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Impacts of phased-out land restoration programs on vegetation cover change in Eastern Tigray, Ethiopia

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Abstract

Background: Land restoration programs in Tigray, also called integrated watershed management (IWM) practices, were implemented by the government and non-governmental organizations since 1980s. These practices aimed at reversing land degradation processes, environmental rehabilitation, and ensure food security at both community and household levels. Most of the implemented IWM projects are now phased-out. The aim of this study is therefore; therefore, to investigate the impacts of phased-out land restoration programs on vegetation cover changes in Eastern Tigray, Ethiopia. Both Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) Landsat imageries at 30 meter by 30 meter spatial resolution were used to examine the land use and land cover conditions taking successful and unsuccessful IWM interventions as case studies. Three time periods were used in the change analysis: before IWM implementation (2007), at the time of IWM projects phase-out (2010), and after IWM phase-out (2017).

Results: The results indicated that for all successful integrated watershed management projects, both the bush/shrub land (19.6 ha) and grassland (8.95 ha) increased during the intervention time for Negash (S-1), Deberewahabit (S-2) and Gemad (S-3) watersheds. However, the bush/shrub land decreased after the integrated watershed management projects phased-out by 9.8 and 11.3 ha for S-1 and S-3 watersheds. At the unsuccessful IWM projects, bush/shrub land increased by 18.21, 11.3 and 9.5 ha during the intervention period, and decreased after project phased-out by 3.92 and 7.2 ha at Debretsiion (S-4) and Laelay wukro (S-5) watersheds. Furthermore, cultivated land increased after phased-out in most of the watersheds.

Conclusions: This study concluded that vegetation cover has been declined in all watersheds after the phased-out period. This may affect significantly the environment in general and livelihood of the community in particular. Therefore, there is a need to provide an emphasis after the implementation of watershed projects and evaluate its impacts regularly.

Keywords: IWM, LULC change, Remote Sensing and GIS, Eastern Tigray, Ethiopia

Introduction

Vegetation cover change is the result of the natural and anthropogenic process (Muluneh 2003; Emiru and Gebrekidan 2013). It is dynamic in nature and provides

a broad understanding of the interaction and relationship between the anthropogenic activities with the natural environment (Briassoulis 2006; Gessese 2018). Land degradation in the form of soil erosion has been one of the most important challenges in the highlands of Ethiopia (Nyssen et al. 2009). The annual soil loss rate from the cultivated steep slope land was estimated at 130 tons ha⁻¹ in the year 2010 (Hagos et al. 1999), and over the last three decades cover about 23% of the land degradation in the country (Gebreselassie et al. 2016). The

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change in vegetation cover affects environment both directly and indirectly economy, and society at various spatial and temporal levels (Briassoulis 2004). LULC has also been recognized by national and international bodies as a critical factor mediating between socioeconomic, political, and cultural behavior and global environmental changes (Turner and Meyer 1994). The LULC alterations are generally caused by population growth, and increasing socio-economic necessities create a pressure on LULC, mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems such as landslides and floods (Seto et al. 2002; Barros 2004). According to Abate (1994), LULC changes and socio-economic dynamics have a strong relationship. As population increases, the need for cultivated land, grazing land, fuel wood, and settlement areas increases and to meet the growing demand of the community for food and energy, and livestock production additional lands must have brought under agriculture leading to land resources degradation.

To alleviate these challenges of land resources degradation, different land restoration activities also called integrated watershed management (IWM) were implemented since 1980s on selected large watersheds located mainly in the highly degraded parts of the highlands of Ethiopia (Zelege 2006). Moreover, IWM practices were implemented since the 1990s in Tigray (Gashaw 2015). Integrated watershed management is a holistic approach that considers a watershed as a holistic system where social, cultural, economic, and environmental components interact together (Wang and Innes 2005). According to Bekele and Tilahun (2007), and Brooks and Eckman (2000), IWM has been promoted in many countries as a suitable strategy for improving productivity and sustainable intensification of agricultural system. The purpose was mostly for implementing natural resource conservation and development programs (Asrat et al. 2005) which in turn affects the agriculture, economic socio-cultural and food security. However, most of the IWM projects are phased-out about 5 years after the implementation. Phase-out refers to the withdrawal of project inputs without continuity of support or arrangements of watershed management practices by the government and non-governmental organizations (Zelege 2014). A number of watershed management projects were phased-out in Tigray as well as the study area. Nevertheless, no studies had conducted on the impact of phased-out IWM projects on vegetation cover change.

