academicJournals

Vol. 9(1), pp. 1-7, January 2017
DOI: 10.5897/IJWREE2016.0693
Article Number: 3B0FC1862314
ISSN 2141-6613

http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Comparative assessment of soil and nutrient losses from three land uses in the central highlands of Ethiopia

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Received 14 October, 2016; Accepted 22 November, 2016

Land use/land cover change drive changes in several ecosystem processes over short and long terms. In Ethiopia, the main land use/land cover change involves conversion of natural ecosystem into cultivated land. However, a recent change also involves conversion of cultivated and grazing land into *Eucalyptus* woodlots. This study was conducted to analyse the effects of such land use/land cover change on soil and nutrient losses. Three land use/ land cover types (cultivated land, grassland and *Eucalyptus* woodlot) were selected for a comparative assessment. A total of twelve runoff plots, each with 43.3 m^2 area and with four replications, were installed. Rainfall depth, runoff volume and sediment samples (500 ml) were collected from each plots every morning and evening for 91 days (from 4th July to 2nd October, 2015) in the main rainy season. The sediment samples for ten consecutive days were stored in separate containers and composite sediment concentration samples were weighed after being filtered and oven dried for 24 hours at 105^{o}c. From the samples taken at the end of the rainy season, separate composite a sample before filtration of one litre was analysed in the laboratory for nutrient losses. The effect of land use/land cover on soil and nutrients losses was statistically tested using analysis of variance. The study found that soil loss significantly differed between the land use/land cover types. Soil loss from cultivated land (16.8 ton/ha) was significantly higher than loss from grassland (7 ton/ha) and *Eucalyptus* stand (8.1 ton/ha). The soil and nutrient losses were positively correlated with runoff volume. There was higher nutrient (N and P) loss from cultivated land than grassland and *Eucalyptus*. From the results, it can be concluded that soil and nutrients losses are above tolerable limit, and perennial land covers including *Eucalyptus* stand reduce soil and nutrient losses significantly. This re-affirms the multi-purpose nature of *Eucalyptus* not only for socioeconomic benefit but also for soil erosion control when planted in appropriate locations.

Key words: Cultivated land, grassland, runoff, sediment concentration, runoff plot.

INTRODUCTION

Land use/ land cover (LULC) changes are occurring throughout human history (Briassoulis, 2000; Lambin et al., 2003; Kindu et al., 2015; Wubie et al., 2016). Among the major changes, the shift from natural ecosystem to cultivated land by involving deforestation is the most common (Zeleke and Hurni, 2001; Bewket, 2002; Dwivedi et al., 2005). Contrary to this process, a recent phenomenon in the Ethiopian highland is the conversion of land back from cultivated to *Eucalyptus* stand (Fisseha et al., 2011; Jenbere et al., 2012; Chanie et al., 2013, Jaleta et al., 2016a).

Eucalyptus has been acclaimed to have social, economic and ecological benefits (Lemenih, 2010; Kebebew and Ayele, 2010; Bekele, 2015). Farmers are continuing planting *Eucalyptus* converting their farm plots due mainly its positive economic benefits (Mekonnen et al., 2007; Adimassu et al., 2010). However, the uncontrolled expansion of *Eucalyptus* also is raising controversies with respect to the alleged ecological effect of the species (Jagger and Pender, 2003; Chanie et al., 2013; Jaleta et al., 2016b). *Eucalyptus* is considered to consume higher water and nutrients and it has allopathic effect on undergrowth vegetation (Nigatu and Michelsen, 1993; Fikreyesus et al., 2011; Chanie et al., 2013). It is also considered as less desirable species for soil-water conservation (Chanie et al., 2013), which has led to banning of its plantings, once in Tigray region, which was latter lifted (Jagger and Pender, 2003).

Soil and nutrient losses from the highlands of Ethiopia is a major environmental challenge owing to high rate of soil erosion (FAO, 1998; Tekele and Hedlund, 2000; Amsalu et al., 2007). The current expansion of *Eucalyptus* is also feared to intensify the problem. Therefore, it is essential that studies are conducted to assess the effect of *Eucalyptus* on soil erosion and nutrient loss to help informed decision making for policy makers as well as plantation developers. The objective of this study was therefore to quantify soil and nutrient losses from under *Eucalyptus* stand in comparison with two other LULC types namely cultivated land and grassland, at Meja River watershed in Central Ethiopia.

