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ORIGINAL ARTICLE

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
Long -term land use and land cover (LULC) dynamics information is essential to understand the trends and make necessary land management interventions, such as in the highlands of Ethiopia. This study analyzed six decades of LULC dynamics of Wanka watershed, Northwestern Ethiopian highlands. Two sets of aerial photographs (1957 and 2017), SPOT 5 and sentinel satellite imageries were analyzed. In addition, 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. 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, appropriate land use planning and strategies that reduce expansion of cultivated land need to be practiced.

Keywords Sustainable land use · Cultivated land · Trends · Land use · Land cover

Introduction

Land use and land cover (LULC) dynamics is one of the foremost causes of land degradation including: soil, forest and water quality deterioration, and disruption of Earth's ecosystem services, and thereof adversely affects socio-economic condition of the given environment (Rindfuss et al. 2004; Lambin et al. 2001). In many parts of the world, Earth's basic attributes and processes like land productivity, flora and fauna diversity as well as biochemical cycles have been changing as a result of natural and human land use/cover dynamics (Nanda et al. 2014). In this regard, human induced LULC dynamics and impacts, takes the lion's share of contribution, particularly at local scale (Gebrelibanos and Assen 2013). Farm land expansion without any adequate management at the expenses of natural LULC categories e.g. forest land, aggravates 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). Some studies indicate that in the highlands of east Africa population pressure provokes natural forestland destruction, loss of biodiversity and hence land degradation (Pellikka et al. 2004). Similarly, Agidew and Singh (2017) reported population pressure as a main factor in accentuating expansion of cultivated and rural settlement land (CRSL) and this compromised land degradation and food insecurity in the highlands of Northeastern Ethiopia. Hassen and Assen (2017), concluded that socio economic factors (e.g. civil war, frequent changes in political

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system and hence land reform) were the main 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 in increasing production, which resulted in productivity maximized through turning of more uncultivated land to agriculture.

In relation to the above findings, it is clear that LULC dynamics is rapid in the Ethiopian highlands, such as in the upstream part of the Blue Nile (Abay) basin, where Wanka watershed is located and 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). In this part of the country, loss of natural resources, agricultural land degradation and in turn low agricultural productivity are prevalent. This has its own implication on sustainability of agricultural land resources of the present study watershed and Ethiopia at large (Hurni et al. 2010).

World's landscape modification has been accentuated by LULC changes (Lambin et al. 2001) and hence LULC change study is the main issue of national and international research programs. Understanding the trends of biophysical attributes of land surface is essential to make intervention particularly via policies and program (Turner et al. 2007). Some studies have been conducted in Ethiopia on LULC dynamics over the past few decades. However, these findings showed discrepancies in patterns and magnitude of LULC dynamics at different scales. Some studies revealed expansion of cultivated land at the expense of other natural LULC types (Agidew and Singh 2017; Wubie 2016; Worku et al.2016; Efrem 2010; Zeleke and Hurni 2001). Others reported that cultivated lands are more or less remained unchanged (Yeshaneh et al. 2013; Woldeamlak 2003; Kebrom and Hedlund 2000). Amsalu et al. (2007) reported expansion of grazing land and bare land in central Ethiopian highlands. Hence, understanding the magnitude and direction of LULC dynamics over time and its implication on land resources at watershed scale is very critical (Yeshaneh et al. 2013; Asmamaw et al. 2011; Lambin et al. 2003).

Therefore, the reasons for the need to conduct this study included: first site specific long term LULC dynamics trend analysis with remote sensing data (aerial photographs, Spot-5 and sentinel 2 satellite images) is useful to make resource analysis, planning and sustainable land use system intervention such as for the study area. Second, LULC dynamics of the study watershed and its implications has not been studied and documented. The objective of this study was, therefore, 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.

Materials and methods

The study site

Wanka watershed lies between 11°29′24″ and 11°42′36″ North latitude, and 37°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 found 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 2238–4086 m 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.

