Journal of Resources Development and Management
ISSN 2422-8397 An International Peer-reviewed Journal
Vol.83 , 2022

Urban Forest Change Detection in Endayesus Area, Tigray, Ethiopia

Berihu Tesfamariam Zeratsion
Mekele environment and forest research center, Mekele, Ethiopia
Email: raeyberi@gmail.com

Abstract
Urban forests are one of the crucial ecosystems for sustainability, by which they provide carbon sequestration, microclimate regulation, recreation and other ecosystem services. To attain the benefits and ensure the livability of urban areas communities and governments have been putting efforts to increase coverage of urban forests. Based on that, this paper aimed to detect forest cover change and contribution of forestry practices in enhancing forest cover of Endayesus urban forest area. Aerial photos were obtained from Ethiopian mapping agency and planning office of Mekele city. Other data were collected from randomly selected 196 sample households and purposively selected 20 officials using questionnaire and interview checklists. Descriptive statistics, SPSS and GIS software were used for analysis and generating figurative and spatial outputs. The study confirmed forest cover in Endayesus increased by 1387.43% from 1965 to 2009. However, existence of bare and bush land use types exist substantially. Exclosing the catchment, plantations, public education and tree management activities contributed in improving forest cover of the area. There should have to be land cover/use plan prepared in a way to maximize the benefits of urban forests within the area based on established multiple criteria. In addition, further research is needed in modeling the possible damage to Mekele city under vegetated and non-vegetated scenarios of Endayesus area in different climatic conditions.
Keywords: urban forest cover, vegetation cover and urban forestry activities
DOI: 10.7176/JRDM/83-01
Publication date: March 31st 2022

1. Introduction

Starting from the beginning of the twenty first century, one of the major issues in sustainable land management is the relationship between towns and forests (FAO, 2012). It is believed that green infrastructures provide equal benefit as gray infrastructure to a city; but communities promoting green infrastructure are more livable; producing fewer pollutants and cost effective to operate. When forests near residential areas and cities are degraded, the forest functions of regulating water flows, preventing landslides, floods and droughts in the nearby downstream areas are lost. This could lead high cost to the community in terms of human life loose, infrastructure destruction, island heat effect and water supply shortage (FAO, 2012).

Globally forests cover almost more than a quarter of the Earth's land surface, estimated approximately 4.2 Billion hectares (Chiras, 2013). FAO (2012) reports Ethiopia's forest cover is 12.2 million ha (11%) (Yitebitu, *et al.*, 2010). If we see in Ethiopia of Addis Ababa, the area covered by forest, mostly eucalyptus, is 7,734 hectares. This is about 15 percent of the total area covered by Addis Ababa, but only 35 percent of the planned green border of the city (Edwards, 2010).

A research in selected areas of Tigray (North Ethiopia) proves that woody vegetation and built up area increased strongly, which mostly occurred at the expense of bush land (Meire, et al, 2012). On the contrary, Tahiri, *et al.*, (2013), on their research in land cover analysis of Mekele showed that sparse forest showed no change over years. Tahiri, et al (2013) also found that urban features in Mekele increased by 200% in the years between 1985 and 2010.

Assessing driving forces of forest cover change and mapping forest cover change of an area enables responsible bodies to have better information on how to conserve forests (Tahir et al, 2013). In Ethiopia such studies have been done so far to investigate land use/land cover and forest covers issues (Solomon et al, 2018). But, these studies were not comprehensive enough in scope and not focused on specific urban forest areas. Therefore, this study analyzed the extent of forest cover change over years and identified the main urban forestry practices enhancing urban forest cover in Endayesus of Mekele city.

2. Materials and Methods

2.1. Description of the study area

According the data from Mekele city municipality (2010), Mekele is found in the Northern part of Ethiopia, 783km far from Addis Ababa. It is the capital city of National, regional state of Tigray, situated within the boundary of Enderta wereda in the southeastern zone of Tigray region. Its geographical location is 13^0 32' North latitude and 39^0 28' East longitudes, specifically within the limit of 13^0 18' 30" - 13^0 39' 52" North latitude and 39^0 22' 30'' -39^0 39" 33" East longitude.