MATERIALS AND METHODS

Description of the study area

Meja River watershed, where this study was done, found at Jeldu district, in West Shewa, central Ethiopia. Tiki and Sochoa sub catchment of the watershed were selected to install the runoff plots for the study. The catchments are located 114 km west of the capital, Addis Ababa, Ethiopia. The study sites is located within 9° 02' to 9° 15' N and 38° 05' to 38° 12' E, altitude ranging from 2400 to 3200 m above sea level (Figure 1). The mean annual temperature ranges from17 to 25°C. The rainfall is bi-modal with the short rainy season from February to May and long rainy season from June to September. The mean annual rainfall is 1400 mm. The site is characterized by a mixed crop-livestock system. Wheat (*Triticum vulgare*), potato (*Solanum tuberosum*) and Enset (*Ensete ventricosum*) are the crops mostly grown. The watershed is known for *Eucalyptus* expansion in the central Ethiopia. *Eucalyptus* woodlots are abundant in the Meja River watershed replacing cultivated land and marginal grazing lands. *Eucalyptus globulus* is the main species of *Eucalyptus* growing in the study area. The soil is characterized as Pellic Vertisol.

Experimental design

The runoff plot (43.3 m^2) was constructed in three LULC types with four replications in two adjacent sub catchments. The LULC types are cultivated land, grassland and *Eucalyptus* woodlot. The cultivated land covered by wheat and the species of *Eucalyptus* growing is four years old *Eucalyptus globules*. The grassland was grazed highly before the instalment of the runoff plots. The details of each runoff plots characteristics were given in Table 1. Two rain gauges were installed to record daily rainfall depth in the two sub catchments. The three LULC types at each site were adjacent and share other biophysical conditions. The runoff and the rainfall depth were registered twice daily: at every morning (6:00 am) and evening (6:00 pm).

Data collection and data analysis

Runoff sample of 500 ml was collected every morning and evening from each runoff plots during the study period (from 4th July to 2nd October, 2015). Samples of each plot were separately stored for 10 consecutive days in a plastic container, which were then composited per plot at end of the 10th day. The composite samples were filtered by Whatman (0.42 µm) filter paper. The filtered material was oven dried by 105°C for 24 h, weighed and converted to dry mass in milligram per hectare (mg/ha) to yield sediment load. Soil loss (ton/ha) was then calculated from the volume of runoff and sediment load (Adimassu et al., 2014).

From each runoff plots, at the end of the rainy season, composite runoff sample of one litre was taken for nutrient analysis in the laboratory. Thoroughly stirred samples were kept for 5 h in the laboratory for sedimentation. Then the topmost water in each container was collected for runoff related nutrient analysis. Total dissolved solid, electric conductivity, pH, ammonia (NH_3)-N, Nitrate (NO3)-N and Phosphate (PO4)-P were analysed at Ethiopian Water Works Design and Supervision Enterprise Water laboratory. The total runoff related nutrient losses of each plot were calculated by multiplying the average concentration of each nutrient in the runoff with the total runoff volume. Dissolved Ammonia was analysed by Phenate method using spectrophotometer, modele Eleco SL-160 double beam ultraviolet (Patnaik, 2010). Dissolved Nitrate and Phosphate was analysed by spectrophotometer, modele Eleco SL-160 double beam ultraviolet (Patnaik, 2010).

Data analysis was done using Genstat 15th edition statistical software. Analysis of variance was used to test the effect of LULC changes on soil loss and nutrient loss statistically significant at $p < 0.05$. Least significant difference (LSD) was tested to compare the mean values at $p < 0.05$. The runoff and soil loss mean values regressed among themselves to see the runoff- soil loss relationships.

