Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 1, No. 6, p. 184-198, 2011
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Analysis of land use/land cover changes in the Debre-Mewi watershed at the upper catchment of the Blue Nile Basin, Northwest Ethiopia

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Received: 10 October 2011
Revised: 02 November 2011
Accepted: 03 November 2011

Key words: Land degradation, land use/cover, remote sensing and GIS, sustainability.

Abstract

Changes in land use/cover at the Debre-Mewi Watershed in northwest Ethiopia were analyzed over a period of 51 years (1957-2008). The changes were measured through interpretation of aerial photos taken in 1957 and 1982, and a Landsat image of 2008, supported by focus group discussions and repeated field visits. Based on the image analysis, four major land use/cover classes (natural forest, shrub, grazing, and cultivated land) were identified for the period 1957 to 1982. In addition to the four land use/cover types, areas covered by Eucalyptus plantation forest and rock outcrop were observed on the 2008 image. In the three consecutive periods, the natural forest cover accounted for 4.48, 1.30 and 0.37%; shrub land cover 6.10, 6.01 and 2.39%; grazing land 18.39, 14.86 and 11.14%; and cultivated land 71.04, 77.83 and 81.51% of the total area (543.82 ha) of the watershed, respectively. Areas under Eucalyptus plantation and rock out crop accounted for 1.28 and 3.30%, respectively, of the total area of the watershed in 2008. Within the last 51 years, the natural forest cover declined by 91.74%, the shrub land by 60.79%, and the grazing land by 39.47%, whereas the cultivated land increased by 14.75%. Between 1957 and 1982, and 1982 and 2008, the largest proportion of the natural forest land (49.21 and 39.63%), shrub land (79.99 and 49.80%), and grazing land (56.83 and 17.04%) were converted to cultivated land use. The implications of these changes suggest that the land use/cover changes have skewed to the rampant conversion of areas once covered with vegetation to cultivation without adequate use of soil and water conservation and rehabilitation practices.

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Introduction

Land is the major natural resource that economic, social, infrastructure and other human activities are undertaken on. Thus, changes in land use/cover have occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Lambin *et al*., 2003). These changes have beneficial or detrimental impacts, the latter being the principal causes of global concern as they impact on human well-being and safety.

Orchestrated by nexus of interacting natural and human drivers, such as construction of human settlements, government policies, climate change or other biophysical drivers (Riebsame *et al*., 1994; Lambin *et al*., 2003), land use/cover changes have significant impacts on land resources such as accelerated soil erosion and deterioration of nutrient status (Shibru *et al.,* 2003; Birru, 2007), and biodiversity, earth's climate, and hydrology (Turner *et al*., 1994; Abiy, 2010). By and large, land use/cover change is increasingly recognized as an important driver of environmental change on both spatial and temporal scales (Turner *et al*., 1994).

Ethiopia, situated in the horn of Africa, has a long history of intensive agriculture and human settlement particularly in the highlands due to the presence of favorable climatic and ecological conditions. However, the high population pressure and the concomitant depletion of the scarce resources have made agriculture of the country unsustainable, forcing its expansion into marginal areas such as steep slopes, swampy plains, and traditionally untapped part of the environment and putting tremendous pressure on soil, vegetation and water resources (Hurni, 1985). As a consequence, considerable land use/cover changes have occurred in Ethiopia during the second half of the 20th century (Solomon, 1994; Gete, 2000; Kebrom and Hedlund, 2000). The results of these studies have identified deforestation and encroachment of cultivation into marginal areas as the main agents of land use/cover change and land degradation in the highlands of Ethiopia.

Numerous studies (e.g., Gete, 2000; Kebrom and Hedlund, 2000; Belay, 2002; Woldeamlak, 2002; Kahsay, 2004; Tsegaye, 2009; Behailu, 2010; Efrem, 2010; Eyayu, 2010) conducted in different parts of Ethiopia have indicated the existence of considerable change in land use/cover over the past 30 to 50 years. Kebrom and Hedlund (2000) reported increases in cultivated and settlement land use at the expense of shrub lands and forests between 1958 and 1986 at Kalu area, north-central Ethiopia. Gete (2000) reported a significant increase in cultivated land at the expense of shrub lands and forests between 1957 and 1995 in the Dembecha area, northwestern Ethiopia. Similarly, Birru (2007) indicated that the grassland cover of the Lake Tana Basin declined continuously over the last 40 years. Tsegaye (2009) reported a considerable increase in agricultural land at the expense of dense forest land in Adaba Dodola, southern Ethiopia. A 90.6% increase in cultivated land between 1957 and 2003 at Tara Gedam, northwestern highlands of Ethiopia was reported by Eyayu (2010). Likewise, a study made by Abiy (2010) indicated a 44.53% increase in cultivated land at the expense of other land uses/land covers in the Antsokia-Gemza District, north-central Ethiopia. In line with this, Belay (2002) reported a serious trend in land degradation resulting from the expansion of cultivated land at the expense of forestlands in the Derekoli Watershed in South Wollo.