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 and 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 (369.4 mm) (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 (*Eucalyptus 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*),

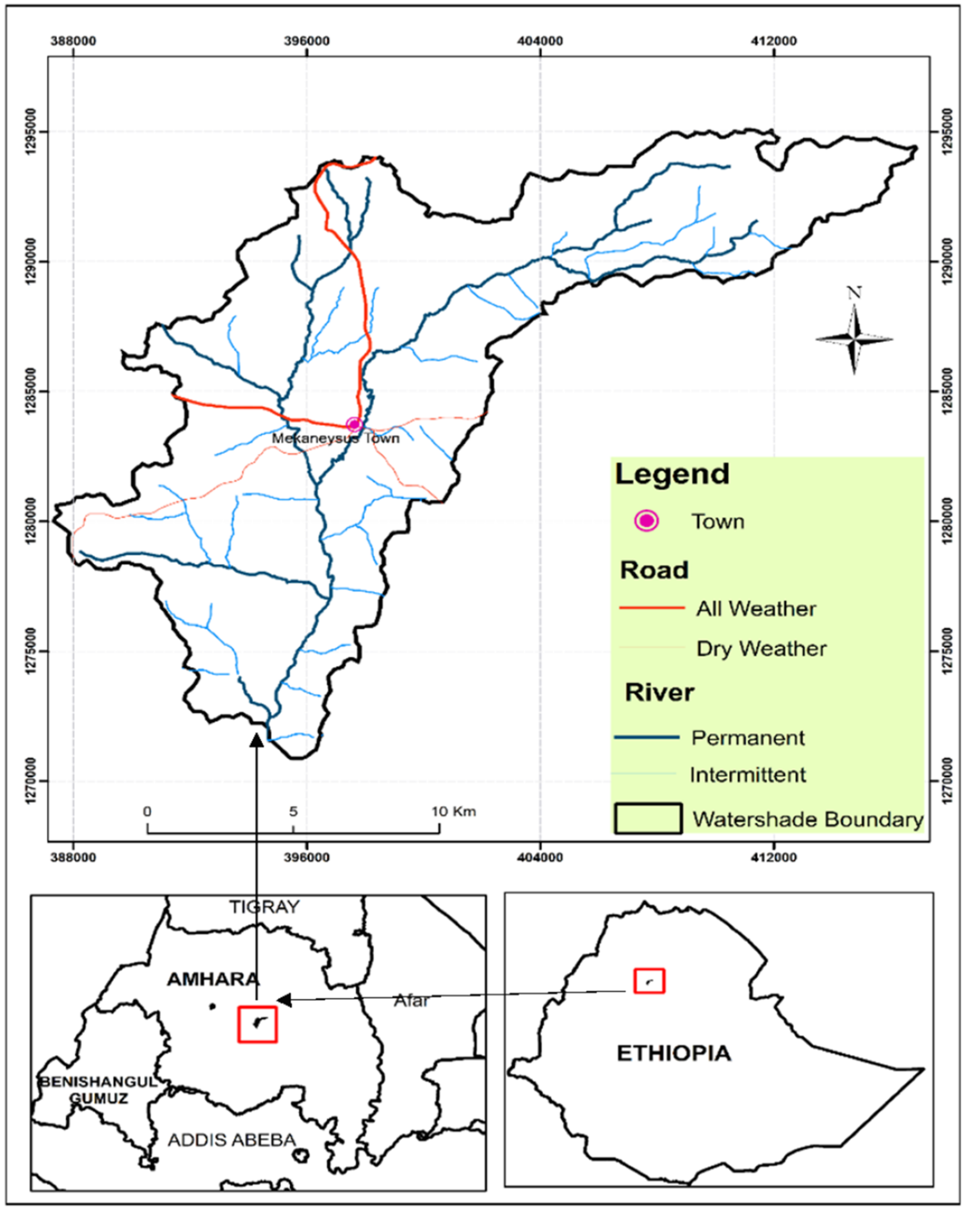

Fig. 1 Location map of Wanka watershed, northwestern Ethiopian highlands

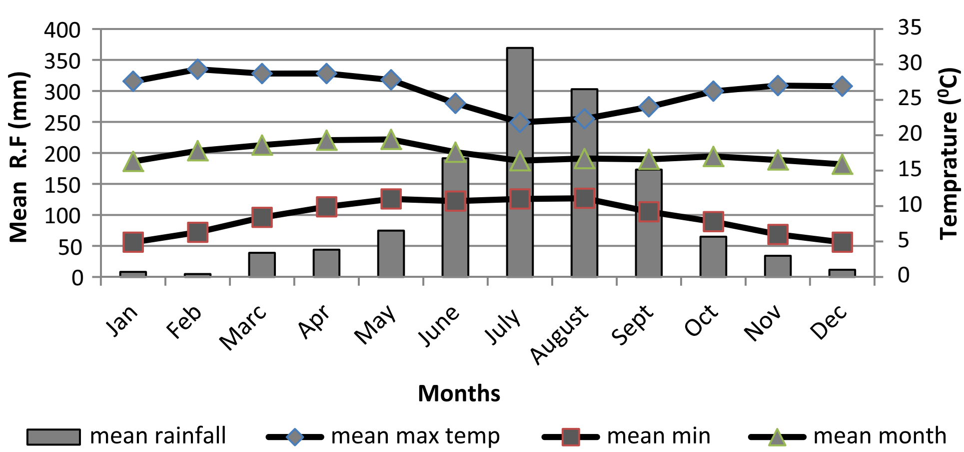

Fig. 2 Rainfall and temperature distribution of Wanka watershed, northwestern Ethiopian highland (1994–2015) (NMSAE 2015)

chick peas (*Cicer arietinum*), potato (*solanum tubersoum*) and oil seeds were dominant crops grown in the watershed.

Data sources and analysis

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

Twenty-seven black and white hardcopy aerial photographs (thirteen for 1957 and fourteen for 1980) and 5-m resolution SPOT-5 satellite image of 2006 were obtained from the Ethiopian Mapping Agency (EMA). In addition, 10 m 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 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 with maximum likelihood algorithm 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. LULC classes produced from multispectral satellite images (SPOT 5 and sentinel 2) need to be synchronized with the LULC classes that identified in aerial photographs (Wubie et al. 2016). Thus, many LULC types that were classified from multispectral satellite images (SPOT 5 and sentinel 2) in the preliminary classification were adjusted to fit the major LULC categories identified in the aerial photographs carefully and hence seven major LULC types (Table 1) were finally identified and recognized.

Extent and rate of LULC change

Four-time series (1957, 1980, 2006 and 2017) LULC maps at a scale of 1: 50,000 were produced (Fig. 4a–d) and temporal changes in LULC were determined. Change detection or transformation matrices for three periods (1957–1980, 1980–2006 and 2006–2017) were performed for the study watershed. Post-classification comparison change detection was used 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.

$$R\Delta(\%) = \frac{At2 - At1}{At1} \times 100$$