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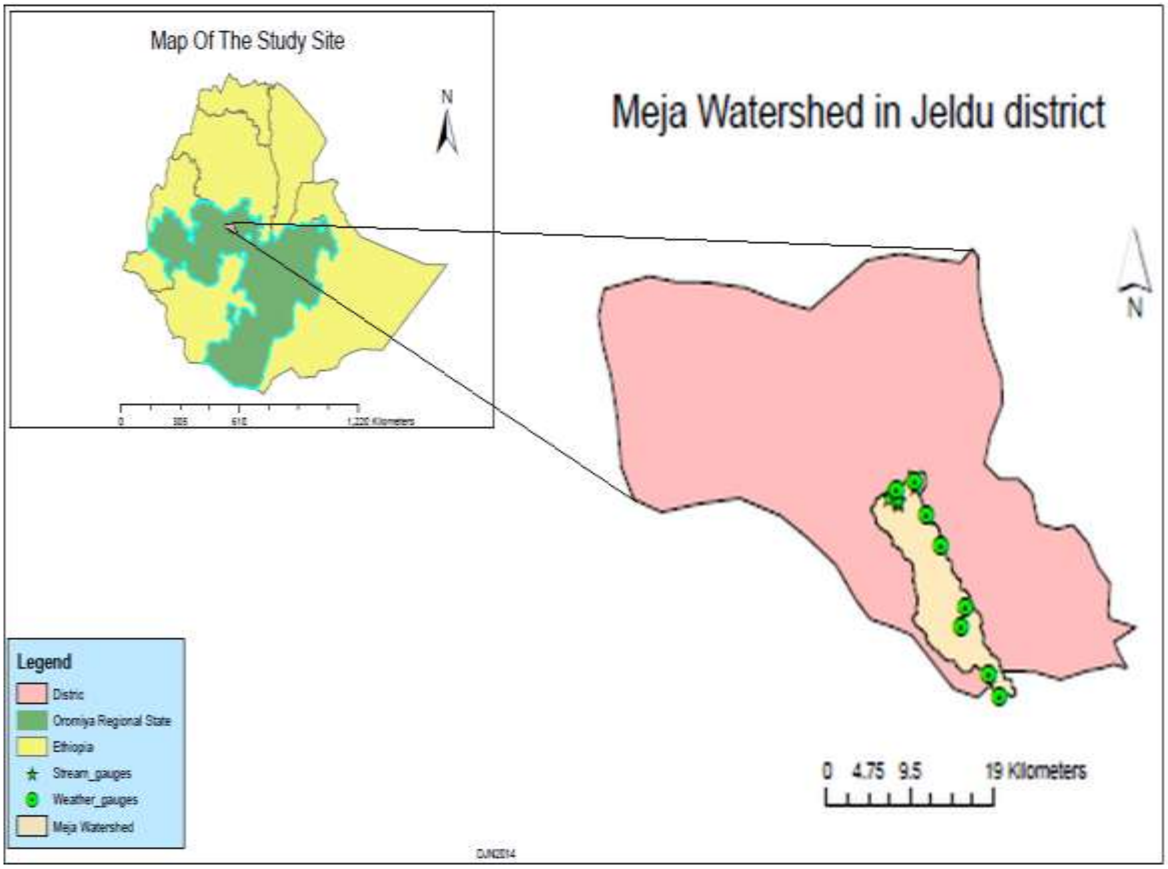

Figure 1. Map of the study area.

Table 1. Biophysical conditions of the runoff plots.

Plot code	Moisture content (%)	EC (µS/m)	Soil temp. (°C)	Slope degree	Stone Cover (cm)			Ground cover			Crown cover (%)
					Low	Middle	Up	Weed	Stubble	Organic residues	
C3	7.49	0.82	28.65	10	_	_	_	75	233	5	-
C4	10.86	1.01	27.5	10	_	_	3	67	396	11.5	-
G3	13.99	1.61	25.9	12	_	_	_	34	Grass	27.5	-
G4	17.72	1.85	26.7	12			_	25	Grass	22.5	-
E3	14.09	1.31	25.9	11	8	23	_	129	-	621	55
E4	17.47	1.6	24.05	11	_	7	_	40	-	482	55
C1	13.03	1.09	26.5	8	_	_	_	65	261	2.5	-
C2	7.04	1.04	24.11	8	2.5	8	9	95	315	0	-
G1	14.27	1.31	25.05	9	_	_	_	38	Grass	4	-
G2	18.73	1.53	22	9	_	_	_	34	Grass	3	-
E1	12.06	0.91	23.7	8	_	_	_	93	-	241	40
E2	12.76	1.18	28.2	8	_	_	_	84	-	196	42

RESULTS AND DISCUSSION

The runoff volume collected within the study period differed significantly between the LULC types. The mean runoff harvested from the cultivated land is 30% higher than that of grassland and 17% higher than that of *Eucalyptus* stand (Table 2). There was slightly higher runoff volume generated from *Eucalyptus* field

Table 2. Total runoff collected from each LULC types within study period.

