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Research Application Summary

Land use and land cover dynamics in Ethiopia: a review

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Abstract

The objective of this review paper is to examine time series land use land cover change in Ethiopia. In the country, most Land Use and Land Cover (LULC) change studies have conducted at catchment level less than 43810 ha. It is thus difficult to understand national level LULC dynamics and its associate environmental impacts. The review result indicated that dramatic land use and land cover change trajectory has occurred in different parts of Ethiopia, resulting in the decline in forest, protected area, and grasslands, whereas cropland has increased. In the northern, northeast and central highlands of the country, LULC change was noticed since early1860s as the photographs indicated agricultural land expansion, fuelwood collection and grazing pressure which have been practiced for more than three millennia. Although forest clearance leading LULC change started since about 1850, it has recently been accelerating in southwestern Ethiopia following immigration and settlement. New causes of LULC change have appeared in southwest lowlands as a result of population growth driven agricultural land expansion, government initiated medium to large scale agricultural investment, fuelwood and charcoal production for selling and settlement. Consequently, the conversion of LULC has had several impacts on the environment; particularly land conversion from forest to agricultural land has contributed to emission of C, loss of biodiversity and land degradation. In conclusion, proper interventions are needed to reduce these adverse effects of trade-off between natural resources base and economic development strategies, particularly agricultural investment.

Key words: Environmental change, Ethiopia, land degradation, settlements

Résumé

L'objectif de cet article de synthèse est d'examiner les séries chronologiques des changements d'utilisation et de couverture des sols en Ethiopie. Dans ce pays, la plupart des études sur les changements d'utilisation et de couverture des sols (LULC) ont été menées au niveau de bassins versants de moins de 43810 ha. Il est donc difficile de comprendre la dynamique de l'utilisation des terres et de la couverture des sols au niveau national et les impacts environnementaux qui y sont associés. Les résultats de l'étude indiquent que des changements spectaculaires dans l'utilisation et la couverture des sols ont eu lieu dans différentes parties de l'Éthiopie, entraînant le déclin des forêts, des zones protégées et des prairies, tandis que les terres cultivées ont augmenté. Dans les hauts plateaux du nord, du nord-est et du centre du pays, le changement d'occupation des sols a été remarqué depuis le début des années 1860, les photographies indiquant l'expansion des terres agricoles, la collecte de bois de chauffage et la pression exercée par les pâturages, qui

sont pratiqués depuis plus de trois millénaires. Bien que le défrichement des forêts ait entraîné une modification du LULC depuis environ 1850, il s'est récemment accéléré dans le sud-ouest de l'Éthiopie suite à l'immigration et à la colonisation. De nouvelles causes de changement du LULC sont apparues dans les plaines du sud-ouest en raison de l'expansion des terres agricoles liée à la croissance démographique, des investissements agricoles à moyenne et grande échelle initiés par le gouvernement, de la production de bois de chauffage et de charbon de bois pour la vente et l'installation. En conséquence, la conversion du LULC a eu plusieurs impacts sur l'environnement ; en particulier, la conversion des forêts en terres agricoles a contribué à l'émission de carbone, à la perte de biodiversité et à la dégradation des sols. En conclusion, des interventions appropriées sont nécessaires pour réduire ces effets négatifs du compromis entre la base de ressources naturelles et les stratégies de développement économique, en particulier l'investissement agricole.

Mots clés : Changement environnemental, Éthiopie, dégradation des terres, établissements humains

Introduction

The growing human population associated with increased demand for food and settlements has substantially altered the natural environment and thus this process on the earth surface influences climate systems, which in turn affect the earth system. Despite natural process contribution, human made land use and land cover (LULC) change has been recognized as the primary contributor to land use and cover changes. As a result, this transformation of natural system affect climate parameters including CO_2 cycle, hydrological cycle and the quality and quantity of ecosystem provisions (Matthews, 1983; Foley *et al.,* 2005), and influences the ground water system (Scanlon *et al.,* 2005). Besides, woody vegetation in sub Saharan Africa has declined to 11% and the climate zone has shifted to drier zones due to human activities (Brandt *et al.,* 2017). Subsequently, these continuous changes are a potential source of environmental change in the present and future.

In Ethiopia, particularly in the Northern and Northeast, LULC/deforestation driven land degradation is an old phenomena and might be related to the country's civilization. There is a limited written documention in relation to the past environmental history/natural resource management. Pankhurst (1995) and McCann (1997) tried to assess deforestation history narrative, using both past traveler memory and ground based photographs, and the result show that vegetation cover changes started early. Bonnefille and Hamilton (1986) reconstructed the pattern of vegetation dynamics in the southwest lowland and highlands based on Macrofossils and pollen dated from 3 to 1.5 million years. Similarly, historical reconstructed result using pollen diagram revealed that there was vegetation cover change and decline between 1700 and 1820 in Ashenge Lake, northern Ethiopia (Lanckriet *et al.,* 2015). Between 1800 and 1990, the predominant farming system, mainly ox-plow, brought significant changes on the highland vegetation covers (McCann, 1995). As a result, most of the northern highlands' dry evergreen forests, grasslands and a large part of the moist evergreen forests have changed to open farm and pasture lands (McCann, 2017).

During Emperor Haile Selassie I regime (1930-1974), extensive deforestation took place subsequent to the promulgation of forest legislation because it placed all large forests under State ownership. Thus, State natural resource policy was responsible for aggravating the process of land degradation (Ibid). Although Derg regime (1975–1985) endorsed tree planting, deforestation

continued due to establishment of State farms, settlements, villegization and hence exacerbated the environmental degradation (Dechassa, 2015; Hassen, 2018). Federal Democratic Republic of Ethiopia government also conducted settlement programs to alleviate food insecurity, reduce land shortage and drought especially during 2003 to 2005. Besides, Growth and Transformation Plan encouraged the establishment of medium-sized and large commercial farms in the lowlands for crop production and biofuels. In line with this more than 1.2 million ha of land was transferred to both domestic and foreign investors between 2004 and 2008 (Mousseau and Sosnoff, 2011; Stebek, 2011; Franks *et al.,* 2017).

Thus, dynamics of the aforementioned LULC change has contributed to changes in the natural system. Despite environmental change modeling conducted globally, human induced historical LULC change which are used for modeling has not yet been conducted at country level in Ethiopia. Fragmented LULC change studies, however, are undertaken here and there. Compiling these available studies at small scale level is important to obtain a sound picture which represent national scale. To the best of our knowledge, such a review has not been conducted in Ethiopia. Yet such information can be used to understand the driving forces of LULC change since in the past and present, the rates and locations of changes; impacts on earth natural system and global carbon balance. The objective of this paper, therefore, is to review the dynamics of land use and land cover changes in Ethiopia with the following basic questions: Where has land use and land cover changes happened in the past? What are the general trends of land use and land cover changes in Ethiopia? What have been the main drivers for land use and land cover change in the past, and how have they changed over time? What have been the environmental impacts of LULC changes into natural habitats at different scales in Ethiopia?