The city has a total population of 273, 459, with 132, 868 Male and 140, 593 Female population (CSA, 2007). It occupies a total area of 74 km $^{2.}$ Mekele is divided into seven administrative sub cities, namely Kedamay weyane, Semien, Hadinet, Adihaki, Aider, Quiha and Hawelti. The agro climatic condition of the city is mild (Weyna Dega), with a maximum average temperature of 24.1 ^{0}C and average minimum temperature of 11.11^{0}C; experiencing the hottest condition in June and coldest in December. It has an annual average rainfall of 618.3 mm/Year (Mekele city municipality, 2010.).

The vegetation cover of Mekele has been observed to vary from time to time. There are some evidences justifying this, in which there are indigenous highland type of forest such as Juniperus procera, Podocarpus(Afrocarpus falcatus), Cordia Africana, Acacia etbaica etc in Enda medhanie alem churchyards and Enda rasi recreational sites (Mekele city municipality, 2010). Endayesus area is also known for its hilly and partly vegetated features. It is found within the city surrounded by Quiha (Eastern part), Semien (North Western part), Kedamay weyane(Western part), and Adihaki(Southern part).

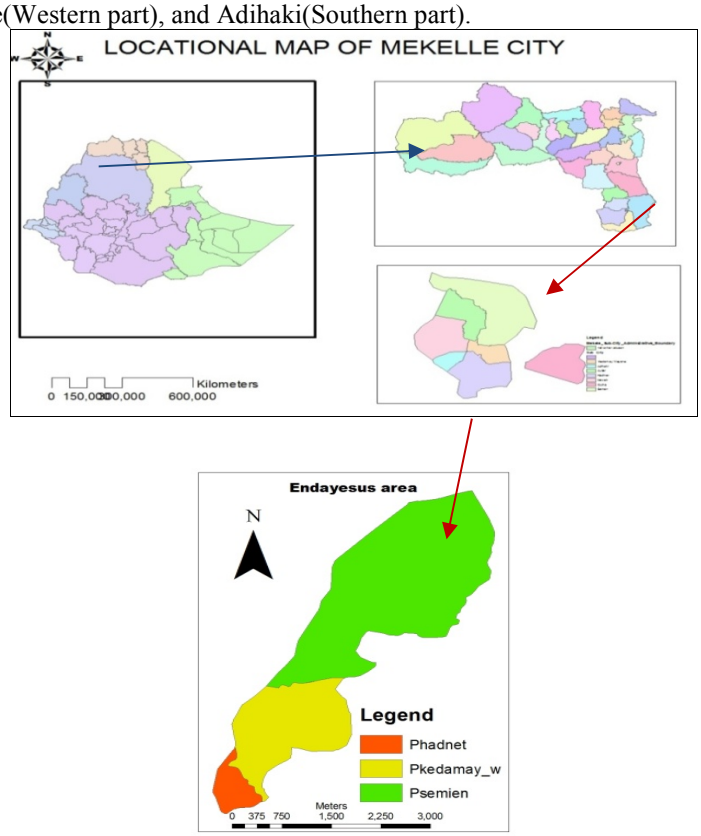

Figure 1. Study area

2.2. Data collection

Aerial photographs of Mekele for 1665, 1994 and 2009 were purchased from Ethiopian mapping agency. These data were used for generating land cover map of the study.

In addition, 196 households were selected using proportionate random sampling from the three sub-cities to assess the contribution of urban forestry practice in improving forest cover of Endayesus urban forest area. Questionnaire and semi structured interview checklist was used to collect data from sampled households. Besides, 20 key informants were selected from different institutions.

2.3. Data analysis

Data collected from households, key informants and aerial photographs were compiled into segregated data bases, cleaned, and checked for accuracy. Statistical tools from SPSS, Microsoft Excel and GIS were used to analyze these data. Spatial analysis was done by which the aerial photos were made to generate seven land cover types in terms of hectare through on screen digitizing in GIS software. The aerial photos were georeferenced using ground control points. The Universal Transverse Mercator (UTM) projection, Clarke 1880 spheroid, and Adindan zone 37 North datum was used for Geo-referencing the photos. In order to distinguish forest cover of the catchment, land cover of the study area was categorized into seven types; these are bare land, built up, bush land, farmland, dense forest, sparse forest and scattered tree population. This classification was done using

supervised method of classification. Finally, land cover map of 1965, 1994 and 2009 were generated through GIS analysis.