In contrast, Woldeamlak (2002) and Muluneh (1994) reported increments in wood lots (Eucalyptus tree plantations) and cultivated land at the expense of grazing land in both Sabat-bet Gurageland in south-central Ethiopia, and in the Chemoga River Watershed in north-western Ethiopia. Land use/land cover changes that occurred from 1971/72 to 2000 in Yerer Mountain and its surroundings indicated an increase in cultivated land leading in to a simultaneous reduction in the grassland areas

(Kahsay, 2004). In the semi-arid areas of the central Rift Valley of Ethiopia, in Keraru and Gubeta-Arjo, cropland area coverage has increased and woodland vegetation cover lost during the period from 1973-2000 (Efrem, 2010).

According to the Swiss National Centre of Competence in Research (NCCR) North-South Syndrome Pre-Synthesis Project; SPSP (Hurni et al., 2004), the highland areas of the Horn of Africa have for centuries been favourable places for settlement and agriculture, as the ecological environment is more favourable than in the surrounding lowlands. However, as time goes by, intensive agricultural use and expansion of cropland into marginal areas have led to severe degradation of the natural resource bases in large areas of these zones. Land is very scarce in many highland areas, leading to unsustainable land use practices. Research findings by Gete (2000), Amare (2007), Birru (2007), and Hurni *et al.* (2010), under the NCCR North-South Research framework that is the conflicting use of land resources in the highland-lowland problem context and/or upstream-downstream resource use, have indicated that dramatic land degradation has been recorded in the highlands of Ethiopia due to land use/cover changes.

Therefore, the need for rational planning of land use/cover development and optimal use of the land resources is evident. That's why precise and credible data on land use/cover change and their trends are necessary for understanding global, regional and local environmental problems (Milanova and Telanova, 2007). Information on land use/land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental protection, economic production, etc. Furthermore, documentation of the land use/cover change provides information for the better understanding of historical land use practices, current land use patterns and future land use trajectory. Therefore, identifying, delineating and mapping of the types of land use/cover are important activities in support of sustainable natural resource management (Zhang *et al.*, 2004).

Although a number of studies have been conducted on land use/land cover changes, it is still crucial to generate site-specific information on land use/cover dynamics to ensure planning of sustainable and integrated management of the land resources. In view of the dire need of this and the alarming rate of degradation of land resources in Ethiopia, this study was conducted to assess the patterns of spatial and temporal dynamics of land use/cover and its implication on the sustainable land management at the Debre-Mewi Watershed in the upper catchment of the Blue Nile Basin, Ethiopia. The results of this study are expected to add value to the ever growing database system in the area of landscape transformation as a result of conflicting land use changes across landscapes in the Ethiopian highlands.

Materials and methods

The study area

Debre-Mewi Watershed (DMW), is located between 11° 20' and 11° 21' N and 37° 24' and 37° 25' E, in the western plateau of the Ethiopian highlands at the northern source region of the Blue Nile River. It is about 30 km southeast of Lake Tana or Bahir Dar city, the capital of the Amhara National Regional State (ANRS), along the highway of Bahir Dar-Mota-Addis Ababa (Fig. 1). It is found mainly in Adet (southern part) and partly in Bahir Dar-Zuria (northern part) Districts of West Gojam Zone, ANRS. The elevation in the Watershed extends from 2200 to 2360 meters above sea level.

The study area is almost crater-shaped having an outlet in its southwestern part (Fig. 2). The eastern and northeastern view of the DMW along the main road to its outlet is nearly gentle followed by steep, moderately steep and gently sloping. In the north western side, it is almost the same scene with the earlier. The DMW is covered by recent deposits of

volcanic materials containing alkaline to transitional basalt parent materials with and chains of volcanic hills and gently sloping mountains (Anteneh, 2009).

According to Addisalem (2009), the soils of the study area consist of Eutric Vertisols (33.28%; 181.0 ha), Eutric Luvisols (24.83%; 135.0 ha), Pellic Vertisols (19.55%; 106.32 ha), Eutric Cambisols (8.29%; 45.1 ha), Eutric Fluvisols (7.43%; 40.4 ha) and Eutric Aquic Vertisols (6.62%; 36.0 ha). The Vertisols, Luvisols and Fluvisols are found in gently undulating lands, while the other soil types occupy the higher altitudes.

According to the Ethiopian agro-climatic zonation (MOA, 1998), the study area falls in the *Weyna Dega* (sub-humid) climatic zone. A twenty four year (1986-2010) climatic data from a nearby meteorological station (Adet, 2240 masl; 10 km south of the study area) recorded an average annual precipitation of 1,167.1 mm which is characterized by a uni-modal rainfall pattern (Figure 3). The mean annual temperature is 20.4 ^{o}C with mean annual maximum and minimum temperatures of 26.9 and 10.8 ^{o}C, respectively. The monthly mean temperature ranges from 17.2 ^{o}C in November and January to 22.1 ^{o}C in May.

The natural vegetation of the Watershed is characterized by very few forests at the eastern upland, scattered trees, and shrubs of different species. The dominant tree species of the natural forest are *Acacia abyssinica* Hochst and *Croton macrostachyus* Del., and the shrub species such as *Vernina amygdalina* Del., *Calpurnea aurea, Carissa edulis,* and *Bersama abyssinica*. In recent years, *Eucalyptus* growing by farmers has been increasing in the DMW. Subsistence agriculture is the main livelihood of the community and crop-livestock mixed farming system is predominant. Crop production in the Watershed is exclusively based on rainfed agriculture. There are grazing sites reserved at different locations of the Watershed. However, this land use is highly threatened by the growth of numerous gullies. The crops commonly grown in the order of decreasing area coverage are; *teff (Eragrostis tef)*, maize *(Zea mays),* grass pea (*Lathyrus sativus*), bread wheat (*Triticum aestivum*), faba bean *(Vicia faba)*, potato *(Solanum tubersoum)*, and hot pepper (*Capsicum frutescence*).