Methods

This review was undertaken through analysis of LULC change studied using global as well as country level studies, mostly of catchment level. Although the review included old study references, most LULC change studies in Ethiopia started recently using 1957 satellite image datasets. Few studies were also conducted by ground based photograph analyses and Participatory GIS application method in Northern highlands of Ethiopia.

Land use and land cover change studies conducted in Northern highlands, Northwestern lowlands and highlands, western lowlands, southwest lowlands and highlands, Central Rift Valley, Southeast highlands, Central highlands and Northeast highlands of Ethiopia were compiled. In each location more than two studies were used as representative to make a good picture and highlight the characteristics and major driving forces of LULC changes. A total of 76 published articles related to the broader topics of LULC dynamics, causes and environmental impacts were compiled for this review which is lower than that used by Muluneh and Arnalds (2010).

In Ethiopia, most LULC change studies were conducted at catchment level covering less than 43810 ha except in the studies of Emiru and Taye (2014) and Degife *et al.* (2018), who covered 0.1x106 and 2.55x106 ha, respectively. In addition, the definition of LULC types in each study is varied which makes it difficult to obtain uniform picture. Considering such inconsistency of definition, we identified few LULC types that have common definition across the studies as well as following studies published in repeatable journal (eg. see in Minta *et al.,* 2018). In this

review, grass lands encompasses grazing and lands that has scattered trees dominating by grass whereas woodlands and shrublands were merged into woodland vegetation. Hence, the LULC types used in this review are natural forest lands, plantations, grass and grazing lands, woodland and shrublands, and croplands. Despite insufficient scientific information reviewed, the compiled data can still be used to demonstrate the spatio-temporal patterns of LULC change in the country.

Synthesis of the findings

Land use and land cover dynamics. Land use and land cover dynamics studies provide information about historical and spatial pattern of earth system as well as cause-effect for understanding of global change and climate change modeling. Despite this, the first attempts in Ethiopia were started only recently by Matthews (1983), who presented global vegetation and land use database in digital form for climate study. Recently, LULC change studies have widely been undertaken worldwide to demonstrate the impact of LULC change resulting from human activities on the past and future global climate changes (Matthews, 1983) and used for modeling global environmental change (Goldewijk, 2001; Song *et al.,* 2018). Besides, estimation and mapping of global LULC change is also important to charaterize biodiversity loss and ecosystem deterioration (Foley *et al.,* 2005; Nelson *et al.,* 2010; Brandt *et al.,* 2017; OECD, 2018), global greenhouse gases emission (Fearnside, 2000; IPCC, 2014), and global surface attributes including earth surface albedo, radiation balance and changes in climate (IPCC, 2014).

Table 1 provides a summarized historical global LULC conversions. Despite the varied estimates of LULC change between studies in the same year, global agricultural lands including crop and pasture land have substantially increased. According to Ramankutty *et al.* (2008) estimates, croplands and pasture lands covered 15 million km^2 and 28 million km^2 during 2000, respectively. This is consistent with estimates in other studies (Matthews, 1983; Ramankutty and Foley, 1999; Goldewijk, 2001; Ramankutty e*t al.,* 2008; Goldewijk *et al.,* 2011; Meiyappan and Jain, 2012), who reported that majority of LULC conversion was carried out between 1990 and 2000 (Table 1). However, the estimate of cropland was 17.6 million km^2 in 1980 (Matthews, 1983) which was higher compared to Goldewijk (2001) estimate of 14.7 million km^2 in 1990. Other recent estimates (Ramankutty *et al.,* 2008; Goldewijk *et al.,* 2011; Meiyappan and Jain, 2012) indicate that cropland was about 15 million km^2 in 2000. This variability or uncertainty of LULC changes estimate might be associated with approaches used to reconstruct historical LULC change including common usage of potential vegetation map, rule-based approach to prioritize land-cover change, and land use data sets used as inputs (Meiyappan and Jain, 2012) which need further efforts to improve the estimates.

Although this available global land use and land cover change is advantageous, the estimates has faced uncertainty associated with scarcity of adequate subnational historical inventory data; downscaling of the regional data to solve this problem and others constraints were proposed (Goldewijk, 2001; Meiyappan and Jain, 2012). In Ethiopia, for instance, almost all land use and land cover change studies were done at catchment level (Muluneh and Arnalds, 2010; Hailu *et al.,* 2018) which suggests that national land use data sets might not be well established. As a result, national level historical land cover change and land use conversion have not yet been well estimated and reconstructed for environmental change modeling and vegetation dynamics studies.

Table 1. The summarized trends and extent of global land use and land cover changes

Reference year	Forest/woodlands	Savana /Grass lands	Shrublands	Plantation	Crop lands	Pasture	Urbanization
			Matthews (1983) (unit: million km^2)				
Pre-agricultural	61.5	33.9	13	-	0.9	-	-
1980	52.4	27.4	12.1	-	17.6	-	-
			Ramankutty and Foley (1999) (unit: million km^2)				
Undisturbed	55.3	33.4	17.9	-	0.0	-	-
1700	52.8	32.3	17.4	-	4	-	-
1850	49.9	31.4	17.1	-	8.2	-	-
1992	43.9	26.7	15.9	-	20.3	-	-
			Goldewijk (2001) (unit: million km^2)				
Undisturbed	58.6	34.3	9.8	-	0.0	0.0	-
1700	54.4	32.1	8.7	-	2.7	5.2	-
1850	50.0	28.7	6.8	-	5.4	12.8	-
1990	41.5	17.5	2.5	-	14.7	31.0	-
			Goldewijk *et al.* (2011) (unit: million km^2)				
1700				-	3	3.24	-
1900				-	8.5	12.9	-
2000				-	15.3	34.3	-
			Meiyappan and Jain (2012) (unit: million km^2)				
1765	45.4	33.7	16.9	-	3.5	4.2	0.0
1900	37.7	31.6	14.6	-	8	12.7	< 0.1
2000	29.5	22.8	8	-	14.8	32.1	0.4
2005	29.4	22.9	8	-	15	31.9	0.5

Land use and land cover changes across the regions in Ethiopia. In the northern highlands of Ethiopia, land management and vegetation trends have been analyzed based on ground based photograph taken at different intervals such as 1868 and 2008 (Nyssen *et al.,* 2009), and 1975 and 2006 (Munro *et al.,* 2008). In their studies, the comparison of the results revealed promising vegetation recovery although land degradation, as a result of LULC changes, started about 1868 as the photographs indicate. Pankhurst (1995) also stated that the first wildlife destruction started since the eighteen century in Northern Ethiopia and later in the southern part of the country. In north Ethiopia, small scale study using Participatory GIS method indicated that 75% of forest and 11% of grazing land were converted to cropland about 50 years ago (Aynekulu *et al.,* 2006). Hence, historical evidences show that LULC change is an old phenomena which may have started since Ethiopian civilization.