Different studies such as Gebresamuel et al. (2010), Tekla et al. (2020), Gebremeskel et al. (2019), Abay et al. (2020) and Hailu et al. (2020) have been conducted on the impact of IWM on vegetation cover, land use and land cover status and changes, as well as soil health by comparing the situation of those watersheds before and

after implementation of the IWM projects (Aggregating the—during and after IWM projects interventions as compared to the before). Nevertheless, many scholars agree that the vegetation cover momentum may not linearly after IWM projects exit, as it is influenced by the exit strategy/approaches followed during project implementation. Moreover, these studies focused on successful IWM projects only, which made their findings less reliable for future development of the IWM interventions due less representation; the present study, however, considered both successful and unsuccessful IWM projects (based on farmers and experts' judgment as well as extensive field survey) to increase the accuracy and acceptability of the research findings. Hence, a critical study aimed at investigating the impact of phased-out watersheds projects (both successful and unsuccessful watersheds) on vegetation cover changes was required so as to influence decision makers on their future IWM projects exist and implementation approaches.

Materials and methods

Study area

The study has been conducted in six watersheds (Negash, Deberewahabit, Gemad, Debretsion, Laelay wukro and Tsigarda) located in the Kilte-Awlaelo district, eastern Tigray, northern Ethiopia (Fig. 1). The district is located at a distance of 45 km north of the regional capital (Mekelle city). Geographically, it is located between 13° 33' 00" and 13° 58' 00" N and 39° 18' 00" to 39° 41' 00" E at an elevation that ranges between 1760 to 2720 m above sea level.

The total area of the district is about 101,758 ha, from which 21% is farmland, 8% grass land, 43% exclosures (area set-aside for a natural recovery of soils and vegetation after a complete protection from human and livestock interference) and the remaining 28% is occupied by unproductive hills and residential areas (MoARD 2007). The district has two main Agro-climatic zones: (i) Dogua/cool, humid highland zone (13.1%) which is located at an altitude of above 2500 m above mean sea level; (ii) Weina Dogua (86.9%), which is located at an altitude that ranges between 1500 and 2500 m above mean sea level (Rabia et al. 2013). The dry season occurs between October and January; while the rainy season occurs between June and September (Tigray Meteorological Agency 2017). The maximum temperature was observed in May and June; while the minimum temperature was observed in the months between September and December (Tigray Meteorological Agency 2017). With respect to the geological formation the study area is dominated by igneous and metamorphic rocks (Precambrian, Paleozoic) (Rabia et al. 2013) rock types. According to FAO (1998), the major reference soil groups of the district are Eutric Cambisols (7%), Vertic Cambisols (44%), Chromic Cambisols (2%),

