventions for land use planning and natural resources management (Lambin et al. 2001; Turner et al. 2007). LULC dynamics is one of the foremost causes of land degradation, including deforestation and forest degradation, deterioration of soil and water quality, decline in natural resources base, and ultimately the disruption of Earth's ecosystem services (Rindfuss et al. 2004; Lambin et al. 2001). In many parts of the world, Earth's basic attributes and processes like land productivity, diversity of flora and fauna as well as biochemical cycles have been changing as a result of natural and human land use/cover dynamics (Nanda et al. 2014). Particularly, the contribution of human induced factors in LULC dynamics and impacts at a local scale is significant (Gebrelibanos and Assen 2013). For example, haphazard expansion of farm lands at the expenses of natural LULC categories e.g. forest land aggravates the loss of biodiversity (Lepers et al. 2005).

LULC change results from a complex interaction of socioeconomic, demographic, ecological and geophysical processes (Wu et al. 2008). Studies conducted in Ethiopia on LULC dynamics have also revealed a number of factors for such changes. For example, Agidew and Singh (2017) reported population pressure being a key issue in accentuating expansion of cultivated and rural settlement land (CRSL) and causing land degradation and food insecurity in the country's Northeastern highlands. According to Pellikka et al. (2004), population pressure has provoked destruction of natural forest land, and resulted in biodiversity loss and land degradation in east African highlands. On the other hand, Hassen and Assen (2017) concluded that socio economic factors (e.g. civil war, frequent changes in political system and hence land reform) were the key drivers for conversion of forest and grass lands to human induced land use pattern in the Northwestern Ethiopian highlands. This was explained in relation to absence of required agricultural technologies to increase production, which resulted in expansion of more uncultivated land to agriculture.

These studies have also shown discrepancies in patterns and magnitude of LULC dynamics at different scales. For example, while some studies revealed expansion of cultivated land at the expense of other natural land use/cover types (Agidew and Singh 2017; Wubie 2016; Worku et al.2016; Efrem 2010; Zeleke and Hurni 2001), others have reported that cultivated lands more or less remained unchanged (Yeshaneh et al. 2013; Woldeamlak 2003; Kebrom and Hedlund 2000). On the other hand, Amsalu et al. (2007) reported expansion of grazing land and bare land in central Ethiopian highlands.

LULC dynamics has been rapidly on the rise in the Ethiopian highlands, such as in the upstream part of the Blue Nile (Abay) basin where the case study Wanka watershed is located. The livelihood of the population largely depends on exploitation of natural resources and subsistence farming (Abegaz et al. 2016; Awlachew et al. 2008). This has an adverse impact on the quality of the environment, such as leading to agricultural land degradation (Lambin et al. 2001). This part of the country is characterized by loss of natural resources, agricultural land degradation and low agricultural productivity (Hurni et al. 2010). In this context, this paper focuses on assessment of the magnitude and direction of LULC dynamics over time and its implication on land resources at watershed scale (Yeshaneh et al. 2013; Asmamaw et al. 2011; Lambin et al. 2003). The main objective of this study was to examine long term spatio-temporal LULC dynamics and its implication on sustainable land use, identify the main causes and to recommend the necessary interventions in Wanka watershed, Northwestern Ethiopia. For the purpose, we carried out site-specific trend analysis of long-term LULC change, using remote sensing data (aerial photographs, Spot-5 and sentinel 2 satellite images) of the watershed area.

Materials and methods

The study site

Wanka watershed lies between $11^{0}29'$ 24'' and $11^{0}42'$ 36'' North latitude, and $37^{0}58'$ 12'' and $38^{0}14'24''$ East longitude (Fig. 1). It is one of the head streams of the Blue Nile (Abay) basin and covers a total area of 252 km^2. In administrative terms, it is located in East Estie district, Amhara National Regional State. The watershed is a part of the extensive Afro-Arabian plateau which is characterized by uplifting of landmasses and out-pouring of lava (Mohr 1971). Like that of the other headstreams of Blue Nile (named as Abay River in Ethiopia) basin, it is characterized by diverse topographic features. The elevation ranges from an altitude of 2,238 meter to 4,086 meter above sea level (m a.s.l) and it experiences subtropical to Alpine climatic conditions. Based on Ethiopian agro ecological zonation system (Hurni 1998), Wanka watershed encompasses *weyna dega* (mid altitude, 1500– 2300 m a.s.l), *dega* (high-altitude, 2300–3200 m a.s.l), *wurch* (alpine 3200-3700 m a.s.l.) and *high wurch* (afro-alpine >3700 m a.s.l). These agro-climatic zones account 0.5%, 88.8%, 8% and 2.7% of the study watershed respectively.