Table 1. Description of land use/cover classes in the Debre-Mewi Watershed.

Land use/cover	Description
Natural forest	Areas covered with forest of both natural indigenous tree and riverine vegetation species
Shrub and bush land	Land covered by shrubs and bushes and sometimes with scattered small trees mixed with grasses.
Grazing land	Land covered by grasses and used for grazing
Cultivated and settlement land	Areas used for rainfed crop production and scattered rural settlements usually associated with cultivated lands.
Eucalyptus plantation	Eucalyptus woodlots grown on small individual farm plots
Rock outcrop	Represents areas covered by rocks

Data sources and analysis

In this study, land use/cover changes were monitored at three period intervals (1957, 1982 and 2008). Data required for the study were generated from systematic analysis of two sets of panchromatic aerial photographs (December 1957 and January 1982) and a multi-spectral Land sat satellite image (Land sat-ETM, December, 2008). The boundary of the study area was delineated on a 1:50,000 topographic map (EMA, 1984).

Before interpreting the aerial photographs and satellite images, a reconnaissance survey was carried out in December 2010 to obtain general understanding of the land use pattern of the study area. Then, identification and classification of the land use/cover on the aerial photographs were monitored through intensive use of stereoscopic magnifying lenses, and six land use/cover categories were identified (Table 1). Since the scale of analysis made it difficult to separate rural dwellings from cultivated land, these were grouped into cultivated

and settlement land cover categories. The aerial photographs were scanned with 1,200 dots per 2.54 cm scanner and saved in a Tagged Image File (TIF) format. The scanned aerial photographs were digitized manually as polygon coverage and geo-referenced according to the Universal Transverse Mercator (UTM) system using Arc GIS 9.2 software. In the process of geo-referencing the photo mosaics, distinctive features such as roads and stream confluences that were clearly visible on the aerial photographs were used as control points.

For the year 2008, the multi-spectral land satellite image (Land sat-ETM, with a resolution of 30 m path 169 and row 152) was used. The land use/cover classes from the image were produced by visual interpretation and digitized on the basis of false color composites of each land use/cover classes. The accuracy of each of the six land use/cover classes from the images were validated by comparing ground reference points collected through extensive field visits (2010) guided by handheld Garmin 76 GPS (Global Positioning System) and topographic maps. Then, using line objects on a 50,000 scale topographic sheet, the images were adjusted and clipped to the frame that covers the study area. The Arc GIS 9.2 software made it possible to link the polygon lines to label the specific land use/cover classification and calculate the spatial statistics of each polygon. Environment for Visualizing Images 4.3 software was used for spatial database processing. Finally, three land use/cover maps were produced corresponding to the three periods (1957, 1982 and 2008). Focused group discussions were also made with ten farmers (3 of them are women) selected by the local people; two development agents and three *Kebele* (village administrative structure) Cabinet Members to obtain additional information on historical and current changes in land use/cover types including both causes and effects. Information from the oldest key informants (age around 80) were also gathered and crosschecked with information provided by younger ones.

Results and discussion

Types of land use/cover in Debre-Mewi watershed

Analysis of the 1957 and 1982 aerial photographs, and 2008 satellite images confirmed the existence of six major land use/cover types (natural forest, shrub and bush land, grazing land, cultivated and settlement land, Eucalyptus plantation, and rock outcrop) in DMW (Table 2 and Figs. 4, 5 and 6). The cultivated and settlement land accounted for 71.04, 77.83, and 81.51% of the total area of the Watershed in the years 1957, 1982 and 2008, respectively (Table 2). On the other hand, the vegetated land, which comprises the natural forest, the shrub and bush land, grazing land, and Eucalyptus plantation, overall accounted for only 28.96, 22.17, and 15.18% of the total area of the Watershed in the years 1957, 1982 and 2008, respectively. During the three periods, the natural forest accounted for 4.48, 1.30, and 0.37%; shrub and bush land for 6.10, 6.01, and 2.39%; and grazing land for 18.39, 14.86, and 11.14%, area of the Watershed, respectively. Between 1982 and 2008, Eucalyptus plantation that accounted for 1.28% of the total area of the Watershed was established by most individual farmers around their homesteads as a source of fuel wood, construction material and income generation.

Table 2. Land use/cover types and areas covered by the respective land use type in the Debre-Mewi Watershed in three different periods (1957, 1982 and 2008).

Land use-cover type	Area covered by respective land use/cover type					
	1957		1982		2008	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Natural forest	24.34	4.48	7.09	1.30	2.01	0.37
Shrub and bush land	33.15	6.10	32.67	6.01	13.00	2.39
Grazing land	100.01	18.39	80.82	14.86	60.60	11.14
Cultivated & settlement land	386.32	71.04	423.25	77.83	443.29	81.51
Eucalyptus plantation	-	-	-	-	6.98	1.28
Rock outcrop	-	-	-	-	17.95	3.30
Total	543.82	100.0	543.82	100.0	543.82	100.00

Table 3. Land use/land cover changes in the Debre-Mewi watershed for the periods between 1957 and 1982, 1982 and 2008, and 1957 and 2008.