3. Results

3.1. Forest cover change in Endayesus area

From the land cover of the catchment in 1965 bare land and farmland accounted 51.6% (443ha) and 36.51% (313.4ha) of the total area of the designated area respectively. The rest land use types; built up, bush land, dense forest, sparse forest and scattered trees account 11.89% collectively. All vegetation types accounted 8.69% (74.6ha) of the total area. Dense and sparse forest cover had coverage of 2.13% (18.3ha) (Table 1).

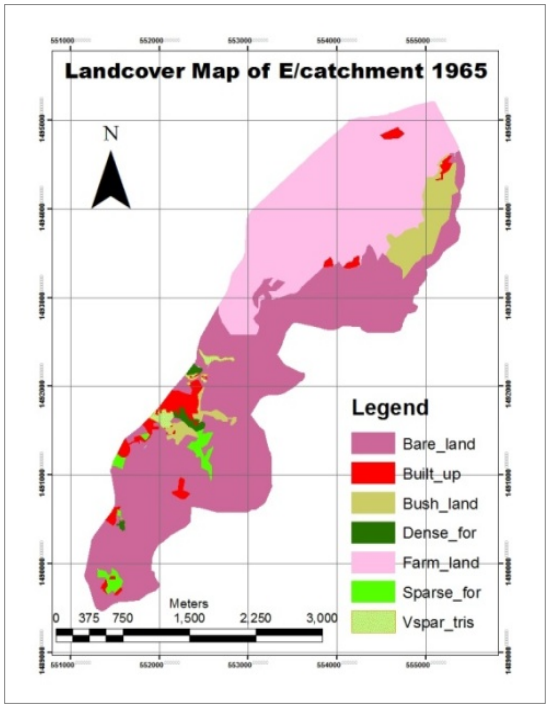

Figure2. L/cover map of E/catchment for 1965

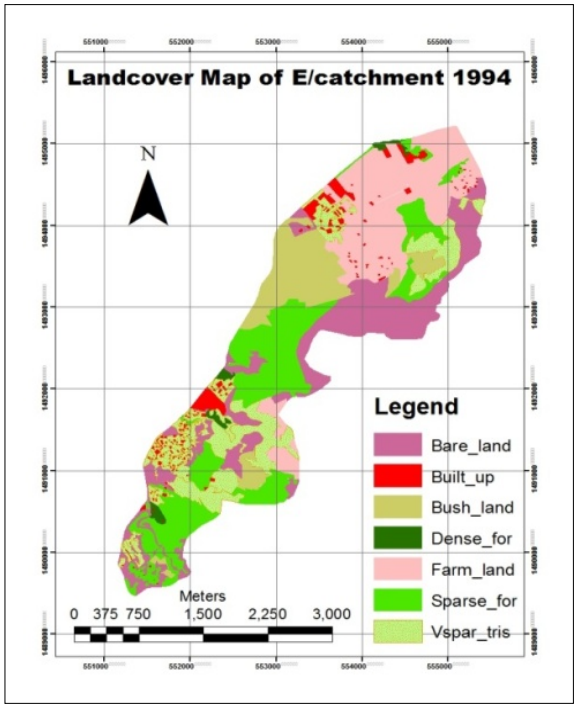

Figure 3. L/cover map of E/catchment – 1994

In 1994 sparse forest, farmland and bare land accounted 23.16% (198.8ha), 22.28% (191.3ha) and 20.85% (179ha) respectively, by which the rest, dense forest, scattered trees, bush land and built up accounted 66.29% collectively. All vegetation types (dense forest, sparse forest, bush land and scattered trees cover) had area coverage of 53.5% (459.3ha). In addition 24.22% (207.9ha) area coverage was recorded from dense and sparse forest cover types (Table 1).