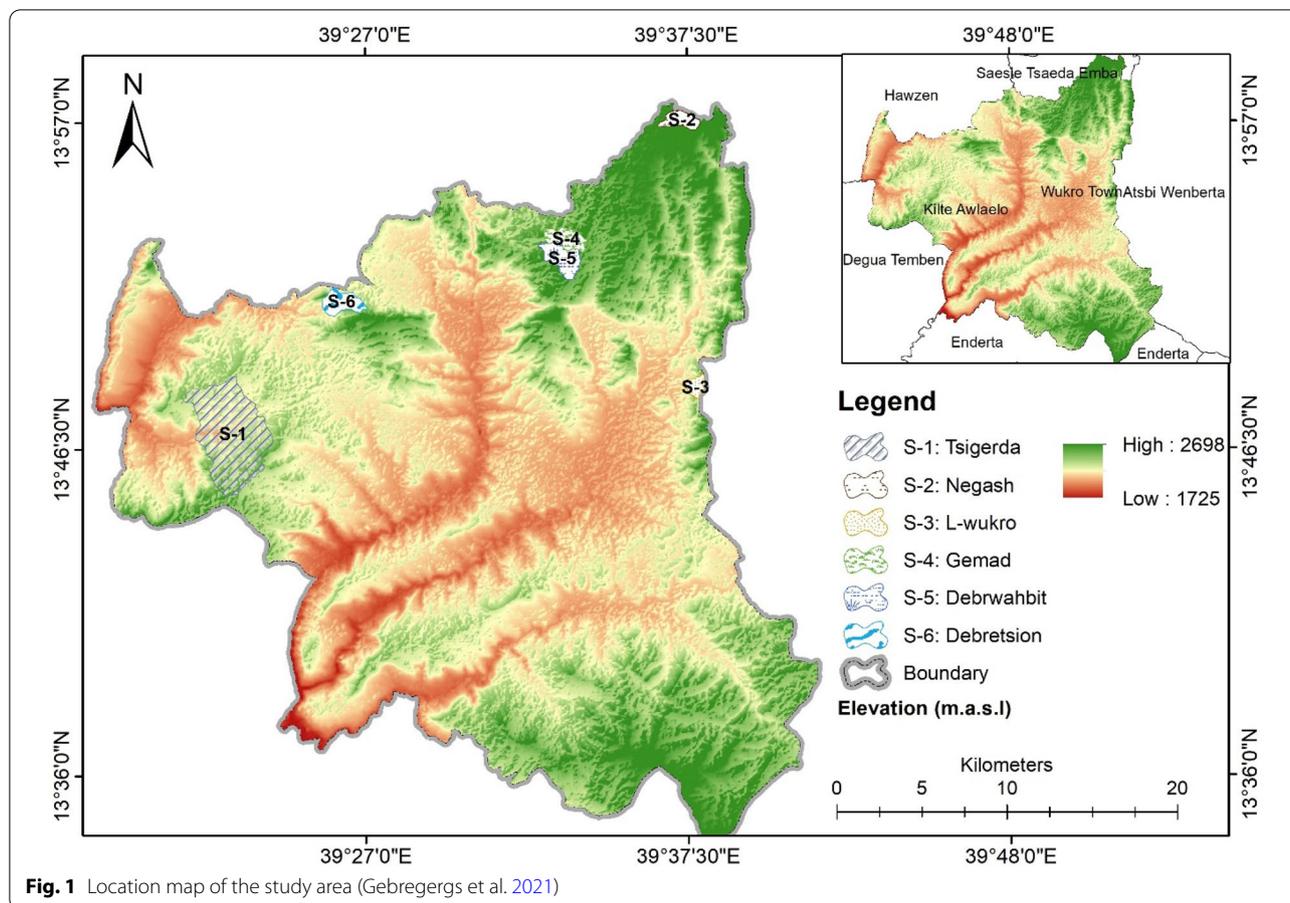


Fig. 1 Location map of the study area (Gebregergs et al. 2021)

Chromic Luvisols (4%) and Lithosols (43%). The livelihood of the community mainly depends on agriculture, which is characterized as mixed farming in which crops are produced and livestock reared, and managed on the same farm. The major crops grown in the area are barley (*Hordeum vulgare*), wheat (*Triticum sativum*), teff (*Eragrostis teff*) and millet (*Eleusine coracana*). While the major livestock herds are sheep, cattle, camel, mule, bees, donkeys, and chicken and goats.

Data collection

Site selection

All the studied watersheds were purposely selected from one Agro-ecological zone (Weina-Degua), representing about 87% of the district, having an age of seven years after project implementation phased-out. The selection of these six watersheds was done in consultation with the district watershed experts and extensive field survey. These experts were from Sustainable Land Management (SLM) project, World Food Program (WFP) and Kilege-Awulaelo District Office of Agriculture and Rural Development. Hence, three successful and three unsuccessful watersheds were selected based on the criteria for watershed

evaluation (Table 1) set by the Tigray Bureau of Agriculture and Rural Development: (i) Ecological impact (vegetation cover, ground water recharge, flood reduction, surface runoff reduction and animal diversity); (ii) socio-economic impact (irrigation water availability, women participation, and fodder production); (iii) Status of implemented soil and water conservation measures (biological and physical).