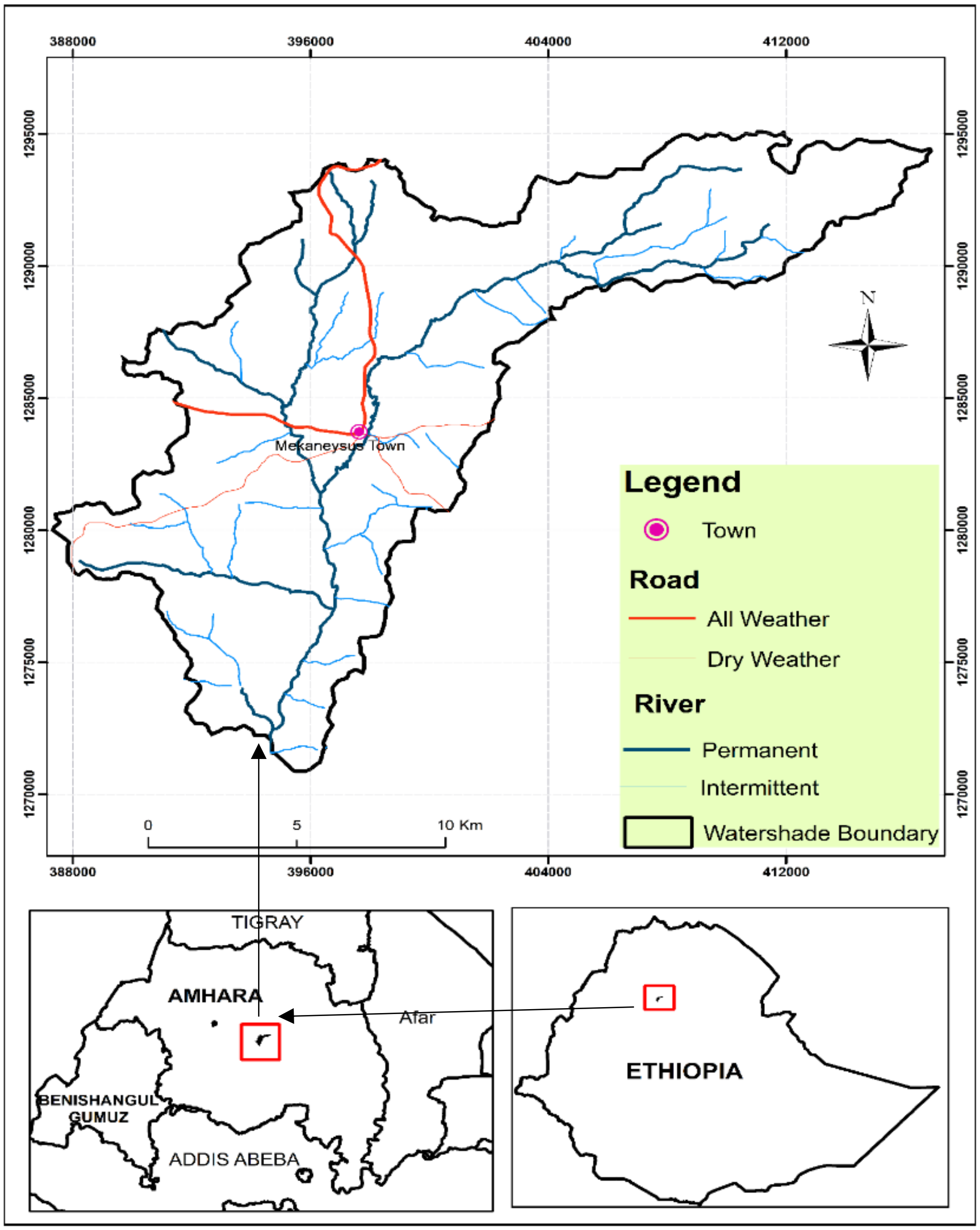


Fig. 1 Location map of Wanka watershed, Northwestern Ethiopian highlands

The mean annual temperature of Wanka watershed is 17.3°C. The mean annual minimum and maximum monthly temperatures respectively are 8.4 °C and 26°C (Fig.2). The annual rainfall recorded in the watershed for the years between 1994 through 2015 is 1320 mm. The rainfall pattern is unimodal with one major (summer) rainy season which extends from June to August, and sometimes it extends up to September. About 80% of the total annual rain falls in June through August with peaking in July (369.4mm) (NMSAE 2015) (Fig.2).

The dominant soil units of the watershed are Chromic Luvisols (41.1%), Eutric Leptosols (34.12%) and Haplic Luvisols (24.84%) (FAO 1990). The natural vegetation cover of the watershed includes grass, bushes, natural as well as plantation trees (*Eucaluptus globulus* and *Cupressus lusitanica*). The main natural tree species were *weyra* (*Olea africana*) and *yabesha girar (Acacia abyssinica*) in lower elevation (2238-2400 m a.s.l), *yabesha tid (Juniperus procera*) in the middle elevation (2401-2700 m a.s.l) and *koso (Hagenia abyssinica*) in upper elevation (>2700 m a.s.l). The livelihood of the population is mainly dependent on a rain-fed subsistence mixed-farming system. *Teff* (*Eragrostis* abyssinica), barley (*Hordeum vulgare*), wheat (*Tiriticum vulgare*), bean (*Phaseolus vulgaris*), peas (*Pisum sativum*), chick peas (*Cicer arietinum*), potato (*solanum tubersoum*) and oil seed crops were dominant crops grown in the watershed.