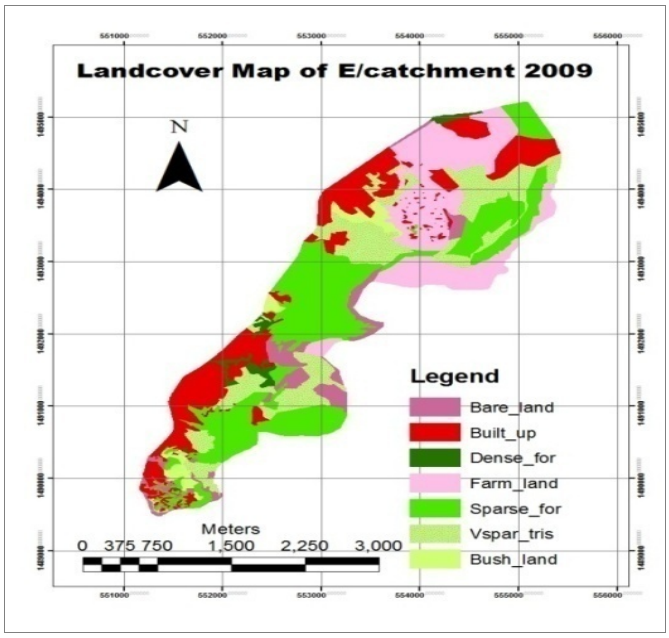

Figure 4. L/cover map of E/catchment for 2009.

In 2009, built up, farm land, sparse forest and scattered trees accounted 19.88% (170.7ha), 20.66% (177.4ha), 29.86% (256.3ha) and 18.65% (160.1ha) of the total area respectively. The other three land cover types cover an area of 10.95% collectively. All vegetation types covered 53.08% (455.7ha) of the total land cover area. Dense and sparse forest cover was found to be 31.71% (272.2ha) of the total (Table 1).

Table 1. Land cover of Endayesus catchment over years by Hectare

		Coverage					
		1965		**1994**		**2009**	
R.N.	**Land cover type**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
1	Bare land	443	51.60	179.0	20.85	54.7	6.37
2	Built up	27.5	3.20	28.9	3.37	170.7	19.88
3	Bush land	49.6	5.78	106.7	12.43	23.4	2.73
4	Dense forest	5.5	0.64	9.1	1.06	15.9	1.85
5	Farm land	313.4	36.51	191.3	22.28	177.4	20.66
6	Sparse forest	12.8	1.49	198.8	23.16	256.3	29.86
7	Scattered trees	6.7	0.78	144.7	16.85	160.1	18.65
		858.5	**100**	**858.5**	**100**	**858.5**	**100**
	All vegetation	*74.6*	*8.69*	*459.3*	*53.5*	*455.7*	*53.08*
	Dense + Sparse forest	*18.3*	*2.13*	*207.9*	*24.22*	*272.2*	*31.71*

As is indicated in the table below, Endayesus are experienced significant variation of spatial land cover over years

Table 2: Land cover change in Endayesus catchment over years

		Variation					
		1965-1994		**1994-2009**		**1965-2009**	
R.N.	**Land cover type**	**Ha**	**%**	**Ha**	**%**	**ha**	**%**
1	Bare land	-264	-59.59	-124.3	-69.44	-388.3	-87.65
2	Built up	+1.4	+5.09	+141.8	+490.66	+143.2	+520.73
3	Bush land	+57.1	+115.12	-83.3	-78.07	-26.2	-52.82
4	Dense forest	+3.6	+65.45	+6.8	+74.73	+10.4	+189.10
5	Farm land	-122.1	-38.96	-13.9	-0.07	-136.0	-43.40
6	Sparse forest	+186	+1453.13	+57.5	+28.92	+243.5	+1902.34
7	Scattered trees	+138	+2059.70	+15.4	+10.64	+153.4	+2289.55
	All vegetation	+384.7	+515.68	-3.6	-0.78	+381.1	+510.8
	Dense + Sparse forest	+189.6	+1036.0	+64.3	+30.93	+253.9	+1387.43

The above table depicts that the highest land cover change in the time period of 1965 – 1994 was recorded by scattered trees population (+2059.7%); followed by sparse forest (+1453.13%) and bush land (+115.12%).