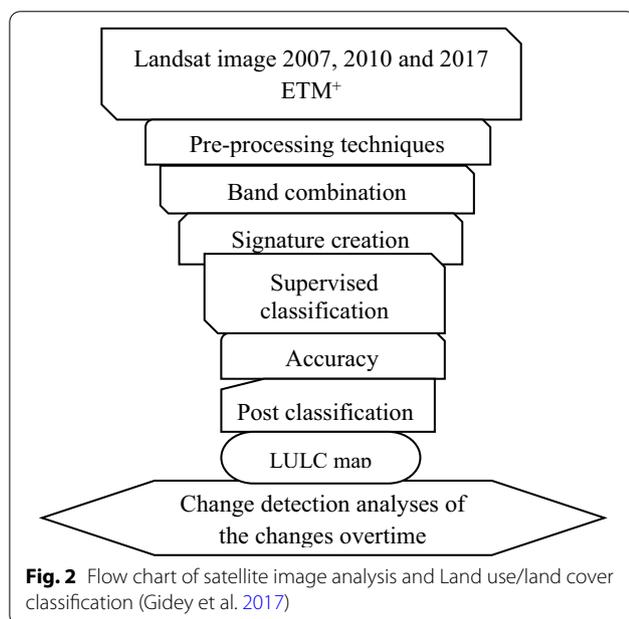
Vegetation cover change analysis

For the vegetation cover change analysis, the Enhanced Thematic mapper ETM+ Landsat images were acquired from the United State Geological Survey (USGS) (<https://earthexplorer.usgs.gov/>) for three different years (2007—before IWM implementation, 2010 during IWM project phase-out, and 2017—the current situation). The image pre-processing techniques such as radiometric, geometric and atmospheric corrections have been applied to produce a good quality image in ArcGIS 10.3. According to Hassan et al. (2016), image pre-processing was vital to establish a direct association between the acquired data and physical occurrences of the study area. A supervised classification was

Table 1 Criteria used to evaluate the performance of integrated watershed management practices in Tigray, Ethiopia

Status of the watershed	Performances evaluation in %									
	Ecological					Socioeconomic			SWC	
Successful	Vgt	Gwat	Rf	Rsr	IAD	liWat	IWP	IFP	Bio	Phy
S-1	80	35	53	63	38	60	90	80	85	75
S-2	75	35	60	65	41	63	85	75	85	73
S-3	75	30	50	59	33	55	78	70	80	69
Unsuccessful										
S-4	40	15	19	21	13	19	15	21	31	39
S-5	45	17	9	11	12	17	27	18	29	36
S-6	45	14	16	17	21	21	19	19	33	47

Vgt: vegetation cover; Gwat: Ground water recharge; Rf: Reducing flooding; Rsr: Reducing surface runoff; IAD: Increase animal diversity; liWat: Increased irrigation water availability; IWP; Increased women participation; IFP: increased fodder production; Bio: biological; Phy: physical; S-1 Negash; S-2: Deberewahabit; S-3 Gemad; S-4 Debretsion; S-5 Laelay wukro; S-6 Tsigerda



Representative ground control points (GCPs), which represent the different land cover classes were also marked using handheld GPS during the field visit. A total of 490 GCPs from successful watersheds and 640 GCPs from unsuccessful watersheds were collected. These GCPs were used to sample representative signatures for the various land cover types (Table 2) and determine the level of accuracy following maximum likelihood classification methods.

Accuracy assessment

Confusion/error matrix was used to verify the accuracy of generated vegetation cover map of the study area. The accuracy map was verified according to Viera and Garrett (2005). Based on these authors, a Kappa coefficient value greater than 0.8 denotes a strong agreement; a value between 0.4 and 0.8 denotes a moderate agreement and a value below 0.4 represent poor agreement. Kappa coefficient was calculated using the following proposed Eqs. (1–4) proposed by Congalton and Green (2008).

$$\text{Overall accuracy} = \frac{n \sum_{i=1}^k mii}{n} \tag{1}$$

conducted to analyze the vegetation cover changes for all studied watersheds (Fig. 2).

Table 2 Description of land cover types

Land use land cover type	Description
Settlements	Land covered by rural village’s (houses), and towns (Fissaha et al. 2017)
Shrub/Bush Land	Land covered by small trees, bushes, shrubs; it is less dense than the woodland (Fissaha et al. 2017)
Grazing Land	Areas with more than 50% cover grasses (mixed with some shrubs) and less than 50% herbaceous, and have bare lands usually used for grazing
Cultivated Land	Areas of land prepared for rainfed and irrigated crops, which includes areas currently under crop, fallow and land under seedbed (Tahir et al. 2017)
Bare land	Land which is mainly covered by bare soil and rock outcrops (Belay et al. 2015; Fissaha et al. 2017)

$$\text{Producer's accuracy} = \frac{n_{ii}}{G_i} \quad (2)$$

$$\text{User's accuracy } i = \frac{n_{ii}}{C_i} \quad (3)$$

$$\text{Kappa coefficient} = \frac{n \sum_{i=1}^k n_{ii} - n \sum_{i=1}^k (G_i C_i)}{n^2 - \sum_{i=1}^k (G_i C_i)} \quad (4)$$

where, i = the class number; n = total number of classified pixels that are being compared to ground truth; n_{ii} = number of pixels belonging to the ground truth; C_i = total number of classified pixels belonging to class i ; G_i = total number of ground truth pixels belonging to class i .