As the result of European intrusion into Ethiopia LULC changes resulted in agricultural land expansion for increasing provisions to soldiers and firewood demand, and this occurred in northern, northwestern and central highlands of Ethiopia, particularly in and around the settlement areas (Pankhurst, 1995). Table 2 shows the four decade phenomena of LULC changes in northwest part of the country. In this region, most of the land use and land cover changes trajectory occurred between 1957 and 1982, for instance, 93.8% of forest were lost or converted to other land uses whereas cultivated lands increased by 78.0% (Zeleke and Hurni, 2001). Similarly, LULC change has continued, particularly, substantial amount of forest and grasslands were converted to other uses. Demissie *et al.* (2017) estimated that as much as 45.3% of forest land was converted to cropland whereas the size of degraded lands increased until 2015. This implies that despite the knowledge that environmental impact of LULC changes have been well recognized, the practice has continued in the country because of cultivation for long periods mainly in the highlands, and this has resulted in decline in the quality of soil physiochemical properties (Lemenih *et al.,* 2005). According to Zeleke and Hurni (2001) report, however, the forest cover of Dembecha increased to 2% in 1995 due to afforestation.

Table 2. The historical trends of land use and land cover changes in Northwest Ethiopia

Sources	Year covered	Forest lands	Grass/ grazing lands	Woodland / shrublands	Crop lands (ha)	Area covered
Demissie *et al.* (2017)	1973	4758	12050		6961	26580.9 ha
	1985	2969	11495		8925	
	1995	1687	9933		10975	
	2003	1234	7993		13251	
	2015	845	7083		14804	
Tadesse *et al.* (2017)	2001	1509	4887		15085	
	2010	643	5590			
	2015	1255	5266			
Zeleke and Hurni (2001)	1957	7342	7544		10692	27103 ha
	1982	452	5579		19031	
	1995	82	4063		20893	
Alemu *et al.* (2015)	1985		180422	850148	253093	3 districts were covered
	1995		173868	780511	312500	(lowlands)
	2010		172990	621420	432455	

Although LULC change has occured in the highlands, recently it is also a major challenge in the lowlands of Ethiopia. This is because of agricultural intensification resulting in declining soil fertility in the highlands (Taddese, 2001; Lemenih *et al.,* 2005), leading to migration of people in search of additional land (Lemenih *et al.,* 2014). Further, government initiatives such as the growth and Transformation Plan has put in place large scale agricultural investment for the production of export crops and biofuels. In line with this, from three districts LULC change analyses, 21.5% of woodlands and shrublands (Table 2) were converted to other LULC types while agricultural lands increased by 38.4% between 1995 and 2010 in northwest Ethiopia (Alemu *et al.,* 2015).

Table 3. The historical trends of land use and land cover changes in Southwest Ethiopia

Sources	Coverage year	Forest lands	Grass/grazing lands	Woodland / shrublands	Crop lands	Area coverage	
Azeb *et al.* (2018)*	1987	4188	13716		2121	25,521 km^2	Gambella at regional level
	2000	4524	10704		2095		
	2017	3948	9112	-	2694		
Emiru and Taye (2014)	1957	5200	10500	58700	12200	100500 ha	Benishangul Gumuz at district level
	1982	2598	5858	49361	34534		
	2006	0	45	24423	64800		
Dessie and Kleman (2007)	1972	48924	-	-	-	in ha	South Central Rift Valley at watershed
	2000	8600	-	-	-		
Gebreslassie (2014)	1973	4714	6407	5097	5525	21831 ha	Central Rift Valley at watershed level
	1980	2246	5036	5262	8199		
	2000	1233	2512	4843	12735		
	2009	322	772	1229	18142		

Although forest clearance leading LULC change started since 1850 (Bonnefille and Hamilton, 1986; Pankhurst, 1995; McCann, 1997), the conversion of natural earth system, including natural forest, to mainly agricultural lands in southwestern Ethiopia has accelerated recently following environmental-induced land degradation, drought and famine in the northern and central highlands of the country. In line with this 80% of natural forests in Sheki village, one of the settlement areas, were converted to other LULC types due to resettlement of mass migrants and indigenous peoples changing their farming practice between 1957 and 2007 (Getahun *et al.,* 2017). According to Reid *et al.* (2000), the crop land expansion between 1987 and 1993 actually started two decades ago (1957-1973). In South Central Rift Valley, about 40324 ha of forest lands were converted to mainly agricultural lands (Table 3) of which 17% was reforested between 1972 and 2000 (Gessesse and Kleman, 2006).

Furthermore, government development policy, agricultural industrialization thrust achieved through increasing large scale agricultural investment, is a new emerging challenge for lowlands natural resources. This agricultural investment has focused on four major regions namely Gambella, SNNPR, Benishangul, and Oromia which are located in Southwest Ethiopia. Between 2004 and 2008, about 1.2x106 (Mousseau and Sosnoff, 2011) to 1.205x106 ha (Stebek, 2011) of lands were transferred to both domestic and foreign investors. This indicates that agricultural land expansion

was undertaken at the expense of natural forest, woodlands and shrublands and grass lands. As a result, 55.6% of LULC change has occurred in Gambella Regional State (Stebek, 2011). As Degife *et al.* (2018) pointed out large scale commercial farmlands increased by 269% while small scale farmlands has decreased in the last three decades. Beside, tropical grasslands have decreased from 53.7% in 1987 to 35.7 in 2017. Out of the total coverage of Gambella National Park, 23.7% of the land was transformed to other LULC types however the size of wetlands has increased since 1987 which is described in Degife *et al.* (2018).

In Benishangul Gumuz Regional State, Mandura district lost its forest cover, whereas the grazing lands and both woodland and shrublands have decreased by 99.6% and 58.4%, respectively while croplands increased by 431.1% between 1957 and 2006 (Emiru and Taye, 2014). This implies that most land use and land cover changes in southwestern Ethiopia, particularly in the lowland, is a recent trajectory compared to in the northern, northeastern and central highlands of the country. Besides, these lowlands are the major focused area for the production of agricultural commodities by the government and other domestic and foreign investors.

Table 4. The historical trends of land use and land cover changes in Northeast and central highlands of Ethiopia

Sources	Year coverage	Forest lands	Grass /grazing lands	Woodland / shrublands	Crop lands	Plantation	Area coverage
Minta *et al.* (2018)	1957	8985	21261	2147	10955	26	43810 ha
	1980	5068	19106	2745	15814	150	
	1995	5094	7556	0	29728	923	
	2014	2471	6935	0	29608	3610	
Tegene (2002)	1957		193	251	994		1528 ha
	1986		290	105	1064		
	2000		333	39	1079		
Agidew and Singh (2017)	1973	584	3584	4317	5854		15195 ha
	1986	520	3230	4084	6695		
	2015	32	2394	3789	8265		

Historical sources indicated that land cover change takes place following movement of Ethiopian King's army and their settlement. Peoples cut trees in order to provide provision for the army for use as energy sources (Pankhurst, 1995; McCann, 1997). McCann (1997) collected and analyzed the ancient traveler views, talks and picture (Figures 1 and 2). The author found similar views that the forests were cleared for crop production and fuel wood. The author concluded that 19th century landscape was not a heavily forested one. Thus, land cover changes might have started following Ethiopian civilization in the northern part of Ethiopia (Tigray) and come to the Wollo dynasty.