From 1994 – 2009 the highest change was observed in built up (490.66%), bush land (-78.07) and dense forest (+74.73%) respectively. The change in land cover type from 1965 – 2009 proved that scattered trees, sparse forest and built up increased substantially by 2289.55%, 1902.34% and 520.73% respectively (Table 2).

All vegetation cover types changed by +515.68%, -0.78% and 510.8% from 1965-1994, 1994-2009 and 1965-2009 respectively. Only dense and sparse forests cover changed by +1036.00%, 30.93% and 1387.43% from 1965-1994, 1994-2009 and 1965-2009 respectively (Table 2).

3.2. Role of urban forestry practices in enhancing forest cover of Endayesus area

It is confirmed that exclosure (inhibiting from disturbance) contributed better (32.4% very high and 34.6% higher) than the other activities in increasing forest cover of Endayesus area. It was also reported that plantation has good contribution (22.3% and 19.1%). 14.4% and 33% respondents said public education contributed very high and high respectively. According the result, 20.7% and 14.4% respondents replied that tree maintenance and care contribute very high and high respectively. Enforcing local bylaws was found the least ranked, by which only 11.2% and 11.7% respondents said it contributed very high and high respectively (Table 3).

Table 3: Role of urban forestry activities in enhancing forest cover of Endayesus

R.N.	Level of contribution	Forestry activities					
			Plantation	Area closure	Tree maintenance & care	Public education	Enforcing local bylaws
1	Very high	F	42	61	39	27	21
		%	22.3	32.4	20.7	14.4	11.2
2	High	F	36	65	27	62	22
		%	19.1	34.6	14.4	33	11.7
3	Medium	F	74	34	56	61	44
		%	39.4	18.1	29.8	32.4	23.4
4	Low	F	30	22	46	28	44
		%	16	11.7	24.5	14.9	23.4
5	Very low	F	3	4	15	6	46
		%	1.6	2.1	8	3.2	24.5
6	No contribution	F	3	2	5	4	11
		%	1.6	1.1	2.7	2.1	5.9
Weighted average		**%**	**56.65**	**63.39**	**51.24**	**55.67**	**40.69**

Furthermore, weighted average of the five urban forestry activities was 63.39%, 56.65%. 55.67%, 51.24% and 40.69% for the role of exclosure, plantation, public education, tree maintenance and enforcing local bylaws respectively. (Table 3).

Apart from these, findings from interview and open ended question show that plantation is no more contributing to forest cover increase of Endayesus catchment. Some noted that the result of most forest cover of Endayesus catchment was obtained due to the plantations of eucalyptus trees done during the 1960s and due to protecting the area from animal and human disturbances. Moreover, some experts claimed that plantations are not done based on justified planning in a way to make the forests sustainable and highly benefiting to the community. For instance, an expert from Mekele University, said, *"plantations in Endayesus catchment should be by asking questions; what types of tree seedling and where have to be planted for what purpose? However, what we are observing here is simply planting. The local government did not consider the points at which area for what purpose should be planted what, for the sake of optimizing the public benefit"*. Data from researcher's observation also showed that urban agriculture office of the city does not have plan about what and where to plant and why.

4. Discussion

4.1. Forest cover change in Endayesus catchment

Land cover analysis of Endayesus catchment was done for 1965, 1994 and 2009, with 29 and 15 years difference in between respectively. The GIS analysis result provides that, during the 1965, the highest land cover with in the catchment was bare land (51.6% of the total land cover) followed by farmland (31.51%). In 1994 the highest land cover was sparse forest (23.16%) followed by farm land (22.28%). Similar with the results of 1994 the highest land cover in 2009 was sparse forest covering 29.86% followed by farm land covering 20.66%. This proves that the catchment's land cover during 1965 was highly dominated by bare land and farm land type of land uses (both covering 83.11% of the total), testifying that the city's built up area and forest coverage was very low. In 1994 sparse forest, farm land and bare land showed similar area coverage (23.16%, 22.28% and 20.85% respectively). Similarly sparse forest, farm land, built up and scattered trees land use types were found relatively dominant (25.63%, 20.66%, 19.88%, and 18.65% respectively) in 2009, the rest

with low proportion in the catchment. This shows that spatial dimension of cities vary through time (Jim and Liu, 2001).