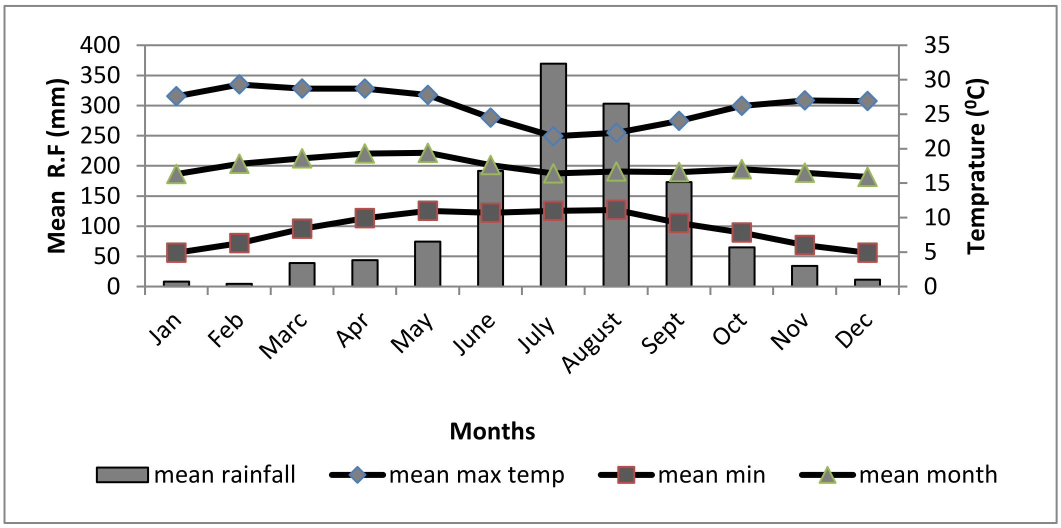


Fig. 2 Rainfall and temperature distribution of Wanka watershed, northwestern Ethiopian highland (1994-2015) (NMSAE 2015).

Data sources and analysis

The required data was gathered from interpretation of Remote Sensing Data and qualitative information was collected through focus group discussions (FGD), key informants interview (KII) and field observations.

Twenty-seven black and white hardcopy aerial photographs (thirteen for 1957 and fourteen for 1980) and 5-meter resolution SPOT-5 satellite image of 2007 were obtained from the Ethiopian Mapping Agency (EMA). In addition, 10 meter spatial resolution sentinel 2 satellite image of 2017, downloaded from ESA's Sentinel Mission (https://scihub.copernicus.eu/dhus), were used to generate geospatial data of the study area.

Aerial photographs of each year (1957 and 1980) were scanned with photogrammetric scanner at 1200 dots per inch (DPI), transformed to digital image and saved in a tagged image file (TIF) format. Aerial photographs were georeferenced based on UTM (Universal Transverse Mercator) projection system using 1:50,000 topographic map as base map, orthorectified and mosaicked. Clearly observed ground control points on the topographic map sheet for each photograph were used as control point for geo-referencing. Similarly, satellite images (sentinel 2 and SPOT 5) were georeferenced based on the same projection system and topographic map used for the aerial photographs. Then, the area of interest was clipped using the boundary of the watershed on the georeferenced aerial photographs (1957 and 1980) and the satellite images. LULC classes on aerial photographs were visually identified and classified based on tone, texture, pattern of features with mirror stereoscope. Screen digitization was performed with ArcGIS software. Rural settlement and cultivated land LULC classes were grouped under the same category, as it is difficult to differentiate them at 1:50,000 scale aerial photographs.

Supervised classification was employed to classify LULC on satellite images (SPOT 5 and sentinel images) and generate discrete LULC types. Training areas for each LULC class were identified and taken by GPS receiver from the different LULC types in field survey. As LULC classes produced from multispectral satellite images (SPOT 5 and sentinel 2) need to be synchronized with the aerial photographs (Wubie et al. 2016), preliminary classification was carefully adjusted to fit the major LULC categories identified in the aerial photographs. As a result, seven major LULC types (Table 1) were produced, finally.

Extent and rate and of LULC change

Four-time series (1957, 1980, 2006 and 2017) LULC maps at a scale of 1: 50,000 were produced (Figures 4 a, b, c and d) and temporal changes in LULC were determined. Change detection or transformation matrices for 3 periods (1957-1980, 1980-2006 and 2006-2017) were performed for the case study watershed. Post-classification comparison of change detection was carried out, as this approach is common to compare maps of different sources and provides detailed "from-to" change class (Teferi et al.2013). The rates of change of LULC classes (%) were calculated using the following formula:

$$\mathbf{R\Delta}\ (\%) = \frac{\boldsymbol{At2-At1}}{\boldsymbol{At1}}\mathbf{x100}$$

Where RΔ is the change of one type of LULC (in percent) between initial time (At1) and the subsequent period (At_2). At_1 is the area (ha) of one type of LULC in t1 period and At_2 is the same LULC with t_1 type in the subsequent period.

Table 1 Description of the major LULC types of Wanka watershed

Land use/cover type	Description
Shrub land	Land area covered by sparsely grown short thorny trees and bushes
Grassland	Areas covered with grasses and herbaceous vegetation
Cultivated and rural settlement	Areas used for farming and rural settlement
Forestland	Areas occupied by trees that formed nearly closed canopies and have thick under growth with an area of greater or equal to 0.5 ha. In some enhanced plantations mixed with 'indigenous' species of trees, such as *Juniperus procera* and *Olea Africana* are main tree types that were grouped under this category.
Bare land	Areas which have no or very little vegetation cover and mainly found on eroded steep mountain slopes and mostly have rock surface
Urban built up	Areas occupied by urban settlement.
Water pond	Small artificial reservoirs produced by construction of small dam

Moreover, as mentioned earlier, focus group discussion (FGD), key informant interviews and field observation were carried out to obtain additional information to triangulate image analysis and identify major drivers of LULC. Five community elders (60-81years old) who grew up in the study area and were believed to have enough knowledge about the LULC change (as they were engaged in farming practices for long time in the area) were interviewed. In addition, one FGD was conducted with six discussants who were between 35 and 65 years old.