Replication	LULC types		
	Cultivated land (mm)	Grassland (mm)	*Eucalyptus* (mm)
1	194.91	156.44	159.78
2	202.21	154.06	158.27
3	183.97	143.61	148.88
4	186.52	137.20	149.07
Mean	**191.90**	**147.83**	**154.58**

Table 3. Means of soil loss within study period at each LULC types.

Land use	Soil loss (ton/ha) per study period
Cultivated land	(14.80±1.19) [a]
Grassland	(7.08±0.48) [b]
Eucalyptus	(8.53±0.69) [b]
LSD (5%)	1.8

Table 4. Means of some nutrient loss from runoff at each LULC types.

Land use	TDS	Ec (µ S/cm)	pH	Ammonia (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)
Cultivated land	75.25	122.00	6.43	4.33	0.39	0.75
Grassland	97.50	166.25	6.62	3.26	0.22	0.75
Eucalyptus	70.50	112.50	6.63	3.51	0.29	0.48
LSD (5%)	36.79 [ns]	61.25 [ns]	0.29 [ns]	3.12 [ns]	0.34 [ns]	0.41 [ns]

ns – no significant difference at $p < 0.05$ least significant difference.

(154.8 mm) than the grassland (147.8 mm).

Similarly, there was significant difference between in soil loss among the land uses/land cover types. The soil *Eucalyptus* field. The soil loss from the cultivated land was greater than the maximum tolerable amount of soil loss which is 10 ton/ha per year in Ethiopia (Hurni and Messerli, 1981; Hurni, 1985). The soil loss from cultivated land recorded in this study matches with the recorded amount from different part of the country (Haile et al., 2006; Girmay et al., 2009; Adimassu et al., 2014). The volume of soil loss has shown the reducing trend as the crop grown fully in cultivated land and resulted comparatively less difference in the final weeks of the experiment on the study area.

Total dissolved solids (TDS), pH, Electric conductivity (Ec), dissolved Ammonia (NH_3), dissolved Nitrate, dissolved Phosphate were checked for the significance difference at $p < 0.05$. The Nitrogen and Phosphorus level in the runoff was analysed indirectly in the form of dissolved Ammonia, Nitrate and Phosphate respectively. The two above listed nutrients and others were essential to show the land quality of the area. There is no significant difference in nutrient loss among the three loss from cultivated land was significantly higher than the other two LULC types (Table 3). There was no significant difference in soil loss between the grassland and land uses in the study site (Table 4). One reason for this might be the sample collection time effect, which was collected at the end of the rainy season, when the soil loss amount was very low due to crop cover increment.

The nutrient analysis from the runoff has indicated that essential nutrients are washed away from the land through runoff. The amount of dissolved ammonia and nitrate lost in runoff was higher in cultivated land than the other two LULC types (Table 5). Total dissolved solids and electric conductivity were higher in grassland than the other two land use. The amount of phosphate lost from *Eucalyptus* field was lower than cultivated land and grassland.

There is significant correlation between land use and runoff at $p < 0.01$. There is also significant correlation at $p < 0.05$ between LULC types and soil loss (Table 6). There is positive correlation between soil loss and runoff in the study area (Figure 2).

Similar to this study Adimassu et al. (2014) has observed that the soil loss from cultivated land reduces

Table 5. Means value of runoff, ammonia, nitrate and phosphate per hectare.

LULC types	Total Runoff (l/ha)	Ammonia (kg/ha)	Nitrate (kg/ha)	Phosphate (kg/ha)
Cultivated land	44329.48	18.86	1.73	3.37
Grassland	34148.15	11.15	0.76	2.59
Eucalyptus	35574.00	12.57	1.02	1.78

Table 6. Correlation between LULC types, runoff and soil loss.