Land use and land cover changes in the central highlands of Ethiopia has continoued (Table 4). In Galessa and the surrounding mountain areas, part of central highlands, the woodlands have been lost; forest lands have declined from 20.5% to 5.6% and pasturelands were converted to croplands, with conversion index greater than 3.81 between 1957 and 2014 (Minta *et al.,* 2018). In their study, the croplands were increased by 170.3% at the expense of pasture, forest and

woodland while croplands has changed back to pasture land because the status of soil fertility as a result of widespread cultivation. In the Northeast highlands, similar historical land use and land cover dynamics has taken place despite little information as to when this trajectory started. Recent studies at watershed scale indicated that LULC change varied with sites, for instance grass land has increased from 1.6% to 4.7% (Tegene, 2002), whereas it shows a sign of declined (Agidew and Singh, 2017). The shrub lands, however, have declined across the study sites from 27.6% to 13.5% (Tekle and Hedlund, 2000), 16.4% to 2.5% (Tegene, 2002) and 28.4% to 24.9% (Agidew and Singh, 2017) in the entire study periods.

Causes of land use and land cover changes in Ethiopia. Land use and land cover change is very serious problem and the process has been continouing alarmingly in tropical regions including Ethiopia. These transformation can be driven by natural process and anthropogenic activities or a combination of several factors. Among others, growing human population driven LULC change is the most prevalent in Ethiopia and hence the given below causes in Figur 3 are associated with human activies. Out of the total reviewed papers, sixteen papers pointed out that population growth triggered change as the primary cause of LULC. In the highlands of Ethiopia, agriculture

Figure 1. The 19th century deforestation, wood to sell in Ankober, central highlands of Ethiopia, 1880 (Source: McCann, 1995)

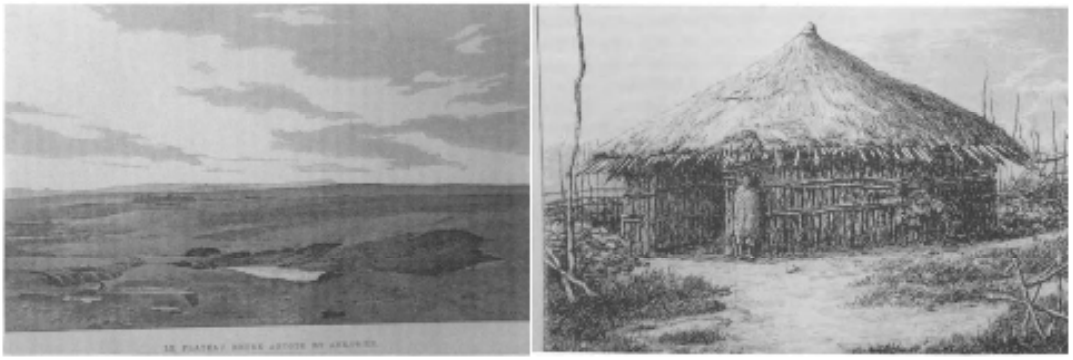

Figure 2. View of the Shawan highlands (left side) and rural Shawan house (right side) (note dung pile at left), 1888 (Sources: McCann, (1997))

land expansion, wood harvesting for fuelwood and charcoal production, overgrazing, land tenure have been identified as mjore contributors to LULC (Table 5). This is consistent with the review in relation to deforestation and land degradation in the highlands (Bishaw, 2001), who documented the major causes of LULC such as human forced agricultural land expansion, shifting cultivation, energy scarcity, grazing pressure and movement of political centers. As a result, recently, about 0.2x106 ha of moist afromontane forests were lost between 2000 and 2013 (Franks *et al.,* 2017).

In Northwest, West and Southwest lowland part of the country, new emerging driving forces since 1957 were documented such as settlement, which has resulted in environmental induced drought and famine in north and northeast Ethiopia, large scale agricultural investment, migration from the highland, market forces, policy incentives for farming and weak formal regulatory system (Emiru and Taye, 2014; Lemenih *et al.,* 2014; Alemu *et al.,* 2015; Degife *et al.,* 2018). As a result, 0.65x106 ha of Combretum-Terminalia woodland vegetation has been converted to agricultural lands between 2000 and 2013 (Franks *et al.,* 2017) although Ethiopian government has developed Climate-Resilient Green Economy and recognized and declared environmental change issues. This trade-off between natural resource management and economic development strategy could be managed to sustain the provision of ecosystem services and goods for the growing population. Table 5 details causes of LULC change across the regions.