Land use/land cover type	Change in land use area (ha and %) coverage; gain (+) or loss (-)					
	1957 - 1982		1982 - 2008		1957 - 2008	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Natural forest	-17.26	-70.87	-5.08	-20.87	-22.27	-91.74
Shrub & bush land	-0.48	-1.45	-19.67	- 59.34	-20.15	-60.79
Grazing land	-19.19	-19.19	-20.22	-20.22	-39.41	-39.47
Cultivated & settlement	+36.93	+9.56	+20.04	+5.19	+56.97	+14.75
Eucalyptus plantation	-	-	+6.98		6.98	
Rock outcrop	-	-	+17.95		17.95	
Total	0		0		0	

Table 4. Land use/land cover transformation proportions in the Debre-Mewi Watershed for the periods from 1957-1982 and 1982-2008.

Land use/ cover type	Changed to	1957-1982		1982-2008	
		Area (ha)	Area (%)	Area (ha)	Area (%)
Natural forest	Shrub and bush land	1.52	6.25	-	-
	Grazing land	3.76	15.45	1.29	18.19
	Cultivated and settlement	11.98	49.21	2.81	39.63
	Eucalyptus plantation	-	-	0.98	13.82
	Unchanged	7.08	29.13	2.01	28.35
Shrub & bush	Grazing land	0.58	1.74	2.64	8.07
	Cultivated and settlement	26.38	79.99	16.27	49.80
	Rock outcrop	-	-	0.77	2.35
	Unchanged	6.19	18.27	13.00	39.79
Grazing land	Shrub and bush land	4.10	4.10	-	-
	Cultivated and settlement	56.84	56.83	13.77	17.04
	Eucalyptus plantation	-	-	1.00	1.24
	Rock outcrop	-	-	11.07	13.69
	Unchanged	39.08	39.07	54.98	68.03
Cultivated & settlement	Shrub and bush land	20.85	5.40	-	-
	Grazing land	37.41	9.68	1.69	0.40
	Eucalyptus plantation	-	-	5.00	1.18
	Rock outcrop	-	-	6.12	1.45
	Unchanged	328.05	84.92	410.44	96.97
Total		543.82		543.82	