Results and Discussion

Land use/cover dynamics

Cultivated and rural settlement land

The analysis of LULC for the study watershed revealed that CRSL was predominant and showed slight continuous increment over the studied period (1957-2017) (Table 2; Figs. 3 a, b, c, and d; Fig. 4). However, compared with the 3 periods, the rate of dynamics of CRSL was more substantial in the first period (1957-1980). It increased by about 17% (2649 ha) at the expenses of mainly shrub and grass lands. The change detection matrix revealed that in this period (1957-1980), about 55.7% (2578 ha) of shrub land, 43.8% (1358ha) of grass land, 38.2% (552 ha) of forest land, 63.9% (315 ha) of bare land and 1.4% (0.33 ha) of urban built up land areas were converted to CRSL (Table 3). Conversely, about 14% (2154 ha) of CRSL was converted to other LULC types in the same period (1957-1980). However, compared to the first period (1957-1980), the rate of change of CRSL in the second (1980-2006) (0.84%) and third (2006-2017) (2%) periods were low (Table 2). This was due to limited availability of suitable land that could be converted to CRSL since 1980. In some regions of Ethiopia, any further expansion of cultivated land has been reduced since 1980 due to lack of suitable land that would be converted to farm land (Assefa and Bork 2014; Zeleke and Hurni 2001). Thus, it seems that expansion of farmland would not be an option for increasing crop production under the present conditions. As a result, increasing crop production in meeting food security of the country needs consideration of alternative approaches, such as farm intensification and use of modern agricultural technologies and inputs. Generally, the gain and loss of CRSL was about 38% (5938 ha) and 19% (2877 ha) respectively throughout the studied period (Fig. 5).

Grass land

Grass land occupied about 12% (3097 ha in 1957), 9% (2282 ha in 1980), 11.8%% (2961 ha in 2007) and 11 % (2799 ha in 2017) of the studied watershed (Table 2). However, its coverage decreased by 26% (815 ha) and 5.5% (162 ha) in the first (1957-1980) and third (2006-2017) periods respectively. This was associated with a conversion of grass land to CRSL. As shown in Table 3 and 5, about 43.8% (1358 ha) and 31.6% (936 ha) of grass land was converted to CRSL in the first and second periods of the study respectively. Conversely, it increased by about 29.8 % (679 ha) in the second period (1980-2006) and this was associated with conversion of mainly shrub land 15% (507 ha) to grass land (Table 4). Relatively grass land coverage expansion was found at upper part of the watershed probably due to restriction of CRSL expansion as a result of cold temperature (Figs. 3 a, b, c, and d). Generally, over the studied period (1957-2017), the loss of grass land by about 67% (2017 ha) exceeded its gain of 57% (1775 ha) in the study area (Fig. 5).

Shrinking of grass land has implication for livestock production. Our key informant interviews indicated that the study watershed had huge size of livestock before some years but now farmers have been forced to reduce their livestock due to shortage of grass land. This ultimately has its negative repercussion on soil fertility as organic fertilizers availability (dung and compost) would be reduced (Worku et al. 2016). There is also a loss of additional income source which could be obtained from the sale of animals and animal products.

Table 2 LULC status and trend of dynamics in Wanka watershed, northwestern Ethiopia in 1957, 1980, 2006 and 2017

	LULC status								Trend of change					
LULC classes	1957 Area (ha)	%	1980 Area (ha)	%	2006 Area (ha)	%	2017 Area (ha)	%	1957-1980 ha	1957-1980 %	1980-2006 ha	1980-2006 %	2006-2017 ha	2006-2017 %
CRSL	15474	61.5	18123	72	18276	72.6	18610	74	+2649	+17.1	+153	+0.84	+334	+1.8
Grassland	3097	12.3	2282	9.1	2961	11.8	2799	11.1	-815	-26.3	+679	+29.8	-162	-5.5
Shrubland	4630	18.4	3382	13.4	2355	9.4	1995	8	-1248	-27	-1027	-30.4	-360	-15.3
Forestland	1446	5.8	774	3.1	645	2.6	590	2.3	-672	-46.5	-129	-16.7	-55	-8.5
Bare land	493	2	545	2.2	676	2.7	759	3	+52	+10.6	+131	+24	+83	+12.3
Urban built up	23	0.09	56	0.22	230	0.91	399	1.6	+33	+143.5	+174	+310.7	+169	+73.5
Pond	0	0	0	0	20	0.08	11	0.04	_	_	_	_	-9	-45
Total	25163	100	25162	100	25163	100	25163	100						

CRSL=cultivated and rural settlement land; ha= hectare; LULC=land use and land cover

Shrub Land

Shrub land was the second dominant LULC class in 1957 and 1980 next to CRSL, and the third dominant LULC type in 2006 and 2017, following CRSL and grass land (Table 2; Fig. 4). However, it showed a declining trend at a rate of 0.95% (44 ha) per annum throughout the period under study (1957-2017). It decreased by 27% (1248 ha) in the first, 30.4% (1027 ha) in the second and 15 % (360 ha) in the third study periods (Table 2). This declining trend was primarily attributed to conversion of shrub land to CRSL. The change detection matrix disclosed that shrub land lost about 55.7% (2578 ha), 50% (1690 ha) and 37.4% (880 ha) (Table 3, 4 and 5) to CRSL in the first, second and third periods respectively. This implies that the primary factor for the decline of shrub lands in the study watershed is expansion of CRSL.