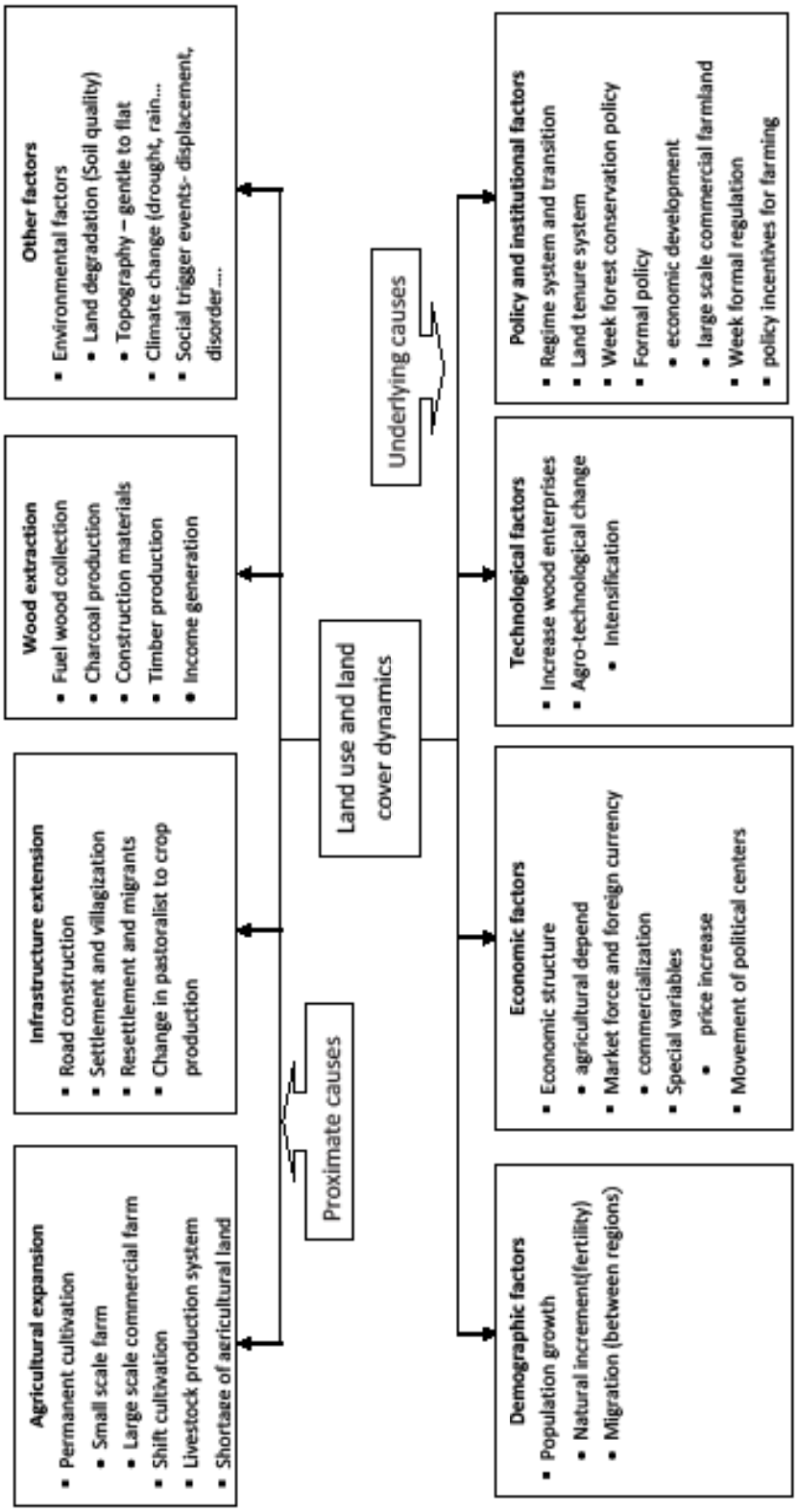

Figure 3. Proximate causes of land use and land cover changes and forces driving the underlying causes in Ethiopia

Table 5. Probable causes of Land Use and Land Cover changes in Ethiopia

Parts of the country	Causes	References
Northwest highlands	Agricultural land expansions and shift cultivation	Zeleke and Hurni (2001)
	Cultivation land expansions, fuelwood and charcoal production, construction materials, regime changes, livestock gazing and government programs (military camp construction, villagization, land redistribution, and land compensation)	Demissie *et al.* (2017)
lowlands	Resettlement and immigration, agricultural expansions, fuelwood and charcoal production, grazing pressure, forest fire, weak formal regulatory system market forces and policy incentives for farming	Alemu *et al.* (2015) and Lemenih *et al.* (2014)
West Ŀlow laṉds	Resttlement nd migration, agricultural land expansion, infrastructural expansion, land redistribution for shift	Emiru and Taye (2014)
Benishangul Gumuz	cultivators, fuelwood and charcoal and weak land tenure system	
Southwest- Gambella	Small scale farmland expansion, large-scale commercial farmland expansion, forest fire, illegal lagging and fuel wood and charcoal	Degife *et al.* (2018)
Southwest highland	Resettlement and migrants and agricultural land expansion, low level of education and awareness, lack of regulations to protect the forests, construction materials, fuelwood and charcoal and land tenure policy	Getahun *et al.* (2017) and Reid *et al.* (2000)
South Central Rift Valley	Small scale agriculture, commercial agriculture, reduction of land productivity, commercial logging, forest fires, regime change and transition time, change economic source from pastoralist to crop production, migration, land tenure system and fuel wood collection	Gebresilassie (2014) and Gessesse and Kleman (2006)
Central highlands	Agricultural land expansion, Land reform in 1974, changes in regime systems + transition periods, weak formal regulatory policy on forest management and timber production	Minta *et al.* (2018)
Northeast highlands	Cultivation land expansion, land shortage, fuelwood and charcoal production, land tenure system during 1974, Rural settlements, climate change (drought and high evapotranspiration and erratic rain fall, and land degradation) and overgrazing	Agidew and Singh (2017), Tegene (2002) and Tekle and Hedlund (2000)

The impacts of land use and land cover changes. Human induced emission of C from various sources including conversion of LULC has had several impacts on the global environment. Global average CO_2 concentration in the atmosphere has increased to 399.4 ± 0.1 ppm in 2015 while annual rates of emission was 9.9 ± 0.5 GtC of which LULC change contributed about 1.0 ± 0.5 GtC (25%) (Quéré *et al.,* 2016). Despite this, little information is available about the overall impact of LULC on global change. Ethiopia emitted 150 Mt CO_2 eq in 2010 which is insignificant compared to in developed countries but this will ncrease to 400 $MtCO_2$ eq about until 2030 (CRGE, 2011). Of these, livestock, crop cultivation, deforestation and forest degradation and combination of other sectors emitted 65 (42%), 12 (9%), 55 (37%) and 19 (12%) $GtCO_2$eq, respectively. Recently, the forest sector in Ethiopia emitted 19.5 $GtCO_2$ and gained 10.2 GtCO2 with net emission of 9.3$GtCO_2$ from deforestation alone between 2000 and 2013 (MEFCC, 2016). This indicates that deforestation and forest degradation is still occuring at alarming rates although the extent of aforestation shows a sign of enhancement.

In Ethiopia, the projected agricultural land expansion to achieve the growth demand of food production will be increased by 3.9% (0.55x106 ha) (Franks *et al.,* 2017) which could be achieved through land expansion at the expense of natural vegetation. Such continuing human influence coupled with previous deforestation might lead to more deterioration ecosystem function, loss of biodiversity, water bodies and global warming, which in turn will affect the welfare of humans, plants, animals and micro-organisms negatively (Teketay, 2004; Eshete *et al.,* 2011; Lemenih and Kassa, 2011). Besides, it will cause habitat fragmentation (Miles *et al.,* 2006), shrinking protected area (Degife *et al.,* 2018; Wassie *et al.,* 2007), and eventually species extinction (Whithore and Sayer, 1992).

Although these disadvantageous of LULC changes occurred, recently degraded lands and natural forests have changed to plantation forest to fulfill the growing demand of wood and wood products. Hence, the extent of global production of forests has increased (FAO, 2015; Keenan *et al.,* 2015; Köhl *et al.,* 2015) which comprised 30% of the global forest covers (FAO, 2015). In this case, LULC change practices have advantages despite that the natural ecosystem has changed.

Several studies (Nambiar, 1999; Carle *et al.,* 2002; Montagnini and Jordan, 2005; Gunter *et al.,* 2011; Lemenih and Kassa, 2014) have demonstrated the potential roles of forest plantation for economical, social and ecological benefits. Forest plantation can facilitate forest succession through modification of biophysical conditions (Keenan *et al.,* 1999; Parrotta, 1999; Parrotta and Jones, 1997; Eshetu, 2001; Carnevale and Montagnini, 2002; Senbeta *et al.,* 2002), maintain biodiversity (Keenan *et al.,* 1999; Parrotta, 1999; Carle *et al.,* 2002; Hartmann *et al.,* 2010; Coote *et al.,* 2012) and improve soil attributes (Parrotta, 1999; Zhang and Chu, 2011). Besides, it can sequester atmospheric CO_2 for growing and accumulation of biomass which is estimated 250 at Gt C (FAO, 2015). It also serves as a tool for economic development (Montagnini and Jordan, 2005) due to the fact that they are sources of wood and wood products such as timber, panel production, pulp wood, energy source and non timber forest products. Furthermore, forest plantation practice creates employment opportunity for millions of people (Carle *et al.,* 2002; Montagnini and Jordan, 2005; Gunter *et al.,* 2011). These benefits of forest plantation have encouraged planting of fast growing tree species to fulfill shortage of wood supply and has to increasing reforestation practices, including in Ethiopia (FAO, 2010) to 0.972x106 ha (FAO, 2015).