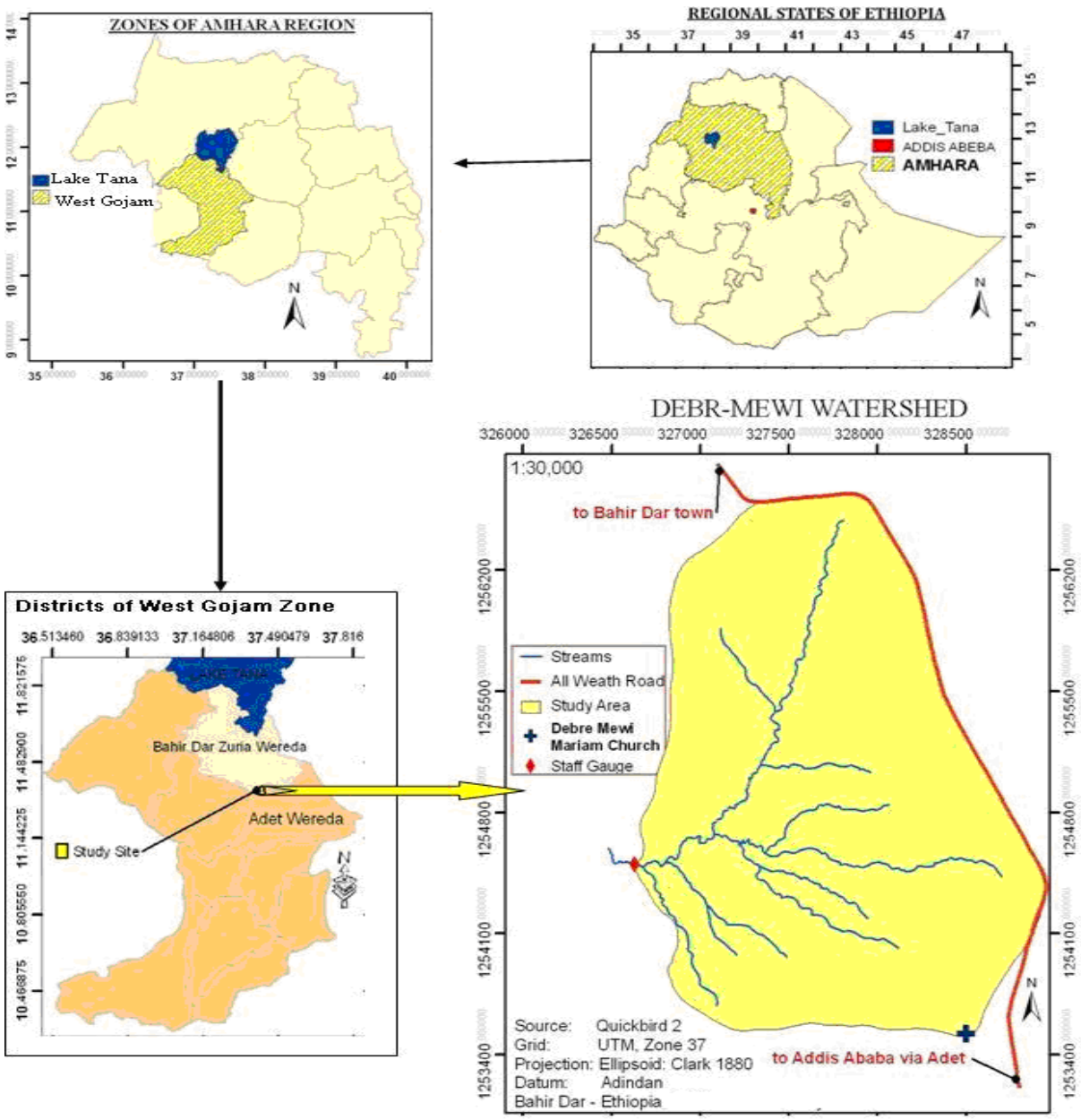

Fig. 1. Location map of Debre-Mewi watershed.

After 1982, some of the severely degraded cultivated and grazing lands were converted to rock outcrop, which constituted 3.30% of the total area of the Watershed. Furthermore, the expansion of the cultivated and settlement land did not stop after 1957 and resulted in extensive conversion of most of the natural forest land, shrub & bush land, and the grazing land cover to cultivated & settlement land.

Extent and type of land use/cover change

In all the periods considered in this study, the cultivated and settlement land was the dominant type of land use/cover in the DMW. This clearly indicates that the currently cultivated land was already under cultivation many years back, which is true for most highlands of Ethiopia (e.g., Crummey, 1998). Between 1957 and 1982, the primary natural forest decreased by 70.87% of its original cover whereas the grazing land and Shrub & bush land

registered a net loss of 19.19 and 1.45% of their original area respectively (Table 3). On the contrary, the cultivated and settlement land increased in extent by 9.56%. This means that deforestation of the natural forest was occurring at an average annual rate of 2.95% resulting in average loss of 0.72 ha of forest cover per annum. Similarly, the loss of the grazing and shrub land took place at 0.80 and 0.06% resulting in average loss of 0.80 and 0.02 ha of these vegetation covers, respectively. These results suggest that there has been substantial deforestation, particularly of the natural forest, in the area during this period. As a result, the cultivated and settlement land expanded at a rate of 0.40% per annum resulting in conversion of 1.54 ha of the natural forest into cultivated and settlement land per annum.