The results of the 2017 image classification were validated by creating a confusion matrix from which different accuracy measures are derived. The confusion matrix was established using 150 GCPs (for *Negash, S-1*), 150 (for *Deberewahabit, S-2*), 90 (for *Gemad, S-3*), 150 (*Debretsiion, S-4*), 120 (for *Laelay-wukro, S-5*) and 90 (for *Tsigerda, S-6*), which were not used in the 2017 image classification. Hence, the overall accuracy of the classified satellite image for 2017 were, respectively, 87.61%, 87.7%, 84.4%, 85.3%, 84.9% and 86.8% for the six watersheds respectively. Moreover, the Kappa coefficient was about 0.81, 0.83, 0.77, 0.82, 0.8 and 0.85 respectively. According to Viera and Garrett (2005), Kappa value greater than 0.8 indicated a strong agreement, while 0.4–0.8 is a moderate agreements, and less than 0.4 a poor agreement. Therefore, according to these ranges, the classification accuracy for the six watersheds in this study ranges from moderate to strong agreement.

Data processing and analysis

Vegetation cover

Changes in vegetation cover due to the integrated watershed management interventions were analyzed by comparing the raster maps of 2007, 2010 and 2017 using their corresponding confusion matrix. Change statistics were computed by comparing image values of one data set to the corresponding value of the second data set in each period following equations (Eqs. 5 and 6) as suggested by Peng et al. (2008) and Kindu et al. (2013).

$$\text{LULC change}(\text{Area in final year} - \text{Area in initial year}) \quad (5)$$

$$\text{LULC change in Percentage} = \left(\frac{\text{Area in final year} - \text{Area in initial year}}{\text{Area in initial year}} \right) * 100 \quad (6)$$

Results and discussion

Impact on implemented land restoration activities

Different soil and water conservation measures, both physical and biological, were implemented in the studied watersheds. The major physical measures implemented in the studied watersheds were hillside terraces at the upper slop, half moon & trench at the middle slope, and gabion checkdam, loose stone checkdam & percolation ponds at the lower slope positions of the watersheds (Table 3). However, the quality of these implemented measures in all these implemented watersheds were highly deteriorated due to IWM projects phase-out and absence of maintainance. The destruction level for hillside terraces varies from 20.8% on upper slope position for S-1 watershed to 97.7% on upper slope position for S-5 watershed. The half moon damage ranges between 18.5% on middle slope position for S-6 watershed, and 30% on middle slope position for S-4 watershed. The damage level for shallow trenches was in the range of 6% on middle slope position for S-3 watershed to 36.9% on middle slope position and S-5 watershed. Furthermore, the quality of the implemented check dams and percolation ponds were highly deteriorated due to infilling with sediment after the IWM project phase-out. The damage level for loose stone checkdams varies from 18% on lower slope position and S-1 watershed to 100% on lower slope position and S-6 watershed; while for that of gabion checkdam was in the range of 28% on lower slope position and S-1 watershed to 100% on lower slope position and S-4, S-5 and S-6 watershed. The destruction level of percolation pond was between 22% on lower slope position and S-2 watershed to 100% on lower slope position for S-4, S-5 and S-6 watershed. The major reasons for the destruction of these implemented land restoration measures were lack of maintenances after the integrated watershed management project phased-out. Studies elsewhere, Medego watershed in northern Ethiopia, reported that lack of maintenance is one the major factors for failure of implemented soil and water conservation strictures (Mekonen and Tesfahunegn 2011).