Local scale LULC change study provides a basis for understanding of the causes and identify new changes which have not been covered by general principles (Lambin *et al.,* 2003). In addition, catchment scale studies also improve the understanding of LULC change effect on a particular or single resource. Surface runoff is influenced by LULC types. For example, Hurni *et al.* (2005) estimated a 5 to 30 times more surface runoff in farmlands compared to vegetative lands. This indicates that soil nutrients are washed through erosion at the croplands. For instance, the concentration of soil organic C and total N was 1.2% and 0.2% in farmlands lower than in dense forest with 2.3% of C and 0.3% of total N (Berihu *et al.,* 2017). This is also consistent with the findings of Lemenih *et al.* (2005), who found that deforestation and subsequent cultivation affected the soil qualities negatively and this led to land degradation in the highlands (Bishaw, 2001; Taddese, 2001; Lemenih *et al.,* 2005). Beside, ecological problems as a result of deforestation (Uhlig, 1992), long term traditional land management and use have been eroded and the land resources and productive capacity has declined leading to significant negative impact on human well-being including frequent famine episode in Ethiopia (Hurni, 1993).

Conclusion and future direction

Quantification and understanding of land use and land cover changes have been undertaken using improved assessment methods at global as well as regional levels. The results have been used for modeling environmental change including biogeochemical cycle, hydrological cycle, climate change projection and the impact of human activities on the earth system process. Besides, it is important to reconstruct the historical interaction of human and environment to support introduction and implementation intervention.

Despite these efforts, land use and land cover change monitoring started only and recently in Ethiopia. As a result, country and regional scale (except Gambella) land use and land cover change studies have been initiated but are limited by lack of historical land in understanding and describing the historical changes in the environment and associated cause-effect. Thus, few scientists have tried to recognize the previous environmental history bases on pollen diagram, collecting the ancient traveler memory, and ground based photographs. This review reveals that land use and land cover change in the form of deforestation is an old phenomenon in the highlands but not clearly known when the event started in northern and northeast highlands, whereas it is a recent trajectory for southwest Ethiopia. Agricultural land expansion, fuelwood collection and movement of political centers were the major causes of LULC in the early 1850s.

Ethiopian regime systems have put their footprint on the natural resources. To our knowledge, deforestation and overexploitation in the northern, northeastern and central highlands may be linked with Ethiopian civilization which resulted into complex environmental problems including land degradation, drought and erratic rainfall. The combination of this human catastrophic and natural events brought famine in the aforementioned parts of the country and hence settlement was started in Northwest, west and southwest since 1950. Land use and land cove change has dramatically changed following settlements between 1950 and 2006. New driver of LULC change has emerged in the lowland parts of Ethiopia as a result of settlement, large scal agricultural investments, migration from the highland, market forces, policy incentives for farming and weak formal regulatory system. Thus, land degradation in the form of vegetation loss, soil fertility decline and imbalanced hydrological cycle is characteristics of the highlands but it is also now

a challenge of lowlands. Appropraite interventions in terms of sustainable land use planing is, therefore, needed in order to manage these adverse trade-off between natural resource management and development strategy.

Future direction

The causes and possible undesirable consequence of the ongoing land use and land cover change needs urgent interventions to reduce the events. Thus, the given below directions could be considered at any levels of policy makers:

- Improve and diversify the rural livelihood strategies by introducing environmental sound technologies (innovative technologies) that modify the traditional agriculture
- Introduce climate smart alternative energy sources with affordable cost to rural households
- Upgrade the existing soil and water conservation work efforts to minimize soil erosion
- Develop and implement realistic, effective and comprehensive sustainable land use planning and management strategies
- Establishing land use database which is used for studying environmental change, agronomy and other related field of studies
- Refine and implement the existing forest management policies by making better institutional integration, especially between forest sector and agriculture
- Revise the CRGE, particularly GTP, to reduce the trade-off between natural resource base and economic development strategies despite the fact that CRGE was developed by accommodating environmental issues.

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References

Agidew, A. and Singh, K. N. 2017. The implications of land use and land cover changes for rural household food insecurity in the Northeastern highlands of Ethiopia : The case of the Teleyayen sub-watershed. *Agriculture and Food Security* 6: 1–14. https://doi.org/10.1186/s40066-017-0134-4

Alemu, B., Garedew, E., Eshetu, Z. and Kassa, H. 2015. Land in North Western lowlands of Ethiopia. *International Research Journal of Agricultural Science and Soil Science* 5 (1): 28–44.

Aynekulu, E., Birhane, E., Wubneh, W. and Begashaw, N. 2006. Monitoring and evaluating land use/ land cover change using participatory geographic information system (PGIS) tools: a case study of Begasheka watershed, Tigray, Ethiopia. *EJISDC* 25: 1–10. https://doi.org/10.1002/j.1681-4835.2006.tb00164.x

Berihu, T., Girmay, G., Sebhatleab, M. and Berhane, E. 2017. Soil carbon and nitrogen losses following deforestation in Ethiopia. *Agron. Sustain. Dev.* 37 (1). https://doi.org/10.1007/s13593-016-0408-4

Bishaw, B. 2001. Deforestation and land degradation in the Ethiopian highlands: a strategy for physical recovery. pp.7-25. In: International Conference on Contemporary Development Issues in Ethiopia, Kalamazoo, Michigan, U.S.A.

Bonnefille, R. and Hamilton, A., 1986. Quaternary and late tertiary history of Ethiopian vegetation. *Symb. Bot. Ups* 26 (2): 48-63.

Brandt, M., Rasmussen, K., Peñuelas, J., Tian, F., Schurgers, G., Verger, A. and Fensholt, R. 2017. Human population growth offsets climate-driven increase in woody vegetation in sub-Saharan Africa. *Nature, Cological and Evolution* 1(0081): 1–6. https://doi.org/10.1038/s41559-017-0081

Carle, J., Vuorinen, P. and Del Lungo, A. 2002. Status and trends in global forest plantation development. *Forest Products Journal* 52 (7/8):12-23.

Carnevale, Â. J. and Montagnini, F. 2002. Facilitating regeneration of secondary forests with the use of mixed and pure plantations of indigenous tree species. *Forest Ecology and Management* 163: 217–227.