Table 3 Change detection matrix of LULC classes between 1957 and1980 in Wanka watershed northwestern Ethiopian highlands

LULC classes		Changed from LULC class in 1957											
		CRSL (ha)	%	GL (ha)	%	SHL (ha)	%	FL (ha)	%	BL (ha)	%	UBU (ha)	%
Changed to LULC class in 1980	CRSL	13320	86	1358	43.8	2578	55.7	552	38.2	315	63.9	0.33	1.4
	GL	596	3.9	1295	41.8	282	6	64	4.4	45	9.1	0	0
	SHL	1019	6.6	365	11.8	1600	34.6	327	22.6	71	14.4	0	0
	FL	185	1.2	14	0.5	86	1.9	468	32.4	20	4.1	0.43	2
	BL	321	2.1	65	2.1	84	1.8	34	2.4	42	8.5	0	0
	UBU	33	0.2	0	0	0	0	0.95	0.07	0	0	22	96
	Total	15474	100	3097	100	4630	100	1446	100	493	100	23	100

LULC=land use and land cover; CRSL=cultivated and rural settlement land; GL=grass land; SHL=shrub land; FL=forest land; BL=bare land; URB=urban built up; ha=hectare

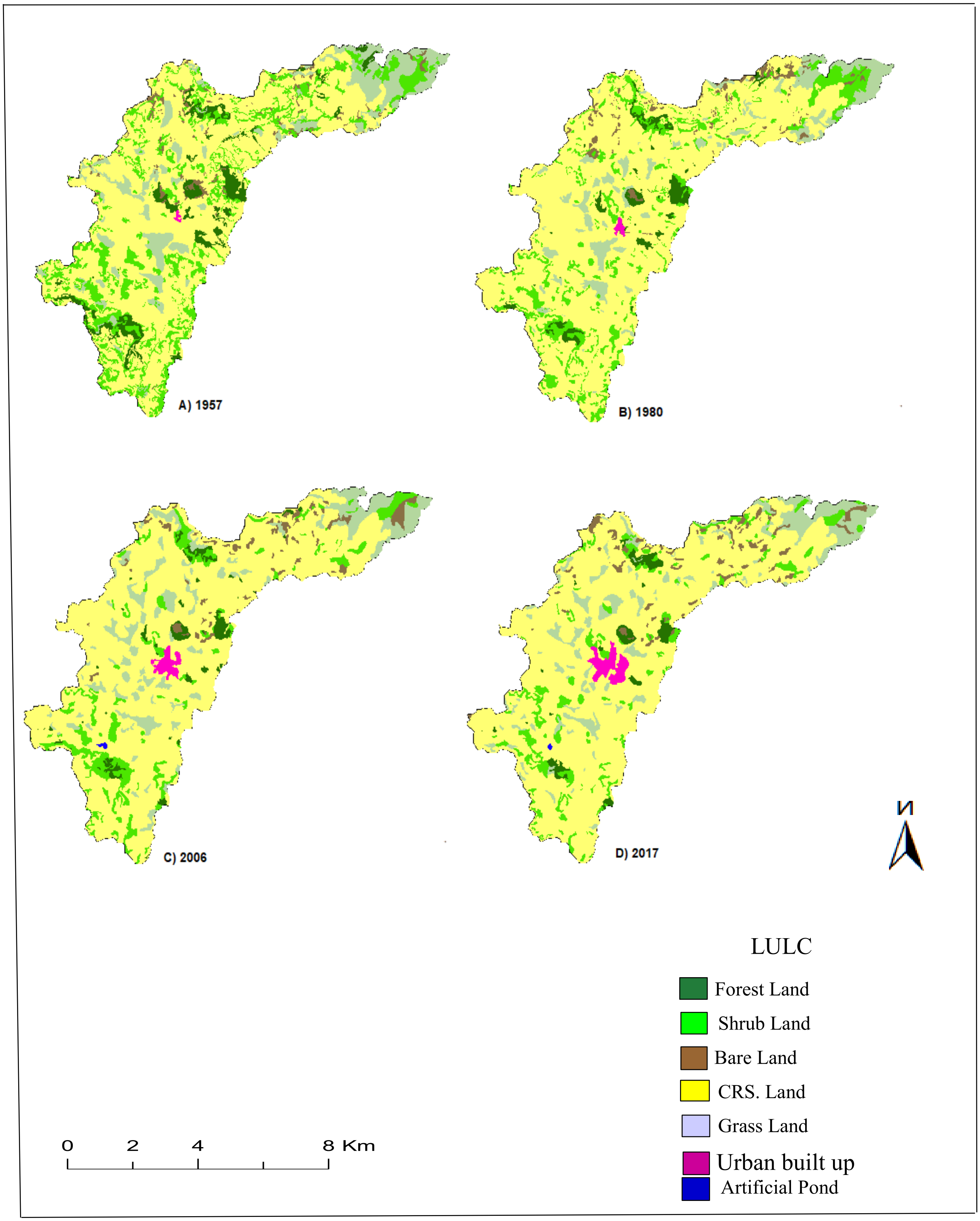
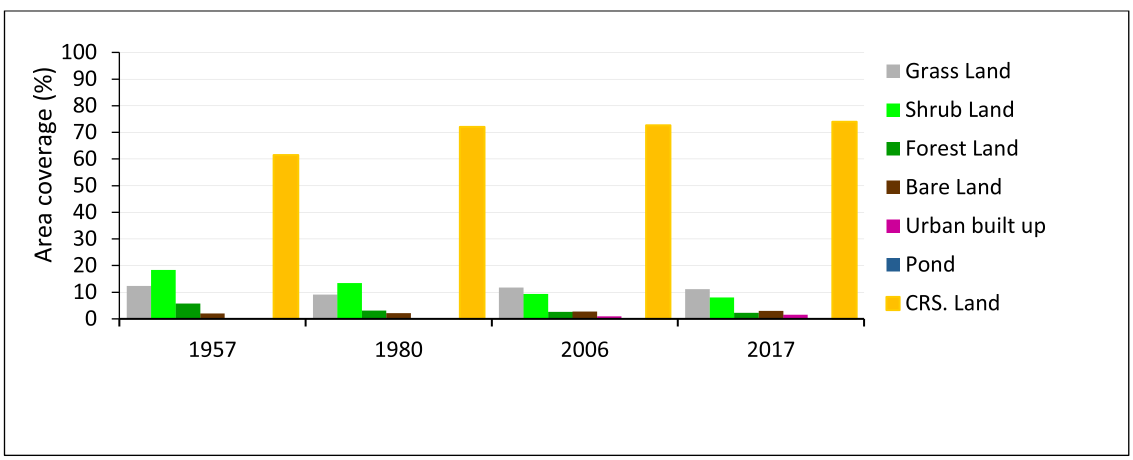