Correlation	LULC types	Runoff	Soil loss
LULC types	1	-	-
Runoff	-0.75**	1	-
Soil loss	-0.70*	0.96**	1

** Correlation is significant at 0.01; *Correlation is significant at 0.05.

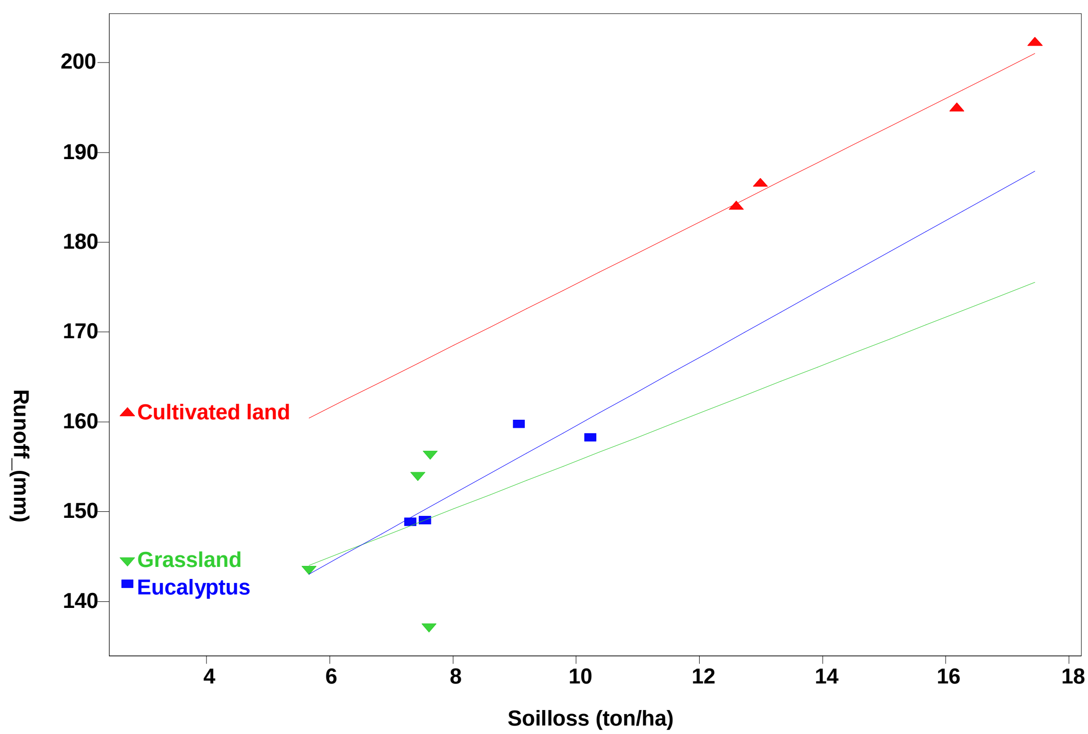

Figure 2. Runoff and soil loss relationship for the study period.

overtime due to the effect of direct rainfall on bare land reduced as the crops grown and cover the land. In different part of Ethiopia soil loss studies have found highly variable annual soil loss from 3.4 ton/ha per year (Walle et al., 2006) to 56.7 ton/ha per year (Gebreegziabher et al., 2008) in non-conserved cultivated land. Others found within the range given above from cultivated land (Haile et al., 2006; Nyssen et al., 2008; Girmay et al., 2009; Adimassu et al., 2014). Further exceptional soil loss was also registered up to 212 ton/ha per year in *Andit Tid*, Ethiopia (Haile et al., 2006). The soil loss from cultivated land has reached up to 300 ton per hectare per year in Ethiopia (Hurni, 1993; Herweg and Stillhardt; 1999; SCRP, 2000). The extent of previous soil erosion, rainfall characteristic, plot size and other variables could be mentioned as causes for variation soil loss in the country.