Coote, L., French, L. J., Moore, K. M., Mitchell, F. J. G. and Kelly, D. L. 2012. Can plantation forests support plant species and communities of semi-natural woodland? *Forest Ecology and Management* 283: 86–95. https://doi.org/10.1016/j.foreco.2012.07.013

Climate-Resilient Green Economy (CRGE). 2011. Ethiopia's climate resilient green economy climate resilience strategy. Climate Resilience Strategy: Water and Energy. Federal Democratic Republic of Ethiopia. 64pp.

Degife, A. W., Zabel, F. and Mauser, W. 2018. Assessing land use and land cover changes and agricultural farmland expansions in Gambella Region, Ethiopia, using Landsat 5 and Sentinel 2a multispectral data. Heliyon, 4, e00919. https://doi.org/10.1016/j.heliyon.2018.e00919

Demissie, F., Yeshitila, K., Kindu, M. and Schneider, T. 2017. Land use / land cover changes and their causes in Libokemkem District of South Gondar, Ethiopia. Remote Sensing Applications: *Society and Environment* 8: 224–230. https://doi.org/10.1016/j.rsase.2017.10.001

Emiru, T. S. and Taye, A. A. 2014. Population dynamics and its impact on land use / cover in Ethiopia : The case of Mandura District of Metekel Zone, Benshangul-Gumuz Regional State. PhD Thesis. University of South Africa.

Eshete, A., Sterck, F. and Bongers, F. 2011. Diversity and production of Ethiopian dry woodlands explained by climate- and soil-stress gradients. *Forest Ecology and Management* 261 (9): 1499–1509. https://doi.org/10.1016/j.foreco.2011.01.021

Eshetu, Y. 2001. Diversity of naturally-regenerated native woody species in forest plantations in the Ethiopian highlands. *New Forests* 22: 159–177.

Fearnside, P. M. 2000. Global warming and tropical land-use change : greenhouse gas emissions from biomass burning, decomposition and soils in forest conversion , shifting cultivation and secondary vegetation. *Climatic Change* 46: 115–116.

Food and Agriculture Organisation (FAO). 2010. Global Forest Resources Assessment 2010: Country Report, Food and Agriculture Organization of the United Nations. Rome 065.

Food and Agriculture Organisation (FAO). 2015. Global Forest Resources Assessment 2015. Food and Agriculture Organization of the United Nations Rome, 2015, ISBN 978-92-5-108826-5, www.fao.org/forestry/fra.

Foley, J. A., Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R. and Snyder, P. K. 2005. Global Consequences of Land Use. *Science* 300: 570–575.

Franks, P., Hou-jones, X., Fikreyesus, D., Sintayehu, M., Mamuye, S., Danso, E. Y. and van Soesbergen, A. 2017. Reconciling forest conservation with food production in sub-Saharan Africa: case studies from Ethiopia, Ghana and Tanzania. IIED Research Report, London.

Gebreslassie, H. 2014. Land use-land cover dynamics of Huluka watershed, Central Rift Valley, Ethiopia. *International Soil and Water Conservation Research* 2 (4): 25–33.

Gessesse, D. and Kleman, J. 2006. Pattern and magnitude of deforestation in the South Central Rift Valley Region of Ethiopia. *Mountain Research and Development* 27 (2): 162–168. https://

doi.org/10.1659/mrd.0730
Getahun, K., Poesen, J. and Van Rompaey, A. 2017. Impacts of resettlement programs on deforestation of moist evergreen afromontane forests in Southwest Ethiopia. *Mountain Research and Development* 37 (4): 474–486.
Goldewijk, K. K. 2001. Estimating global land use change over the past 300 years : The HYDE Database. *Global Biogeochemical Cycles* 15 (2): 417–433.
Goldewijk, K. K., Beusen, A., Van Drecht, G. and Vos, M. 2011. The HYDE 3 . 1 Spatially explicit database of human-induced global land-use change over the past 12 , 000 years. *Global Ecology and Biogeography* 20 (1):73–86. https://doi.org/10.1111/j.1466-8238.2010.00587.x
Gunter, S., Weber, M., Stimm, B. and Mosandl, R. 2011. Silviculture in the tropics. Springer Heidelberg Dordrecht London New York.
Hailu, B. T., Fekadu, M. and Naus, T. 2018. Availability of global and national scale land cover products and their accuracy in mountainous areas of Ethiopia : A review (unpblished). https://doi.org/10.20944/preprints201807.0431.v1
Hartmann, H., Daous, G., Bigue, B. and Messier, C. 2010. Negative or positive effects of plantation and intensive forestry on biodiversity: A matter of scale and perspective. *The Forestry Chronicle* 86 (3): 354–364.
Hurni, H., Tato, K. and Zeleke, G. 2005. The implications of changes in population, land use, and land management for surface runoff in the upper Nile basin area of Ethiopia. *Mountain Research and Development* 25 (2): 147-154.
Hurni, H. 1993. Land degradation, famine, and land resource scenarios in Ethiopia. pp 27-62. In: Pimentel, D. (Ed.). World soil erosion and conservation. Cambridge University Press: Cambridge.
IPCC. 2014. Climate change 2014. Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, Unit.
Keenan, R. J., Lamb, D., Parrotta, J. and Kikkawa, J. 1999. Ecosystem management in tropical timber plantations : Satisfying economic, conservation, and social objectives. *Journal of Sustainable Forestry* 9 (1-2): 117–134. https://doi.org/10.1300/J091v09n01
Keenan, R. J., Reams, G. A., Achard, F., Freitas, J. V. De, Grainger, A. and Lindquist, E. 2015. Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *Forest Ecology and Management* 352: 9–20. https://doi.org/10.1016/j.foreco.2015.06.014
Köhl, M., Lasco, R., Cifuentes, M., Jonsson, Ö., Korhonen, K. T., Mundhenk, P. and Stinson, G. 2015. Changes in forest production , biomass and carbon : Results from the 2015 UN FAO Global forest resource assessment. *Forest Ecology and Management* 352: 21–34. https://doi.org/10.1016/j.foreco.2015.05.036
Lambin, E. F., Geist, H. J. and Lepers, E. 2003. Dynamics of land-use and land-cover change in the tropical regions. *Annu. Rev. Environ. Resour.* 28: 205–241. https://doi.org/10.1146/annurev.energy.28.050302.105459
Lemenih, M., Karltun, E. and Olsson, M. 2005. Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agriculture, Ecosystems and Environment* 105: 373–386. https://doi.org/10.1016/j.agee.2004.01.046
Lemenih, M. and Kassa, H. 2011. Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia. CIFOR, Bogor, Indonesia.
Lemenih, M. and Kassa, H. 2014. Re-greening Ethiopia: History, challenges and lessons. *Forest*

5: 1896–1909. https://doi.org/10.3390/f5081896

Lemenih, M., Kassa, H., Kassie, G. T., Abebaw, D. and Teka, W. 2014. Resettlement and woodland management problems and options: a case study from North-western Ethiopia. *Land Degradation and Development* 25 (4): 305–318. https://doi.org/10.1002/ldr.2136

Matthews, E. 1983. Global vegetation and land use: New high-resolution data bases for climate studies. *Journal of Climate and Applied Meteorology* 22: 474–487.