Impact on vegetation covers

This study identified five major land cover types, which includes bush/shrub land, cultivated land, bare land, grass land and built-up area (Fig. 3). The results showed

Table 3 Phased-out projects impact on implemented soil and water conservation measures

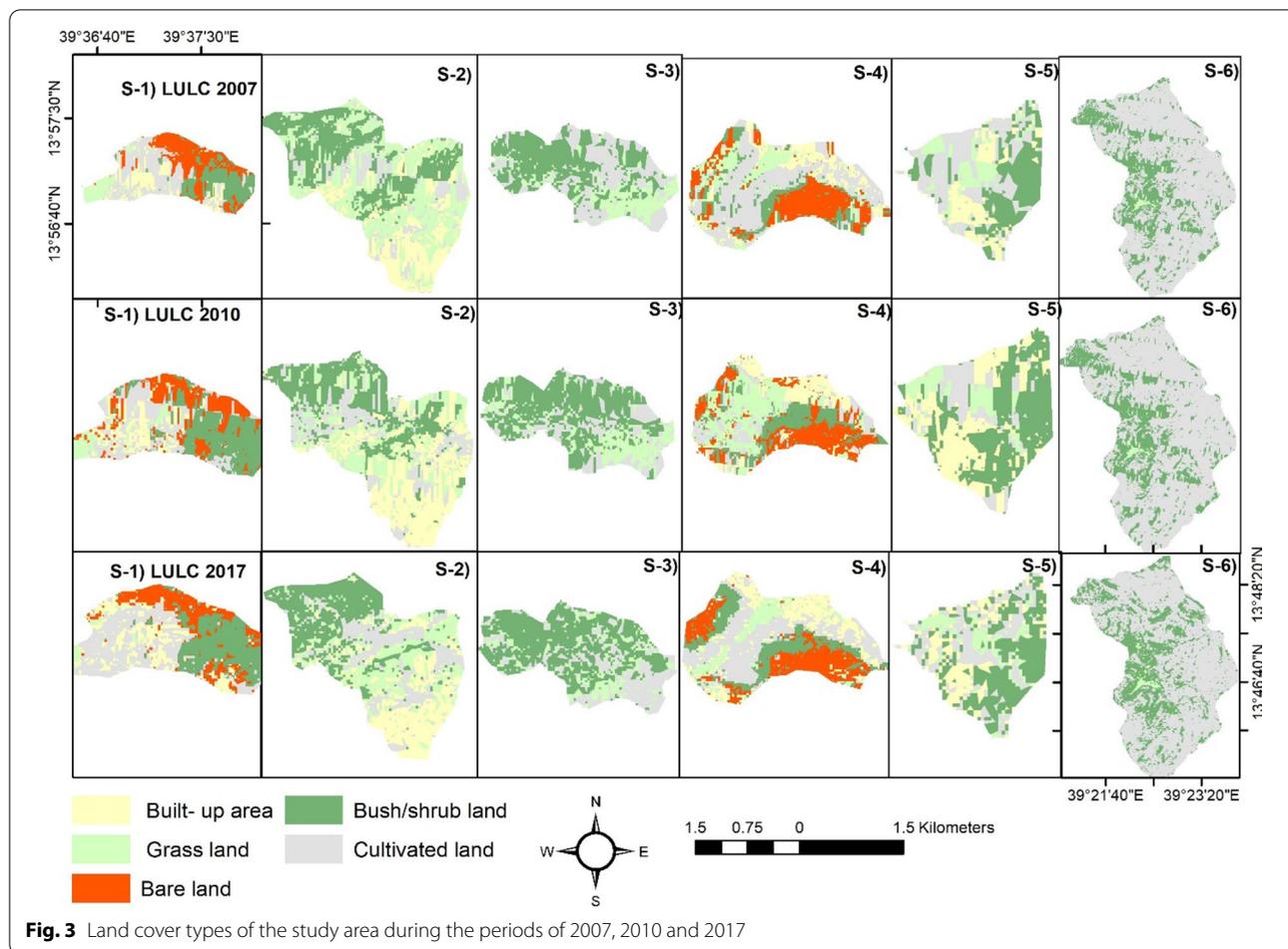
Watershed	Implemented SWC structures								
	U-slope	Total in number	Damaged in %	MI-slope	Total in number	Damaged in %	L-slope	Total in number	Damaged in %
S-1	Hillside terraces	115	20.8	half moon	37	24	Gabion check dams	25	28
				stone bund	68	22	Loss stone check dams	18	22
							Percolation pond	4	75
S-2	Shallow trench	98	11	hillside terrace	103	20	Gabion check dams	40	42
	Hillside terraces	101	33.21	shallow trench	118	21.6	Percolation pond	9	22
S-3	Shallow trenches	91	29.5	half moon	37	29	Lose stone check dams	25	60
				hillside terrace	23	21	Gabion check dams	9	33
				shallow trench	71	24.56	Lose stone check dams	32	59
S-4	Hillside terraces	146	66.68	Half moon	180	30	Hand dug well	18	44
				Stone bund	68	22	Gabion check dams	25	100
				Shallow trench	70	32	Loss stone check dams	37	94
S-5	Hillside terraces	165	97.7	Shallow trench	131	36.9	Percolation pond	2	100
							Half moon	250	33.2
S-6	Hillside terraces	246	64.9	Half moon	200	18.5	Gabion check dam	9	100
				Hillside terrace	25	36	Gabion check dams	7	100
				Shallow trenches	35	14.2	Lose stone check dams	2	100
							Percolation pond	3	100