The annual sediment yield in cultivated land is higher than grassland, plantation, and conservation area in Tigray, North Ethiopia (Girmay et al., 2009). Oppositely, Nyssen et al. (2008) has found less mean soil loss from arable land (9.9 ton/ha/year) than rangeland (17.4 ton/ha/year) in Tigray, Ethiopia. Adimassu et al. (2014) has found greater soil loss from un-conserved cultivated land comparing with cultivated land conserved by soil bund. According to Hurni (1993) the average amount of soil loss from cultivated land was 40 ton per hectare per year in Ethiopia, which is higher than this study, Girmay et al. (2009) and Adimassu et al. (2014). Defersha and Mesele (2012) have also found higher soil loss from cultivated land than other LULC types. The soil loss study, from sub catchments in the same experiment sites with this study, has found lower sediment loss (2.4 ton/ha) and this is due to some sediment might be deposited on its way before reaching the outlet. It could be the reason of reduction of the value of soil loss (Erkossa et al., 2015).

Similar to this study, Girmay et al. (2009) has found no significant difference in soil loss among grassland, exclosure and plantation sites. Grassland has lower soil loss than cultivated land and bare land (Defersha and Mesele, 2012). Similar to the study by Girmay et al. (2009), this study confirms that soil loss from the cultivated land and other degraded land can be significantly reduced when lands are converted into plantation and especially exclosure.

There was no significant difference on nutrient loss from runoff associated P and K observed on cultivated land under different land management practices (Adimassu et al., 2014). The nutrient loss, specially the N and P losses, from the catchment were strongly related to the soil loss. This emphases that where there is high soil loss, there is also high nutrient loss; for instance N (9.7 kg/ha) and P (4.7kg/ha) losses were observed from catchments (Erkossa et al., 2015). Similar to the above, this study has found that higher nutrient loss where there is high soil loss in cultivated land. On contrary to the above, Girmay et al. (2009) has stated that nutrient loss was not only dependent on the sediment loss, but the soil condition of the land where nutrients losses can also influence. Soil and nutrient losses significantly reduced by application of land management practices such as soil bund on cultivated land (Adimassu et al., 2014). According to Haileslassie et al. (2006) nutrient loss rates vary between the land use types and the land management practices.

CONCLUSION AND RECOMMENDATIONS

This study has investigated that the effects of LULC change specially *Eucalyptus* expansion on soil and nutrient losses from runoff (N and P). The study has found that soil loss from each LULC types significantly varied. Cultivated land has contributed the major soil loss in the catchments. The soil loss from cultivated land is higher than the tolerable average soil loss limit given in the country. There was no significant effect on soil loss by changing from grassland to *Eucalyptus* plantation or vise verse. In other words, planting *Eucalyptus* on degraded land could reduce soil loss from the land. There was no significant difference in nutrient loss from runoff at each LULC types. However, the mean amount of soil nutrients loss from cultivated land is higher than other LULC types. Even, greater than the value given by Food and Agriculture Organization (FAO) for nutrient loss from cultivated land. The study has found that the negative correlation between LULC change and soil and nutrient losses in the study area. Similarly, it has found that strong correlation between the volume of soil and nutrient losses from the plots. In summary, cultivated land in the site needs land management practices such as physical and biological soil conservation measures to reduce the soil and nutrient losses beyond the tolerable limit. This study, along with other studies, which have been done in different part of the country on the effect of plantation on erosion, has proved that reduction of soil loss in plantation sites. *Eucalyptus* plantation or woodlot can reduce the soil and nutrient losses through soil erosion. This implies that apart from the socioeconomic benefits, *Eucalyptus* can also be used as biological soil erosion conservation measures on selected sites. Further studies of *Eucalyptus* need to be done in diversified agro ecological zones by considering its effect on soil and nutrient losses from runoff with spacing, long term erosion controlling effect, species and topographic effect. To this extent, this study recommends the policy makers and the experts to consider *Eucalyptus* as one of erosion conservation option where there is land degradation reached the climax and where there is limitation of conservation trees in the area.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The first author is funded by Alliance for Green Revolution in Africa (AGRA) in Sokoine University of Agriculture for his entire PhD study. International Foundation for Science (IFS) has supported the research work. The authors recognize the support given by Central Ethiopia Environment and Forestry Research Center in Ethiopia and Sokoine University of Agriculture in Tanzania.

REFERENCES

Adimassu Z, Mekonnen K, Yirga C, Kessler A (2014). Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia. Land Degrad. Dev. 25:554-564.