where $R\Delta$ is the change of one type of LULC in percent between initial time (At1) and the subsequent period (At2). At1 is the area (ha) of one type of LULC in t1 period; At2 is the same LULC with t1 type in the subsequent period.

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

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. In some areas enhanced plantations mixed with 'indigenous' species of trees. *Juniperus procera* and *Olea Africana* are main indigenous trees
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

community elders (60–81 years old) who grew up in the study area and were believed to have enough knowledge about the LULC change (engaged in farming practices for long time in the area) were interviewed. In addition, one FGD was conducted with six discussants who were within 35–65 years old.

Results and discussion

Land use/cover dynamics

Cultivated and rural settlement land (CRSL)

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; Fig. 3a–d; Fig. 4). However, compared to the three 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% (1358 ha) 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 of Ethiopia. As a result, increasing crop production in meeting food security of the country needs considering 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 2006 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 depicted in Tables 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 may be due to CRSL expansion restriction as a result of cold temperature (Fig. 3a–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 interviewees indicated that the study watershed had huge size of livestock before some years, but now farmers are 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)

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

LULC status									%	Trends of LULC dynamics					
LULC classes	1957 Area (ha)	%	1980 Area (ha)	%	2006 Area (ha)	%	2017 Area (ha)			1957–1980		1980–2006		2006–2017	
										ha	%	ha	%	ha	%
CRSL	15,474	61.5	18,123	72	18,276	72.6	18,610		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	25,163	100	25,162	100	25,163	100	25,163		100						

CRSL cultivated and rural settlement land, *ha* hectare, *LULC* land use and land cover