U-slope upper slope; MI-slope middle slope, L-slope lower slope; S-1 Adikesho, S-2 Deberewahabit, S-3 Gemad, S-4 Debretsion, S-5 Laelay-Wukro, S-6 Tsigerda

that the most dominant land cover type in most watersheds (S-1, S-2, S-4 and S-6) and in the year 2007 was cultivated land, while, bush/shrub land was dominant in the remaining (S-3 and S-5) watersheds (Fig. 3 and Table 4). However, during intervention period (2007 - 2010) bush/shrub land dominated in all watersheds except S-4 and S-6 watersheds. This, however, could not sustain after the implementing project phase-out, in which the area of cultivated land was back to its dominance (Fig. 3).

There was a significant vegetation cover changes in the studied watersheds and years. The area coverage of bush/shrub land has been increased by 1.9–51.6%, during the project intervention years (2007–2010)

(Table 4). This finding is in line with that of Hussien (2009) for land use land cover change of Lenche Dima watershed within the Blue Nile basin that reported an increase in bush land from 17 to 22% in the years between 1986 and 2000 after the implementation IWM.. This increase bush/shrub lands, for the studied watersheds, was at the expense of the cultivated areas, in which it declined during the intervention period by 2.3–53.7%. Similarly, Alemayehu et al. (2009) in eastern Tigray reported a decrease in cultivated area from 55 to 52% in the years between 1994 and 2005 following implementation of watershed management. Gebresamuel et al. (2010) for the Maileba and Gum Sellasa watersheds in Northern Ethiopia also



reported a decrease in area of cultivated land by 5–9% due to implementation of land restoration measures. Moreover, Hussien (2009) for Lenche Dima watershed reported a decline in cultivated land coverage from 52% in 1986 to 48% in 2000 up on land restoration measures implementation. The increase in bush/shrub land coverage was further induced due to shrinking in bare land area by 1.5–18% (Table 4). This corresponds with the findings of Kebrom and Hedlund (2000) for Kalu area of north central Ethiopia that reported a decline in bare land by 1.4–8.5% up on land restoration activities implementation. However, the progressive increase in vegetation cover was impeded in most of the studied watersheds after the IWM projects phased-out (2010–2017). The area coverage of bush/shrub land has been declined by 7.2–15.4% in four out of the six studied watersheds. The decline was related to an increase in cultivated land area. This corresponds to the findings of Zeleke and Hurni (2001)

for the Dembecha area of Gojjam who that reported a reduction in the area coverage of bush/shrub land to agriculture and settlement in response to population growth.

Conclusions

The quality and quantity of soil and water conservation practices of each watershed deteriorated after Integrated Watershed Management (IWM) projects phased-out. Vegetation cover change analysis results also showed a decrease in bush/shrub land at the Negash, Gemad, Debretsiion and Laelay-Wukro by 9.8, 11.3, 3.92 and 7.2 ha, respectively, after IWM phased-out. Whereas, built-up areas and cultivated land increased in all studied watersheds. It can be concluded that vegetation cover reduced in all watersheds after the IWM project phased-out. IWM project phased-out. The implication of this study is therefore, decision makers should modify strategy or approaches of the