Adimassu Z, Kessler A, Yirga C, Stroosnijder L (2010). Mismatches between Farmers and Experts on *Eucalyptus* in Meskan Woreda, Ethiopia. In: Proceedings of the Conference on Eucalyptus Species Management, History, Status and Trends in Ethiopia. (Edited by Gil L, Tadesse W, Tolosana E, Lopez R), 15-17 September 2010, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia. pp. 146-159.

Amsalu A, Stroosnijder L, De Graaf J (2007). Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. J. Environ. Manage. 83:448-459.

Bekele T (2015). Integrated Utilization of *Eucalyptus globulus* grown on the Ethiopian Highlands and its Contribution to Rural Livelihood: A Case Study of Oromia, Amhara and Southern Nations Nationalities and People's Regional State Ethiopia. Int. J. Basic Appl. Sci. 4(2):80-87.

Bewket W (2002). Land cover dynamic since the 1950s in Chemoga watershed, Blue Nile basin, Ethiopia. Mt. Res. Dev. 22:263-269.

Briassoulis H (2000). Factors influencing Land Use and Land Cover Change. In: Encyclopedia of Land use, land cover and soil sciences. Land cover, land use and global change. (Edited by Verheye WH). Encyclopedia of Life Support System. pp. 1-9.

Chanie T, Collick SA, Adgo E, Lehmann CJ, Steenhuis ST (2013). Eco-hydrological impacts of *Eucalyptus* in the semi humid Ethiopian Highlands: the Lake Tana plain. J. Hydrol. Hydromech. 61(1):21-29.

Defersha MB, Melesse AM (2012). Field scale investigation of the effect of land use on sediment yield and runoff using runoff plot data and models in the Mara River basin, Kenya. Catena. 89(2012):54-64.

Dwivedi RS, Sreenivas K, Ramana KV (2005). Land-use/land-cover change analysis in part of Ethiopia using Landsat Thematic Mapper data R. Int. J. Remote Sens. 26 (7):1285-1287.

Erkossa T, Wudneh A, Desalegn B, Taye G (2015). Linking soil erosion to on-site financial cost: lessons from watersheds in the Blue Nile basin. Solid Earth. 6:1-10.

Food and Agriculture Organization (FAO) (1998). The soil and Terrain Database for Northeastern Africa. Land and Water Digital Media Series 2. FAO, Rome.

Fikreyesus S, Kebebew Z, Nebiyu A, Zeleke N, Bogale S (2011). Allelopathic effects of *Eucalyptus camaldulensis* (Dehnh.) on germination and growth of tomato. Am-Eur. J. Agric. Environ. Sci. 11(5):600-608.

Fisseha G, Gebrekidan H, Kibret K, Yitaferu B, Bedadi B (2011). Analysis of land use/land cover changes in the Debre-Mewi watershed at the upper catchment of the Blue Nile basin, northwest Ethiopia. J. Biodivers. Environ. Sci. 1(6):184-198.

Gebreegziabher T, Nyssen J, Govaerts B, Getnet F, Behailu M, Haile M, Deckers J (2008). Contour furrows for in situ soil and water conservation, Tigray, northern Ethiopia. Soil Tillage Res. 103:257-264.

Girmay G, Singh BR, Nyssen J, Borrose T (2009). Runoff and sediment associated nutrient losses under different land uses in Tigray, northern Ethiopia. J. Hydrol. 376:70-80.

Haileslassie A, Priess J, Veldkamp E, Lesschen JP (2006). Smallholders' soil fertility management in the Central High- lands of Ethiopia: implications for nutrient stocks, balances and sustainability of agro ecosystems. Nutr. Cycle Agro Ecosyst. 75(1):135-146.

Herweg K, Stillhardt B (1999). The variability of soil erosion in the Highlands of Ethiopia and Eritrea. Research Report 42, Centre for Development and Environment, University of Berne, Switzerland. P 81.

Hurni H, Messerli B (1981). Mountain research for conservation and development in Simen, Ethiopia. Mt. Res. Dev. 1:49-54.

Hurni H (1985). Erosion – productivity - conservation systems in Ethiopia. Proceedings 4th International Conference on Soil Conservation, Maracay, Venezuela. pp. 654-674.

Hurni H (1993). Land degradation, famine, and land resource scenarios in Ethiopia. In: *World soil erosion and conservation* (Edited by Pimentel, D.), Cambridge Studies in Applied Ecology and Resource Management. Cambridge University Press. Cambridge. pp. 27–61.