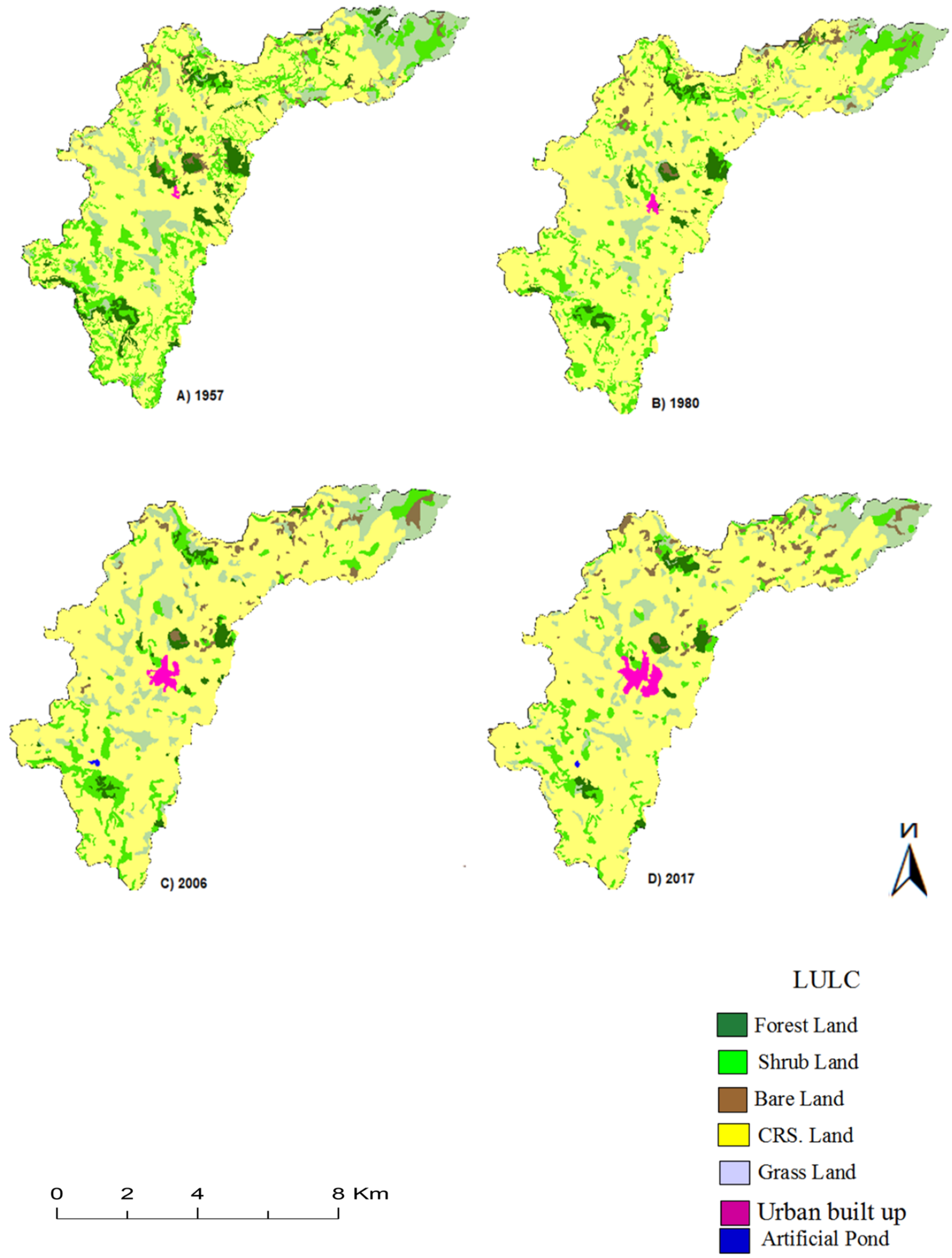

Fig. 3 Land use/cover maps of Wanka watershed for 1957, 1980, 2006 and 2017

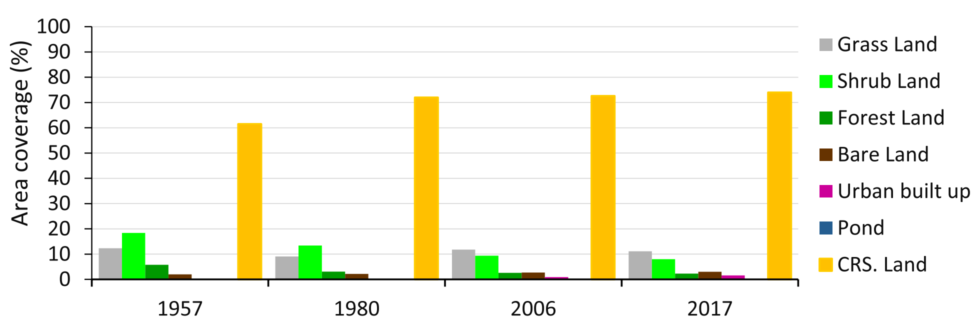

Fig. 4 LULC classes area coverage in the study period (1957–2017). *CRS* cultivated and rural settlement