Table 4 Land use/land cover change of the study area from 2007 to 2017

LULC 2007- 2010	S-1			S-2			S-3			S-4			S-5			S-6																							
	2007	2010	Change																																				
	ha	%	ha	%																																			
BL/SL	38	23	58	33	20	10	80	26	89	29	9	3	97	44	116	52	19	9	36	14	54	21	18	7	36	34	47	31	11	-3	499	25	508	26	10	1			
CL	53	31	42	24	-10	-7	109	36	81	27	-28	-9	79	36	55	25	-24	-11	98	38	45	18	-53	-20	26	25	17	23	-9	-2	1467	74	1433	72	-34	-2			
BU	21	12	25	14	4	2	64	21	74	24	10	3	-	-	-	-	-	-	33	13	37	14	4	2	32	31	-	-	-	-	-	-	-	-	-	-	-		
BaL	45	27	37	21	-8	-6	-	-	-	-	-	-	-	-	-	-	-	-	59	23	59	23	-1	0	-	-	35	28	35	28	-	-	-	-	-	-	-		
GL	12	7	15	9	3	1	51	17	60	20	-	-	46	21	51	23	-	-	33	13	64	25	31	12	12	11	11	10	-1	-1	20	1	44	2	24	1			
LULC 2010- 2017	S-1			S-2			S-3			S-4			S-5			S-6																							
	2010	2017	Change																																				
	Ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	
BL/SL	58	33	48	28	-10	-5	89	29	89	29	0	0	116	52	104	45	-11	-7	54	21	50	20	-4	-2	36	34	40	37	4	4	-36	-34	559	28	594	62			
CL	42	24	53	31	11	7	81	27	73	24	-8	-3	55	25	58	25	3	0	45	18	81	31	35	14	26	25	21	20	-6	-5	-26	-25	1406	71	1432	96			
BU	25	14	28	16	3	2	74	24	76	25	2	1	-	-	-	-	-	-	37	14	47	18	10	4	32	31	35	33	-	-	-	-	-	-	-	-	-	-	
BaL	37	21	33	19	-4	-2	-	-	-	-	-	-	-	-	-	-	-	-	59	23	54	21	-5	-2	-	-	-	-	35	-	35	-	-	-	-	-	-	-	
GL	15	9	11	6	-4	-2	60	20	65	21	-	-	51	23	68	29	-	-	64	25	28	11	31	-14	12	11	10	10	-1	-1	-1	-1	21	1	21	1	24	1	
LULC 2007- 2017	S-1			S-2			S-3			S-4			S-5			S-6																							
	2007	2017	Change																																				
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	
BL/SL	38	23	48	28	10	5	80	26	89	29	9	3	97	44	104	45	8	2	36	14	50	20	14	6	36	34	40	37	4	4	499	25	559	28	60	3			
CL	53	31	53	31	0	-1	109	36	73	24	-36	-12	79	36	58	25	-21	-10	98	38	81	31	-18	-7	26	25	21	20	-6	-5	1467	74	1406	71	-61	-3			
BU	21	12	28	16	7	4	64	21	76	25	13	4	-	-	-	-	-	-	33	13	47	18	14	5	32	31	35	33	-	-	-	-	-	-	-	-	-		
BaL	45	27	33	19	-12	-7	-	-	-	-	-	-	-	-	-	-	-	-	59	23	54	21	-6	-2	-	-	-	-	35	-	35	-	-	-	-	-	-		
GL	12	7	11	6	-2	-1	51	17	65	21	-	-	46	21	68	29	-	-	33	13	28	11	31	-2	12	11	10	10	-1	-1	20	1	21	1	24	1			

S-1 Adikesho; S-2 Deberewahabit; S-3 Gemadi; S-4 Debretsion; S-5=Laelay wukro; S-6 Tsigerda
 BL/SL: Bushland/Shrubland; CL: Cultivated land; BU: Built-up area; BaL: Bareland; GL: Grassland

implementation of IWM and implementation of IWM should generate income to the community that ensures their continued intervention than creating dependency for implementation of IWM.

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Authors' contributions

All authors have contributed a lot to the success of this manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The raw data as well as all supported materials used to conduct the research are available.

Declarations

Ethics approval and consent to participate

This study is part of our project entitled "Status, challenges and alternative options for sustainable watershed management after watershed project phased out". All authors confirmed that there is no ethical conflict.

Consent for publication

All authors have read the manuscript carefully and agreed to submit for publication.

Competing interests

The authors declare that they have no competing interests.

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