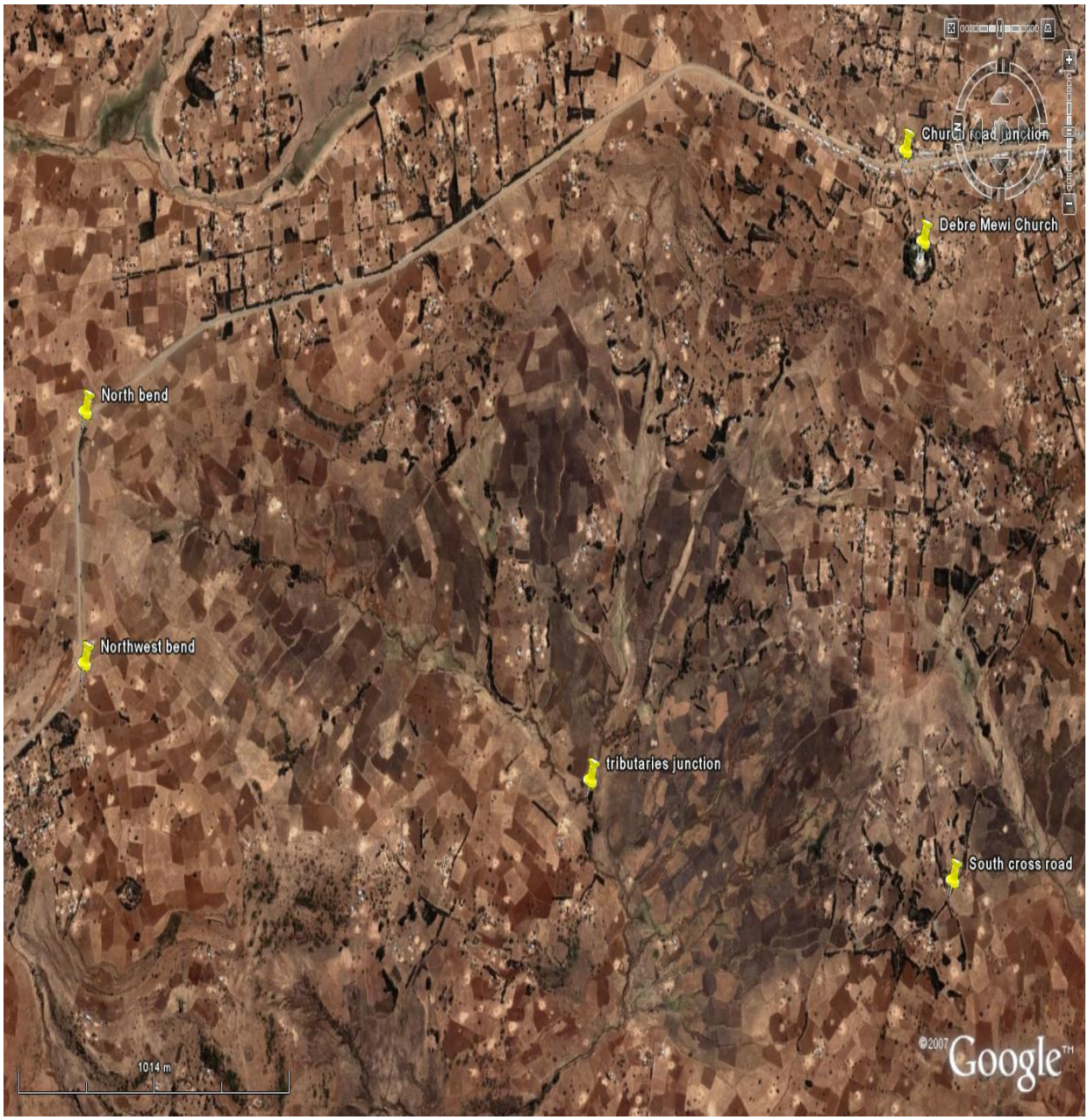

Fig. 2. Aerial view of the landscape of Debre-Mewi Watershed (image from Google Earth, 2007).

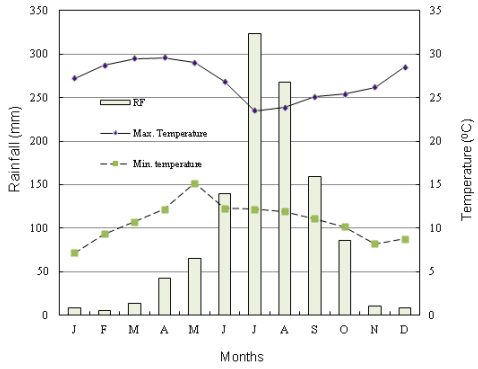

Fig. 3. Mean monthly rainfall (RF), maximum and minimum temperatures (Temp) of the Debre-Mewi Watershed (1986 -2010).

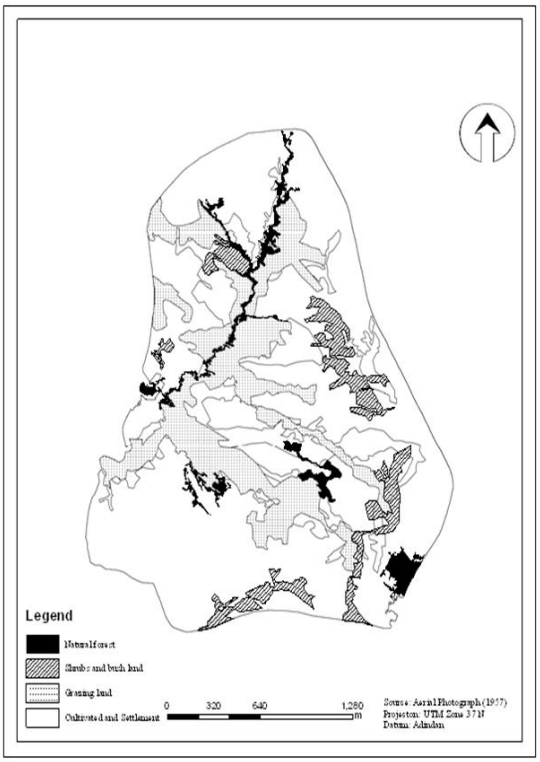

Fig. 4. Land use/cover map of the Debre-Mewi Watershed in 1957.

The enormous deforestation and conversion of the land under natural vegetation into cultivated and settlement land continued between 1982 and 2008 notwithstanding with relatively reduced magnitude. Following this, the cultivated and settlement land expanded by 5.19% whereas the grazing land, and the shrub and bush land contracted by 20.22 and 59.34%, respectively. These figures suggest that the shrub and bush land contracted at a much higher rate (at an average rate of 2.23% per year) than that between the 1957 and 1982 period. Nevertheless, the rate at which the grazing land shrunk between 1982 and 2008 was nearly the same as that between 1957 and 1982. Similarly, the rate of decline of the natural forest (20.87%) was insignificant (taking place at an average rate of 0.19 ha per year) compared to the huge reduction in extent that took place between 1957 and 1982 (Table 3).

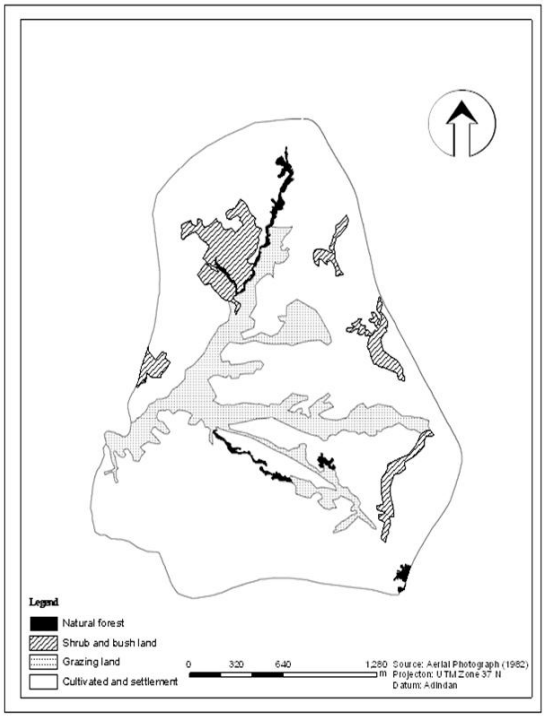

Fig. 5. Land use/cover map of the Debre-Mewi Watershed in 1982.