Fig. 3 Land use/cover maps of Wanka watershed for 1957,1980, 2006 and 2017

Forest land

In the case study watershed, forest land coverage showed a continuous declining rate at an annual average rate of about 1% (14 ha) over the analysis period (1957-2017). It accounted for 5.8% (1,446 ha) area of the watershed in 1957, but this declined to 774 (3%) in 1980, 654 (2.6%) in 2006 and 590 ha (2%) in 2017 (Table 2). The change detection matrix revealed that transformation of forest land to other LULC categories exceeded its gain throughout the study period (Table 3, 4, 5). However, this was highly pronounced in the first period (1957-1980). Though forest land gained about 305 ha, it lost roughly 3 times of its gain (978 ha) in the period of 1957-1980. In this period, about 38% (552 ha), 22.6% (327 ha), 4.4% (64 ha) and 2.4% (34 ha) of the forest land was converted to CRSL, shrub, grazing and bare lands respectively. The most likely reason for the reduction of significant area of forest land in this period could be the change of government in 1974/75. In many parts of Ethiopia there was destruction of forest during this transition period due to weak government control (Assefa and Bork 2016; Amsalu 2007). Similarly, 27.6% (214 ha) and 18.8% (121 ha) of forest land was converted to CRSL in the second and third periods respectively (Table 4 and 5).



CRS=Cultivated and Rural Settlement

Fig. 4 LULC classes area coverage in the study period (1957-2017)

Table 4 Change detection matrix of LULC classes between 1980 and 2006 in Wanka watershed northwestern Ethiopian highlands

LULC classes		Changed from LULC class in 1980											
		CRSL (ha)	%	GL (ha)	%	SHL (ha)	%	FL (ha)	%	BL (ha)	%	UBU (ha)	%
Changed to LULC class in 2006	CRSL	15090	83.3	880	38.6	1690	50	214	27.6	347	63.7	2	3.6
	GL	1312	7.2	1087	47.6	507	15	10	1.3	47	8.6	0	0
	SHL	970	5.4	211	9	944	28	193	25	36	6.6	1	1.8
	FL	181	1	9	0.4	109	3.2	321	41.5	25	4.6	0	0
	BL	354	2	93	4.1	120	3.5	23	3	85	15.6	0	0
	UBU	196	1.1	2	0.1	12	0.4	13	1.7	5	0.9	53	95
	PN	20	0.1	0	0	0	0	0	0	0	0	0	0
	Total	18123	100	2282	100	3382	100	774	100	545	100	56	100

Bare land

Bare land expanded continuously from 1957 to 2017 and it covered 2%, 2.2%, 2.7% and 3% area of the Wanka watershed respectively in 1957, 1980, 2006 and 2017 (Table 2). Various LULC classes transformed to bare land throughout the study period (1957-2017). The transformation of CRSL to bare land accounted the largest share over the studied periods. In the first, second and third study periods about 321 ha (2.1%), 354 ha (2 %) and 347 ha (1.9%) area of CRSL respectively were transformed to bare land (Table 3, 4 and 5). This is due to land degradation. Bare land expansion was highly pronounced in the upper part of the watershed (Fig. 3 b, c and d). This may be due to severe soil erosion that resulted from topographic nature of the area and intensive cultivation with poor land management (see also, Maitima et al. 2009).

Urban built up and small artificial pond

Mekaneyesus town, which is situated at the heartland of the watershed, has been expanding throughout the study period. It covered a very small portion i.e. 23 ha (0.09%) of the watershed in 1957 but expanded significantly after this period at the expenses of mainly CRSL and forest land. It increased by 143.5%, 310.7% and 73.5% in the first, second and third periods respectively (Table 2). In the first period it gained 33 ha (0.2%) and 0.95 ha (0.07%) area from CRSL and forest land respectively but lost a total area of 0.76 ha (3.4%). Similarly, in the second period, it gained about

196 ha (1.1%) and 13 ha (1.7%) respectively from CRSL and forest land. In the third period about 211 ha (1.2%) and 5 ha (0.8%) area of CRSL and forest land respectively transformed to urban built up area (Table 3,4 and 5). This implies reduction of agricultural land and crop production, and shrinkage of forest resources. Similarly, drastic expansion of urban built-up area at the expense of cultivated land was also reported in the northeastern and northern Ethiopia (Kebrom and Hedlund 2000; Gebrelibanos and Assen 2013).