Jagger P, Pender J (2003). The role of trees for sustainable management of less favored lands: the case of *Eucalyptus* in Ethiopia. For. Policy Econ. 5:83-95.

Jaleta D, Mbilinyi B, Mahoo H, Lemenih M (2016a). Evaluation of Land Use/Land Cover Changes and *Eucalyptus* Expansion in Meja Watershed, Ethiopia. J. Geogr. Environ. Earth Sci. Int. 7(3):1-12.

Jaleta D, Mbilinyi B, Mahoo H, Lemenih M (2016b). Eucalyptus expansion as relieving and provocative tree in Ethiopia. J. Agric. Ecol. Res. Int. 6(3):1-12.

Jenbere D, Lemenih M, Kassa H (2012). Expansion of Eucalypt farm forestry and its determinants in Arsi Negelle district, south central Ethiopia. Small-Scale For. 11(3):389-405.

Kebebew Z, Ayele G (2010). Profitability and household income contribution of growing *Eucalyptus globules* (Labill.) to smallholder farmers: the case of central Highland of Oromia, Ethiopia. Eur. J. Appl. Sci. 2(1):25-29.

Kindu M, Schneider T, Teketay D, Knoke T (2015). Drivers of land use/land cover changes in Munessa-Shashemene landscape of the south-central highlands of Ethiopia. Environ. Monit. Assess. 187(7):4671.

Lambin EF, Geist HJ, Lepers E (2003). Dynamics of land-use and land cover change in tropical regions. Ann. Rev. Ecol. Evol. Syst. 28:205-241.

Lemenih M (2010). Growing Eucalypts by smallholder farmers in Ethiopia. In: Proceedings of the Conference on *Eucalyptus* Species Management, History, Status and Trends in Ethiopia. (Edited by Gil, L, Tadesse W, Tolosana E, Lopez R), 15–17 September 2010, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia. pp. 91-103.

Mekonnen Z, Kassa H, Lemenih M, Campbell B (2007). The role and management of *Eucalyptus* in Lode Hetosa district, central Ethiopia. For. Trees Livelihoods 17:309-323.

Haile M, Herweg K, Stillhardt B (2006). Sustainable land management – A new approach to soil and water conservation in Ethiopia. Berhanena Selam Printing Enterprise, Addis Abeba. P 304.

Nigatu L, Michelsen A (1993). Allelopathy in agroforestry systems: the effects of leaf extracts of *Cupressus lusitanica* and three *Eucalyptus* spp. on four Ethiopian crops. Agrofor. Syst. 21:63-74.

Nyssen J, Poesen J, Moeyersons J, Haile M, Deckers J (2008). Dynamics of soil erosion rates and controlling factors in the Northern Ethiopian highlands – towards a sediment budget. Earth Surf. Process. Landforms 33(5):695-711.

Patnaik P (2010). Handbook of environmental analysis: chemical pollutants in air, water, soil and solid wastes. Second edition. CRC Press, Boca Raton London, New York. P 824.

Soil Conservation Research Programme (SCRP) (2000). Concept and methodology: Long term monitoring of agricultural environment in six stations in Ethiopia. Soil Erosion and Conservation Database. Bern, Switzerland and Addis Abeba, Ethiopia: Centre for Development and Environment (CDE) and Ministry of Agriculture. Bern, Switzerland.

Tekele K, Hedlund L (2000). Land cover changes between 1958 and 1986 in Kalu district, southern Wello, Ethiopian. Mt. Res. Dev. 20:42-51.

Walle S, Chantawarangul K, Nontananandh S, Jantawat S (2006). Effectiveness of grass strips as barrier against runoff and soil loss in Jijiga area, northern part of Somali region, Ethiopia. Kasetsart J. 40:549-558.

Wubie MA, Assen M, Nicolau MD (2016). Patterns, causes and consequences of land use/cover dynamics in the Gumara watershed of Lake Tana basin, Northwestern Ethiopia. Environ. Syst. Res. 5:1-8.

Zeleke G, Hurni H (2001). Implications of land use and land cover dynamics for mountain resource degradation in the North western Ethiopian Highlands. Mt. Res. Dev. 21(2):184-191.