Furthermore, the results of analysis of the land use/cover data of the three years indicated that there existed considerable conversions and modifications of one type of land use/cover into another one in the Watershed (Table 4). These are believed to be the major contributing factors for the general decline in vegetated lands and increase in the area put under cultivation and settlement use. Accordingly, the high rate of contraction in natural forest cover between 1957 and 1982 was due to its conversion/modification into cultivated and settlement land (49.21%), grazing land (15.45%), and shrub land (6.25%). Similarly, the shrub and bush land declined due largely to its conversion into

cultivated and settlement land (79.99%), and to a lesser extent to grazing land (1.74%). Besides, the grazing land also shrunk due to its conversion to cultivated and settlement land (56.83%), and shrub land (4.10%). All these conversions imply that the largest proportion of the natural forest land, grazing land, and shrub and bush land were lost to cultivated and settlement land, indicating the immense pressure the ever increasing population of the area has put on the natural resource-base of the watershed.

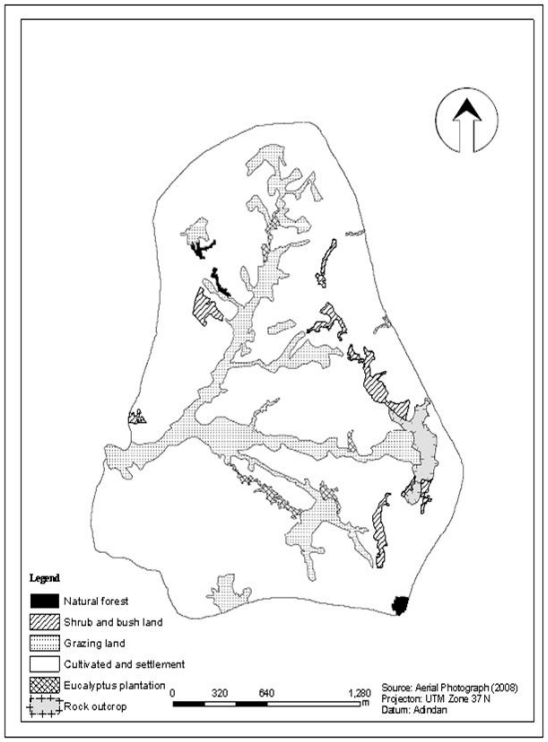

Fig. 6. Land use/cover map of the Debre-Mewi Watershed in 2008.

Similarly, between 1982 and 2008, the conversion of vegetated lands to cultivated and settlement land continued albeit modestly. The large proportion (39.63%) of the remaining small area of the natural forest, which probably was riverine vegetation, was converted into cultivated and settlement land followed by its modification to grazing land (18.19%). Further, the relatively large decline in shrub and bush land was attributed to its conversion to cultivated land (49.80%), grazing land (8.07%), and rock outcrop (2.35%). Similarly, the expansion of cultivated and settlement land continued to the grazing land even during this period, taking away 17.04% of the total grass land area. A sizeable proportion of the grazing land was also converted to rock outcrop (13.69%) and a very small proportion (1.24%) was revegetated by Eucalyptus plantation planted around the homesteads of individual farmers.

During the three consecutive periods, the cultivated land was also converted into other forms of land use/cover. Consequently, 9.68 and 0.40% of the previously cultivated land was converted to grazing land between 1957 and 1982, and 1982 and 2008, respectively. Similarly, 5.40% of the cultivated land was changed into shrub land between 1957 and 1982. During the same period, 1.45 and 1.18% of the cultivated land was converted into rock outcrop and Eucalyptus plantation, respectively.

Over the last 51 years, the cultivated and settlement land has expanded by an average rate of 0.29% per year, taking 1.12 ha per year from the other land use/cover types of the Watershed. On the other hand, the grazing land has shrunk by 0.77% per year, losing 0.77 ha every year. The shrub and bush land has also registered a considerable loss of 1.19% per year, resulting in an average loss of 0.40 ha every year. Of all the vegetation covers, the natural forest cover was the most affected one. This land cover declined annually by about 1.80%, resulting in an annual loss of 0.44 ha of the original forest cover.

The large-scale conversion of the natural forest, shrub and bush land, and grazing land to cultivated and settlement land could be attributed to the high demand for agricultural land and construction of human settlement, presumably associated with the high population growth in the area (Woldeamlak, 2003; Hurni, 1993; Mortimore, 1993; Solomon, 1994). Change in government policies (Riebsame *et.al*, 1994; Lambin *et al*., 2003), which may lead to national-level land reform and allocation of land under natural vegetation to young landless farmers,

might have also contributed to the increase in cultivated and settlement land cover (Yigremew, 1997; Woldeamlak, 2003). The encroachment of agriculture to these marginal areas, in turn, might have led to accelerated soil erosion (Gete, 2002; Shibru *et al*., 2003; Birru, 2007) and development of deep and wide gulley (Figure 7) that were observed during the field survey. The large-scale change in land cover that has occurred in the watershed can also affect processes at the earth's surface and result in change in climate and hydrology (Turner *et al*., 1994) of the Watershed.