The area of the artificial small pond in 2006 shared about 20 ha (0.08%) of the area of the study watershed and its size was reduced to 11 ha (0.04%) in 2017 (Table 2). This is perhaps due to siltation by sediments that eroded from the surrounding upland areas. This has an implication that soil erosion which accentuated by poor land management is a major threat to sustainable land management in the Wanka watershed. The other possible reason could be reduction of water that drained to the pond from the stream (Gomit stream) on which the pond was constructed. As reported by our key informants the volume of water in the local streams/rivers of the study area (Gomit, Chena and Wanka) has been reduced from time to time.

Table 5 Change detection matrix of LULC classes between 2006 and 2017 in Wanka watershed, northwestern Ethiopian highlands

LULC classes		Changed from LULC class in 2006													
		CRSL (ha)	%	GL (ha)	%	SHL (ha)	%	FL (ha)	%	BL (ha)	%	UBU (ha)	%	PN (ha)	%
Changed to LULC class in 2017	CRSL	16370	89.6	936	31.6	880	37.4	121	18.8	235	34.8	33	14.3	12	60
	GL	648	3.5	1756	59.3	269	11.4	16	2.5	110	16.3	0	0	0	0
	SHL	621	3.4	195	6.6	1026	43.6	133	20.6	16	2.4	2	0.9	0	0
	FL	75	0.4	13	0.4	127	5.4	355	55	21	3	0	0	0	0
	BL	347	1.9	59	2	43	1.8	15	2.3	294	43.5	0	0	0	0
	UBU	211	1.2	2	0.07	10	0.4	5	0.8	0	0	195	84.8	0	0
	PN	4	0.02	0	0	0	0	0	0	0	0	0	0	8	40
	Total	18276	100	2961	100	2355	100	645	100	676	100	230	100	20	100

Causes of LULC dynamics in Wanka Watershed

Population growth

As discussed earlier, demographic pressure has been highlighted as one of the underlying causes of LULC dynamics (Lambin 2003). In the Ethiopian highlands it forms one of the main causes of LULC dynamics and deforestation (Hassen and Assen 2017; Gebrelibanos and Assen 2013; Bewket and Abebe 2013; Asmamaw et al. 2011). The available population data of the study area showed an increasing trend of population. According to the three consecutive periods (1984, 1994 and 2007) census data of the Central Statistical Agency of Ethiopia (CSA), the population of the study area has increased by 26.4% (between 1984 and 1994) and 6.3% (between 1994 and 2007). The population density (167 persons/km^2) is also considerably higher than the Amhara National Regional State density (122.3 persons/km^2) (ANRBoFED 2012). According to our FGD discussants, population growth resulted in expansion of CRSL and reduction of forest and shrub lands in search of cultivable land and materials (e.g. fuel wood, constructional materials, etc.) and shortening or total abandoning of fallowing practices in the study watershed. As reported by key informants (community elders) before three to four decades, the population size was low and hence there was no shortage of cultivable and grazing lands.

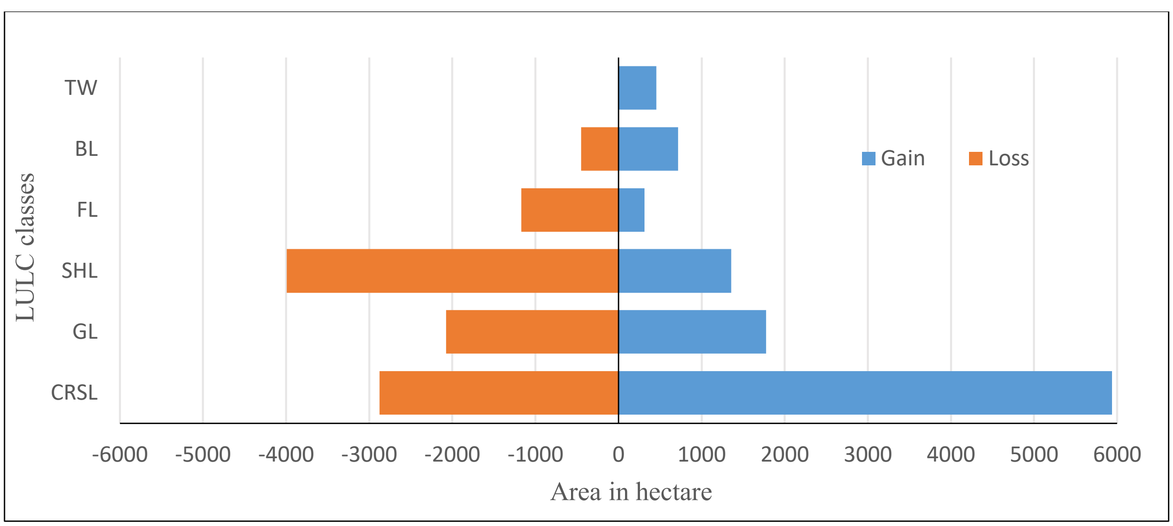
Land expansion for agriculture and rural settlements

Our study of the LULC dynamics in the Wanka watershed disclosed the presence of significant expansion of CRSL at the expenses of other LULC types (mainly forest, shrub and grass lands) throughout the study period (1957-2017). For example, the change detection matrix revealed that over the study period (1957-2017), CRSL lost only 2877 ha (18.6%) of land to other LULC classes, but it gained more than two times of its loss i.e. 5938 ha (38.4%) (Fig. 5). The information obtained from key informants and FGD discussants also corroborated that CRSL has expanded towards other LULC types as crop cultivation was the major livelihood of the rural population.