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	13,320	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	15,474	100	3097	100	4630	100	1446	100	493	100	23	100

GL grass land, *SHL* shrub land, *FL* forest land, *BL* bare land, *URB* urban built up

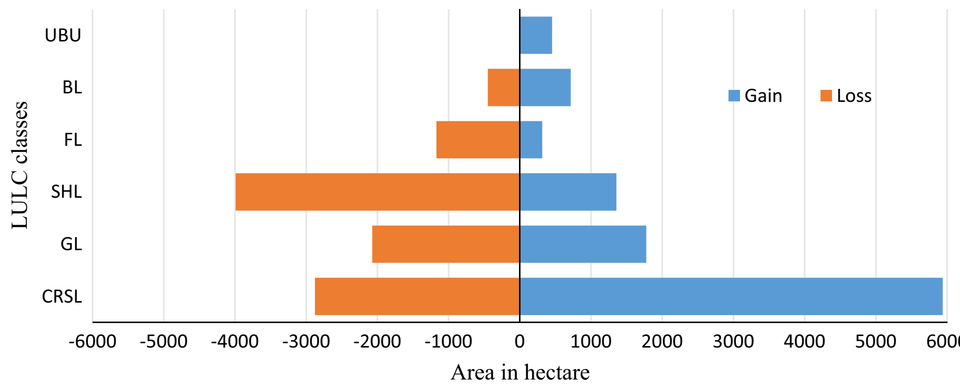

Fig. 5 Gains and losses of LULC categories between 1957 and 2017 in Wanka watershed, northwestern Ethiopian highlands. *URB* urban built up, *BL* bare land, *FL* forest land, *SHL* shrub land, *GL* grazing land, *CRSL* cultivated and rural settlement land

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	15,090	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	18,123	100	2282	100	3382	100	774	100	545	100	56	100

and there is a loss of additional income source which can be obtained from sale of animals and animal products.

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) (Tables 3, 4, 5) to CRSL in the first, second and third periods respectively. This implies that the primary factor for the declining of shrub lands in the study watershed is expansion of CRSL.

Forest land

In the study watershed, forest land coverage showed a continuous declining at annual average rate of about 1%

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	%
Changed to LULC class in 2017	CRSL	16,370	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	18,276	100	2961	100	2355	100	645	100	676	100	230	100	20	100

(14 ha) over the analysis period (1957–2017). It shared 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 (Tables 3, 4, 5). However, this was highly pronounced in the first period (1957–1980). Though forest land gained about 305 ha, it lost roughly three 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 1974/75 government change of the country. In many parts of Ethiopia there was destruction of forest during the transition period of the political system 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 (Tables 4, 5).

Bare land

Bare land expanded continuously from 1957 to 2017 and covered 2%, 2.2%, 2.7% and 3% area of the study watershed in 1957, 1980, 2006 and 2017 respectively (Table 2). Various LULC classes transformed to bare land throughout the study period (1957–2017). But the transformation of CRSL to bare land accounted the largest share over the studied periods. In the first, second and third periods about 321 ha (2.1%), 354 ha (2%) and 347 ha (1.9%) area of CRSL respectively were transformed to bare land (Tables 3, 4, 5). This is due to land degradation. Bare land expansion was highly pronounced in the upper part of the study watershed (Fig. 3 b–d). This may be due to severe soil erosion that resulted from topographic nature of the area and intensive cultivation with poor land management. Land degradation is caused by intensive cultivation without appropriate land management (Maitima et al. 2009).