Similar with other findings (Weldeamlak, 2002 and Southworth and Tucker, 2001), the three vegetation types, dense forest, sparse forest and scattered trees population has come increasing from time to time, except bush land showed a decreasing trend (Weldeamlak, 2002). In the time period from 1965-1994 dense forest, sparse forest and scattered trees increased by 65.45%, 1453.13% and 2059% respectively. Similarly from 1994-2009 the area coverage increase was 74.73%, 27.92% and 10.64% respectively for the three vegetation classifications. In general, these three vegetation classifications increased by 189.1%, 1902.34% and 2289.55% in the time period of 1965-1994, 1994-2009 and 1965-2009 respectively. This means 0.24ha per year, 5.5ha per year and 3.5ha per year average increase of dense forest, sparse forest and scattered trees cover is recorded respectively. On the other hand, the change in all vegetation cover types showed an increasing trend from 1965 – 1994 (515.68%), a decreasing trend from 1994 – 2009 (0.78%) and an increasing trend from 1965 – 2009 (510.8%). If we see the change of dense and sparse forest cover types, an increase of 1036%, 30.93% and 1387.43% is recorded from 1965-1994, 1994-2009 and 1965-2009 respectively. These research results are in line with other studies which prove that vegetation cover improved (Southworth and Tucker, 2011and Weldeamlak, 2002), built up area increased, bush land and bare land decreased (Eleni et al, 2013 and Weldeamlak, 2002) temporally. On the other hand many agreed that forest cover declined (Eleni et al, 2013, Bosco, et al, 2011 and Gete and Hurni, 2001)

Similar with theses vegetation covers the built environment also increased significantly by 5.09%, 490.66% and 520.73% from the year intervals of 1965-1994, 1994-2009 and 1965-2009 respectively. The rest land use types showed negative increase in all the time interval periods, with bare land being the highly decreased one (87.65% decrease from 1965-2009).

A research in selected areas of Tigray (North Ethiopia) found similar findings with the results of this research. It proves that woody vegetation and built up area increased strongly, which mostly occurred at the expense of bush land (Meire, et al, 2012). On the contrary, Tahir, et al, (2012), on their research in land cover analysis of Mekele showed that sparse forest showed no change. This could be due to methodology and material differences or due to this research's focus on specific area of Mekele. Tahir, et al, (2012) also found that urban features in Mekele increased by 200% in the years between 1985 and 2010.

4.2. Role of urban forestry practices in enhancing forest cover of Endayesus Catchment

Forestry practices have been being practiced for years in Ethiopia, including in urban areas. These activities resulted promising results in the vegetation cover changes of the country. Urban forestry in Endayesus catchment of Mekele is the responsibility of urban agriculture office with the help of Mekele University. Results from the survey indicated that urban forestry practices in Endayesus catchment are enabling forests to increase. According most respondents exclosure was said highly contributing in enhancing forest cover of the catchment (63.39%). Creating awareness on the importance of urban forestry is an important component of its development strategy (Fuwape and Onyekwelu, 2010). In doing so the city seems moving some miles. Plantation (56.65%) and public education (55.67%) about urban forestry was the next highest ranked activity in its contribution to forest increase of Endayesus catchment. This shows that reforestation contributing in enhancing forest cover (Southworth and Tucker, 2011) of urban areas.

But, some said that in the recent times plantation is becoming investing for nothing, because planted trees did not always survive even until the next year. They believe the forest cover is in a good situation because trees planted before years are being protected well in which disturbance level is low. One expert stated *"had it been successful in forest cover increase like is planted every year, it could be a great move; but recently planted trees are good for nothing. The trees we are observing are those which were planted before many years and also regenerated by themselves"*. But this could not be to mean that plantation contributed nothing, rather, is not equivalent with the efforts made and is not as expected, especially in the recent times.

Meyfroidt, and Lambin, (2011) indicated that developing tropical countries have recently been through forest cover increase, due to performing different forestry activities; showing similar trends with this research. Theses authors also state that planted trees has increased by 4.9Mha/year during the period 2000-2010 globally.