McCann, J. C. 1997. The Plow and the Forest: Narratives of deforestation in Ethiopia, 1840-1992. *Environmental History* 2 (2): 138–159. Retrieved from http://www.jstor.org/stable/3985505

MEFCC. 2016. Ethiopian's forest reference level subnission to the United Nations Framework for Conventions on Climate Change (UNCCC).

Meiyappan, P. and Jain, A. K. 2012. Three distinct global estimates of historical land-cover change and land-use conversions for over 200 years. *Front. Earth Sci.* 6 (2): 122–139. https://doi.org/10.1007/s11707-012-0314-2

Miles, L., Newton, A. C., Defries, R. S., Ravilious, C., May, I., Blyth, S. and Gordon, J. E. 2006. A global overview of the conservation status of tropical dry forests. *Journal of Biogeography* 33: 491–505. https://doi.org/10.1111/j.1365-2699.2005.01424.x

Minta, M., Kibret, K., Thorne, P., Nigussie, T. and Nigatu, L. 2018. Land use and land cover dynamics in Dendi-Jeldu hilly-mountainous areas in the central Ethiopian highlands. *Geoderma* 314: 27–36. https://doi.org/10.1016/j.geoderma.2017.10.035

Montagnini, F. and Jordan, C. F. 2005. Tropical forest ecology: The basis for conservation and management. Springer Berlin Heidelberg New York.

Mousseau, F. and Sosnoff, G. 2011. Understanding land lnvestment deals in Africa: Country report for Ethiopia. The Oakland Institute, Oakland. 65pp.

Muluneh, A. and Arnalds, O. 2010. Synthesis of Research on land use and land cover dynamics in the Ethiopian highlands. UNU-Land Restoration Training Programme Keldnaholt, 112 Reykjavik, Iceland (unpublished), 1–39.

Nambiar, E. K. S. 1999. Productivity and sustainability of plantation forests. *Bosque* 20 (1): 9–21.

Nelson, E., Sander, H., Hawthorne, P., Conte, M., Ennaanay, D., Wolny, S., Manson, S. and Polasky, S. 2010. Projecting global land-use change and its effect on ecosystem service provision and biodiversity with simple models. *PloS one* 5 (12): 1–22. https://doi.org/10.1371/journal.pone.0014327

Organisation for Economic Co-operation and Development (OECD). 2018. Monitoring land cover change. Better policies for better lives, Environmental Performance and Information Team. OCED.

Pankhurst, R., 1995. The history of deforestation and afforestation in Ethiopia prior to World War I. *Northeast African Studies* 2 (1): 119-133.

Parrotta, J. A. 1999. Productivity , nutrient cycling, and succession in single- and mixed- species plantations of *Casuarina equisetifolia*, *Eucalyptus robusta* and *Leucaena leucocephala*. *Forest Ecology and Management* 124: 45–77. https://doi.org/10.1016/S0378-1127(99)00049-3

Parrotta, J. A., Turnbull, J. W. and Jones, N. 1997. Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management* 99: 1–7. https://doi.org/10.1016/S0378-1127(97)00190-4

Quéré, C.L., Andrew, R.M., Canadell, J.G., Sitch, S., Korsbakken, J.I., Peters, G.P., Manning, A.C., Boden, T.A., Tans, P.P., Houghton, R.A. and Keeling, R.F. 2016. Global carbon budget 2016. *Earth System Science Data* 8 (2): 605-649.https://doi.org/10.5194/essd-8-605-2016

Ramankutty, N., Evan, A. T., Monfreda, C. and Foley, J. A. 2008. Farming the planet: 1.

Geographic distribution of global agricultural lands in the year 2000. *Global Biogeochemical Cycles* 22:1–19. https://doi.org/10.1029/2007GB002952

Ramankutty, N. and Foley, A. 1999. Estimating historical changes in global land cover : Croplands historical have converted areas. *Global Biogeochemical Cycles* 13 (4): 997–1027.

Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C. J. and Mulatu, W. 2000. Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. *Landscape Ecology* 15 (4): 339–355. https://doi.org/10.1023/A:1008177712995

Scanlon, B. R., Reedy, R. C., Stonestrom, D. A., Prudic, D. E. and Dennehy, K. F. 2005. Impact of land use and land cover change on groundwater recharge and quality in the southwestern US. *Global Change Biology* 11(10): 1577–1593. https://doi.org/10.1111/j.1365-2486.2005.01026.x

Senbeta, F., Teketay, D. and Naslund, B.-Å. 2002. Native woody species regeneration in exotic tree plantations at Munessa-Shashemene Forest, southern Ethiopia. *New Forests* 24: 131–145.

Song, X.P., Hansen, M. C., Stehman, S. V., Potapov, P. V., Tyukavina, A., Vermote, E. F. and Townshend, J. R. 2018. Global land change from 1982 to 2016. *Nature* 560: 639–643. https://doi.org/10.1038/s41586-018-0411-9

Stebek, E. N. 2011. Between ‘ land grabs ’ and agricultural investment: Land rent contracts with foreign investors and Ethiopia’s normative stetting in focus. *Mizan Law Review* 5 (2): 175–214.

Taddese, G. 2001. Land Degradation : A challenge to Ethiopia. *Environmental Management* 27(6): 815–824. https://doi.org/10.1007/s002670010190

Tegene, B. 2002. Land-cover / Land-use changes in the Derekolli catchment of the South Welo Zone of Amhara Region , Ethiopia. *Eastern Africa Social Science Research Review* 18 (1): 1–20.

Teketay, D. 2004. Causes and consequences of dryland forest degradation in Sub-Saharan Africa. *Walia* 24: 3–20.

Tekle, K. and Hedlund, L. 2000. Land cover changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. *Mountain Research and Development* 20 (1): 42–51.

Uhlig, S. K. 1992. Tropical mountain ecology in Ethiopia as a basis for conservation, management and restoration. pp. 127–128. In: Goldammer, J. G. (Ed.). Tropical Forest in Transition. Birkhiiuser Verlag Basel/Switzerland.

Wassie, A., Bongers, F., Teketay, D. and Sterck, F. 2007. Ethiopian Church Forests: opportunities and challenges for restoration. PhD Thesis, Wageningen Univeristy, Wageningen, The Netherlands.

Whithore, T. C. and Sayer, J. A. 1992. Tropical deforestation and species extiniction. Chapman & Hall, London. xvii + 147 pp.

Zeleke, G. and Hurni, H. 2001. Implications of land use and land cover dynamics for Mountain resource degradation in the Northwestern Ethiopian Highlands. *Mountain Research and Development* 21 (2): 184–191.

Zhang, H. and Chu, L. M. 2011. Plant community structure, soil properties and microbial characteristics in revegetated quarries. *Ecological Engineering* 37:1104–1111. https://doi.org/10.1016/j.ecoleng.2010.05.010