Urban built up and small artificial pond

Mekaneyesus town, which is situated at the heart land of the watershed, has been expanding throughout the study period. It covered a very small portion 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 that there is reduction of agricultural land and in turn food crop production, and shrinkage of forest resources. Hence, measures like provision of non-farm activities in rural areas should be practiced. Similarly, drastic spatial expansion of urban built-up area at the expense of cultivated land 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 this size is reduced to 11 ha (0.04%) in 2017 (Table 2). This is perhaps due to siltation by sediments that were eroded from the surrounding upland areas. This has an implication that soil erosion which is accentuated by poor land management is a major threat to sustainable land management in the study watershed; hence there is a need of sustainable land management intervention. The other possible reason could be reduction of water that drain to the pond from the stream (Gomit stream) on which the pond was constructed. As reported by the 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.

Causes of LULC dynamics in Wanka watershed

Population growth

Demographic pressure is 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.

Agricultural and rural settlement land expansion

The studied LULC dynamics disclosed a presence of significant expansion of CRSL at the expenses of other LULC (mainly forest, shrub and grass lands) throughout the study period (1957–2017) in the Wanka watershed. This implies that CRSL expansion is one of the major reasons of LULC dynamics in the study area. 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, 5938 ha (38.4%) (Fig. 5). According to the information obtained from key informants and FGD discussants, in the Wanka watershed CRSL has expanded towards other LULC types as crop cultivation was the major livelihood of the rural population of the study area.

Consequently, farmers were forced to convert grazing, forest and shrub lands to cultivated land to increase agricultural production to feed their increased family size. However, further expansion of agricultural land will not continue as there was no suitable land that could be converted to cultivated land. As reported by key informants and FGD discussants, there was no enough land to be distributed to landless youth. Also, in the study watershed 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 should be emphasized.

Institutional and policy factors

In the study period (1957–2017), the political system of the country has been changed two times (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 the 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, indigenous trees like *wayra* (*Olea africana*) *abesha tid* (*Juniperus procera*), *embis* (*Allophylus abyssinicus*) *and koso* (*Hygenia abyssinica*) had been destructed for different purposes. In addition, in 1991 there was a huge destruction of government controlled communally planted trees that mainly consisted of *Eucalyptus globulus*.

Construction and firewood materials collection

Almost all households in the study area entirely depend on natural and planted vegetation (used as source of fire wood, charcoal and construction material) for their energy 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 due to farm and settlement land expansion, and fuelwood and constructional materials collection.

Implication of LULC dynamics

Throughout the study period (1957–2017), CRSL, bare land and urban built up LULC categories showed a continuous expansion trend. On the other hand, forest, grass and shrub lands revealed a declining trend in the study watershed. This has an implication on shortage of fuelwood and construction material, sustainability of land resources subsequently, agricultural productivity declines and out-migration of rural population. Other studies conducted in other parts of Ethiopia also revealed expansion of CRSL at the expense of shrub and wood land accentuated land degradation (Worku et al. 2016; Asmamaw et al. 2011; Kebrom and Hedlund 2000) and soil quality decline (Lemenih et al. 2005). According to our FGD discussants and key informants, conversion of substantial size of grazing lands to CRSL resulted in decreasing cattle rearing in the area and in turn shortage of income that can be earned from sale of domestic animals, dung for fuel and soil fertility management (reduced organic farming). Thus, intervention is needed to reverse further expansion of cultivated and ensure sustainable land use in the study watershed by giving emphasis to strategies that create job opportunities for farm land seekers and encouraging farmers to maximize crop productivity by intense 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 study watershed 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 six decades long spatio-temporal LULC dynamics analysis of Wanka watershed disclosed a presence of transformation of forest, shrub and grass lands to CRSL and this has implication on the sustainability of natural resources. Deterioration of forest, shrub and grass lands accelerates soil erosion and subsequently result in declines of agricultural productivity as cultivated land expansion at the expense of natural vegetation accentuates soil erosion (Bewket and Abebe 2013). CRSL expansion at the expense of grass land adversely affects animal rearing practice and in turn additional income from animal and animal products sale. Decision makers should give due attention to the problems and make suitable interventions. Maximizing agricultural productivity by intensification with technology, creating off/non-farm job opportunities in the rural villages and encouraging community participation in the protection of the destruction of forest, shrub and grass lands as well as rehabilitating of bare lands need to be considered. Moreover, area expansion of the district capital (Mekaneyesus) should consider sustainability of the natural resource base for agriculture. In addition, further detail studies about the households' livelihood strategies to cope the problem have to be undertaken, which can also guide in finding out future interventions.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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