As a consequence, farmers were forced to convert grazing, forest and shrub land to cultivated land to increase agricultural production to feed their increasing family size. However, further expansion of agricultural land may not be possible as there is no suitable land that could be converted to cultivated land. As reported by key informants and FGD discussants, there was not enough land to be distributed to landless youth. Also, there was no off-farm employment opportunity that could absorb the landless youth. Thus, intensive agriculture with modern technology and diversification of income of the rural community need to be emphasized.

Institutional and policy factors

In the study period (1957-2017), political system of the country has changed, at least, twice (in 1974 and 1991). This resulted in a redistribution of land and in turn increased land fragmentation. In 1974, the socialist government proclaimed land to the tiller (*meret larashu*) and distributed land to the peasants that was concentrated in the hands of landlords. The 1974 transition period of government change also gave room to destruction of forest cover. Local community elders stated that there was substantial destruction of forest land in order to get fuelwood and agricultural land in the transition period of government changes. As a result, in 1974 to 1975, indigenous trees like *wayra (Olea africana) abesha tid (Juniperus procera), embis (Allophylus abyssinicus) and koso (Hygenia abyssinica)* were destructed for different purposes. In addition, in 1991 there was a huge destruction of government controlled communally planted trees that mainly consisted of *Eucaluptus globulus*.



LULC=land use land cover; URB=urban built up; BL=bare land; FL=forest land; shrub land; GL=grazing land; CRSL=cultivated and rural settlement land.

Fig. 5 Gains and losses of LULC categories between 1957 and 2017 in Wanka watershed, northwestern Ethiopian highlands.

Collection of firewood and timber

Almost all households in the study area entirely depended on natural and planted vegetation (used as source of firewood, charcoal and construction materials) for their energy and timber supply. Substantial increment of cultivated and rural settlement land, as well as urban built up area over the study period (1957-2017) implies the destruction of forest and shrub lands for the expansion of farm and settlement lands, which also increased the use of firewood and construction materials.

Implications of LULC change dynamics

Throughout the study period (1957-2017), CRSL, bare land and urban built up land use/cover categories showed continuous trends of expansion. On the other hand, forest, grass and shrub lands revealed a declining trend. This can have several implications such as in terms of loss of productive land and forest resources, shortage of firewood and construction materials, decline in agricultural productivity, and out-migration of rural population. Studies from other parts of Ethiopia have also revealed that the reason for the accentuation of land degradation and soil decline in the country is the expansion of CRSL at the expense of shrub and wood land (Worku et al. 2016; Asmamaw et al. 2011; Kebrom and Hedlund 2000; Lemenih et al. 2005). Our FGD discussants and key informants also highlighted that the conversion of substantial size of grazing lands to CRSL resulted in decreasing cattle rearing in the area. This, in turn, also negatively impacted their income which could be earned from sale of domestic animals and also affected the management of soil fertility (due to reduced availability of cattle dung). This implies that interventions are urgently needed in the case study area to reverse current trends of LULC changes (e.g. farm expansion). For this, it is necessary to give emphasis to land use strategies that create off-farm job opportunities for youths and encourage farmers to maximize crop productivity through intensive use of agricultural technologies.

LULC dynamics has also an implication on out-migration of rural population (mainly the youth) of Wanka watershed as there was no off-farm employment opportunity that could absorb the young population. Key informants reported that substantial numbers of rural communities left the area permanently and moved to the nearby town, Mekaneyesus, (the district capital) due to mainly shortage of farm land (Table 2). Some (mainly youths) still migrate to southwestern Ethiopia and remit cash for their family. This has an implication of expansion of the town (Mekaneyesus) at the expenses of farm and forest land and in turn accelerating shortage of farm land and agricultural productivity. Moreover, increasing out-migration of productive labor forces has its own adverse impact on the rural community of the study area, which, paradoxically, may reduce pressure on rural land resources.

Conclusion

The analysis of six decades of LULC change dynamics in Ethiopia's Wanka watershed in the Northwestern highlands disclosed the presence of varying rate of transformation for a number of LULC types, e.g. forest, shrub and grass lands to cultivated and rural settlement land (CRSL), which, in turn will have implications on the sustainability of available natural resources in the area. Deterioration of forest, shrub and grass lands can accelerate soil erosion and subsequently will result in decline of agricultural productivity, as expansion of cultivated land at the expense of natural vegetation accentuates soil erosion further (Bewket and Abebe 2013). CRSL expansion at the expense of grass land adversely has also affected the practice of animal rearing, with impacts on household income and soil fertility. We recommend that appropriate land use planning and strategies that reduce expansion of cultivated land need to be practiced. Some of these measures include: maximizing productivity through agricultural intensification and use of appropriate technology; more active community participation in the protection of forest, shrub and grass lands; rehabilitation of bare lands. Moreover, planners and decision-makers (such as at the regional and district levels) need to consider sustainability of the natural resource base for agriculture while developing policies for expansion of urban centers. Strategies like creating off/non-farm job opportunities in the villages and changes in urban planning should also be emphasized. In addition, more detailed studies about the households' livelihood strategies to cope with the existing LULC change dynamics need to be undertaken, which can also guide in finding out suitable interventions for the future.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Not applicable

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