Fig. 7. Livestock management and its consequences on land degradation in the Debre-Mewi watershed.

The findings of this study are in consent with the findings of many other studies made in different parts of the country, which reported a significant decline of forest and shrub land cover due to its conversion to other land uses particularly to cultivated and settlement land (Kebrom and Hedlund, 2000; Gete and Hurni, 2001; Belay, 2002; Tsegaye, 2009; Efrem, 2010; Eyayu, 2010). Furthermore, the field observations and discussions made with the local farmers suggest that shortage of land for crop production and grazing compelled farmers to expand agriculture to the steep slopes that are vulnerable to degradation. In support of this observation, Hurni (1985) indicated that high population pressure often leads to expansion of agriculture into marginal areas that are prone to degradation.

In line with the findings of this study, Kahsay (2004) and Amsalu (2006) attributed the decline in grassland cover to expansion of cultivated and settlement area driven by increasing human population. This phenomenon is especially common in the northwestern parts of Ethiopia where grazing lands are increasingly being transformed to cultivated and settlement land due to population pressure (Lakew *et al.,* 2005; Woldeamlak 2003). The conversion of the grazing lands into cultivation and settlement land in turn creates scarcity of grazing land for livestock. This scarcity has further led to the modification of natural forest, and bush and shrub land to grazing lands. In support of the findings of this study, Betru, (2002), Woldeamlak (2003), Amare, (2007) and Hurni *et al.* (2010)

reported that over grazing due to very high livestock population density is one of the major contributing factors to the extensive land degradation observed in most parts of the ANRS (Figure 7).

The land use/cover types identified as rock outcrops were created as a result of, among others, the interacting effects of the limited vegetation cover, intensive and continuous cultivation with no crop rotation and expansion of agriculture into the steep slopes, trampling of soil by livestock during post harvest grazing and concentration of these animals on pocket hillsides during wet season, and overgrazing due to reduction of grazing land (Betru, 2002; Amsalu, 2006). As a consequence, some of the cultivated and grazing lands were severely degraded to the extent that no vegetation could grow. Some of these lands were actually converted into very wide and deep gullies. Discussions made with the local people also suggest that the problem of such land degradation was exacerbated after grazing and cultivation were started on the very steep slopes. In favor of the findings of this study, Betru (2002) indicated that reduction of grazing land could lead to overgrazing that paves the way for accelerated erosion, which may lead to the development of severe gullies.

The other consequence of conversion of the natural forest, and shrub and bush land is shortage of woody vegetation for firewood and construction. This problem was eminent in the DMW. In response to this growing scarcity of woody vegetation, farmers started to grow eucalyptus around their homesteads. This increased areal coverage of Eucalyptus plantation in response to growing scarcity of natural forest was reported by Woldeamlak (2002, 2003) and Muluneh (1994).

Land use/cover changes and the need for sustainable land management options

As shown in the section above, there have been land cover changes in the study area during the last 51 years. Based on this change, the current status (2008) of natural forest, shrub, grazing lands, eucalyptus plantation and rock outcrop accounted for 0.37, 2.39, 11.14, 1.28 and 3.30 % of the total study area, respectively. Of the total watershed area cultivated and settlement land cover accounted for 71.04, 77.83, and 81.51 percents in the year 1957, 1982, and 2008, respectively.

One of the immediate impacts of destruction of forest cover is shortage of fuel wood and construction materials for the farming community. This condition forces farmers to burn crop residue and organic manure for cooking and heating. This resulted in depletion of organic matter in cultivated lands. People in the study area have indicated that in recent years, the fertility of the soil has worsened in almost all parts of the Watershed. As the land becomes more fragmented and more continuously cultivated, soil might also run the risk of becoming degraded (Ovuka, 2000). Through centralized, top-down approach, experts who instruct farmers to introduce 'their' soil conservation innovations could not earn acceptance from the farmers (Azene, 1997, 2001). Field observation and discussion with farmers suggest that shortage of land compelled farmers cropping and cultivating steep slope lands that are vulnerable to degradation. All these suggest the need for participatory sustainable land management options in the study area.

Conclusions

Land use/cover changes that have been occurring in Debre-Mewi Watershed between 1957 and 2008 indicated that the area under natural forest, shrub and grazing lands were declining continuously. On the other hand, cultivated and settlement land was the main land use type over the study period kept on expanding dramatically. Even though land under cultivation was very large in the area during the 1950s that was about 70%, its expansion is still a very important concern. This result showed that the removal of natural forest, shrubs and grasses and replacement with annual crops causes serious land degradation by converting some steeply sloping

lands into rock outcrops, and waterways into gullies. Therefore, sustainable land management systems and practices such as proper land use system, soil and water conservation practices, and diversification of off-farm livelihoods are urgent need for the study area. In conclusion, the results of the present study will provide useful base line information to understand the magnitude and implications of land use/cover changes, on land resource degradation whereby planning sustainable land management are possible.

Acknowledgements

The authors acknowledge the financial support provided by the Haramaya University. They also recognize the Bahir Dar University, Amhara Region Agricultural Research Institute and Adet Agricultural Research Center for their cooperation during the implementation of this study. They also thank Sosina Getachew for covering the expense of publishing the article and the local residents of the study area for their enthusiastic participation in the interviews and group discussions.

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