5. Conclusion

Vegetation cover in 1965 was very limited, by which bare land use type was highly dominant. Where as in both 1994 and 2009 dense forests, sparse forest and scattered tree population increased at an encouraging rate. This success was due to continuous plantation and protection activities over years. It is a prospect that forest cover is increasing and bare land is decreasing and a challenge that built up area is increasing within the restricted urban forest area. Nevertheless, significant amount of area coverage is found bare land, bush land and with scattered trees population, seeking to be changed to forest area. Exclosure is having good contribution in enhancing forest

cover of Endayesus. Plantation and public education are also putting their own signature significantly.

The catchment should have land cover/use plan, prepared in a way to maximize the benefits of urban forestry within the catchment based on established multiple criteria. In addition, modeling the possible damage to Mekele city under vegetated and non-vegetated scenarios of Endayesus catchment in different climatic conditions is important for residents and the local government to be prepared for the possible damages, if any.

References

Bosco, NJ, Geoffrey, MM, and Kariuki, N. (2011), 'Assessment of landscape change and occurrence at watershed level in city of Nairobi', African Journal of Environmental Science and Technology Vol. 5, no.10, pp. 873-883.

Chiras, D,(2013), *Environmental science*, Jones and Bartlet learning company, USA.

CSA (2007), *Population and Housing Census Report-Country - 2007,* Central Statistical Agency of Ethiopia.

Edwards, S,(ed.) 2010, Ethiopian Environment Review, Eclipse Printing Press, Addis Ababa, Ethiopia.

Eleni Y, Wagner, W., Exner-Kittridge, M., Legesse, D. and Blöschl, G (2013) 'Identifying Land Use/Cover Dynamics in the Koga Catchment, Ethiopia, from Multi-Scale Data, and Implications for Environmental Change', *ISPRS Int. J. Geo-Inf.* 2013, *2*, 302-323; doi:10.3390/ijgi2020302

FAO (2012), 'Urban and peri-urban forestry in Africa: the outlook for woodfuel', *Urban And peri-urban forestry working paper no. 4*, page, 95. Rome

Fuwape, J, and Onyekwelu, J, (2010), 'Urban Forest Development in West Africa: Benefits and Challenges', Journal of Biodiversity and Ecological Sciences, vol.1, no.1, pp. 2008-9287

Gete and Hurni (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

Jim, CY and Liu, HT (2001), 'Patterns and Dynamics of Urban Forests in Relation to Land Use and Development History in Guangzhou City, China', *The Geographical Journal*, Vol. 167, No. 4

Mefroidt, P and Lambin E (2011), 'Global Forest Transition: Prospects for an End to Deforestation', *Annual review of environment and resources*, Vol.36:343-371

Meire, E, Frankl, A, Wulf, D, Mitiku, H, Deckers, J and Nyssen, J (2012), 'Land use and cover dynamics in Africa since the nineteenth century: warped terrestrial photographs of North Ethiopia', *Reg Environ Change,* DOI 10.1007/s10113-012-0347-9

Municipality of Mekele City (2010), Environmental and physical features of Mekele city (un published).

Solomon, N, Hishe, H, Annang, T, Pabi, O, Asante, I and Birhane, E (2018), 'Forest Cover Change, Key Drivers and Community Perception in Wujig Mahgo Waren Forest of Northern Ethiopia', *Land* 2018, 7, 32; doi: 10.3390/land7010032

Southworth, J and Tucker, C (2001) 'The Influence of Accessibility, Local Institutions, and Socioeconomic Factors on Forest Cover Change in the Mountains of Western Honduras', *Mountain Research and Development,* 21(3):276-283. 2001

Tahir, M, Imam, E, Tahir, H (2013), 'Evaluation of land use/land cover changes in Mekelle City, Ethiopia using Remote Sensing and GIS', *Computational Ecology and Software*, vol. 3, no. 1, pp. 9-16

Woldeamlak, B (2002, 'Land Cover Dynamics Since the 1950s in Chemoga Watershed, Blue Nile Basin, Ethiopia', *Mountain Research and Development*, 22(3):263-269. 2002.

Yetebitu, Zewdu and Sisay (2010), 'Manual for assessment and monitoring of carbon in forest and other land uses in Ethiopia (Draft), Ethiopian Forest Research Center, Addis Ababa, Ethiopia