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Shrinkage and Carbon Stock in Wetlands of Fogera Plain, *North West Ethiopia*

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Abstract
This study investigates the shrinkage and carbon sequestrationin wetlands of Fogera plain,North West Ethiopia. Landsat MSS of 1973, Landsat TM of 1994 and Landsat ETM+ 2011 were used for change detection. Supervised image classification through maximum likelihood classifier algorithm and qualitative data collection methods wereused. Composite soil samples in three replications at a depth of 0-75 cm were collected and samples organic carbon and organic matter was analyzed in soil laboratory. The result of Landsat images analysis showed that the area of the wetland was 25% of the area in1973 while it shrinkedin to 19.59% in 2011.There is a significant difference ($p < 0.05$) in soil OC and OM content in between different classes of wetlands. The organic carbon content of soils in wetlands where there is sediment deposition is very low. In less disturbed wetlands, there is better carbon content than other state of wetlands. Totally, carbon sequestration potential of these wetlands is very low in comparison with the carbon content of the wetlands of other parts of the world. This study recommends further upstreamwatershed conservation efforts and payment for the ecosystem services and benefits for such like ecosystems is to be started.
Key words; carbon sequestration, sediment deposition

1. Introduction

Wetlands are important natural resources which provide a range of environmental and socio economic functions [1]. More importantly, wetlands are among the strategies of lowering CO2 emissions to mitigate climate change by sequestering CO2 from the atmosphere than other natural resources[2].But there are controversies on this regard. For instance, there is research out put which discover there is a rapid C sequestration in wetlands associated with rapid mineral deposition takes place in wetlands[3]. In contrast Minnesota Board of Water and Soil Resources research out wetlands release carbon both through natural and seasonal changes and more drastically when wetlands equilibrium is affected by human interference[4]. Because of these controversies there is a recognized need for additional research on wetland carbon sequestration to assess the state of science on this emerging topic at local level.

Even though wetlands are critically important ecosystems that provide globally significant environmental, social and economic benefits, they are under serious threat. Miserably the degradation and loss of wetlands is more rapid than that of other ecosystems. For this agricultural land expansion, climate change and sedimentation are the major causes[1]. In connection to wetlands degradation it is hardly possible to know how much carbon would be released if wetlands are destroyed. Scientific evidence must be gathered soon that shows carbon storage potential of wetlands. Knowing how much carbon stored in wetland is a means to find a way to combat global warming and rising CO2 levels in the atmosphere.

Large part of Fogera woreda is floodplain and this woreda is rich in wetlands. But these wetlands are characterized by extensive cultivation. The land for rice production was 6 hectare in 1985/86 E.C while it increases into 15,119 hectare in 2003/2004. In parallel, the production of rice increase from 160 quintal in 1985/86 E.C to 856,794 quintal in 2003/2004 E.C (Government Communication Office, 2011). Sedimentation owing to erosion of the upstream watersheds (Rib and Gumera) is also another major problem.Mainly these problems are observable in the wetlands of Shesher and Welela wetlands. At all there is no practice of sustainable agriculture in the environs of wetlands of Fogera plain.As is identifying change in area and describing ecological character of wetlands is one framework of Ramsar convention, this study has conducted to assessthe shrinkage and carbon sequestration inwetlands of Fogera Plain.

2. Materials and Methods

2.1 Description of the Study Area

Fogera plain is found in South Gonder zone, Amhara regional state. Astronomically this woreda is located between 11º 42'- 12 º 03'N latitude and 37 º 25'- 37 º 58' E longitudes. This plain is bordered with Lake Tana from the West.

The elevation is ranged from 1500- 2500m. Topographically, 11 % is mountainous, 13% undulating and 76% is plain. The woreda has the potential for different crop cultivation mainly for rice and is totally in Weynadega agroecology. The annual rainfall is 1284 mm and annual temperature ranges from 10.3ºC to 18.75ºC(Ethio Government Communication Office, 2011). In Fogera plain, different spot wetlands are found. But large area of

wetlands is found in the plain of Shesher and Welela. The wetlands of shesher cover the area of Shina, Nabega, Shega and Kidist Hana kebeles of Fogera Woreda. According to Development agents, Land administrator expert and local people, Shesher dries usually in February or March; whereas, Welala dries in April or May. In rainy years, when there is high overflow from Ribb River, Welala never dries throughout the year. The Shesher and Welala wetlands are valuable for the local community. They provide water, grazing for livestock and fish for food.

2.2 Research Methodology

2.2.1 Methods and Procedures for Wetlands Shrinkage Study

For this study the shape file of this area was taken from Ethio GIS 1994 and used as a base map. The Landsat satellite images of MSS for the date January 1973, Landsat TM for the date December 1994 and Landsat ETM+ for the date January2011 which have 58m, 28.5m and 28.5m resolution respectively were acquired. WGS_1984_UTM_Zone_37N projection was used to georeference and to georectify the images. Satellite images were classified by supervised classification through maximum likelihood classifier algorithm on ERDAS Imagine 8.6. After having the spatial and temporal maps of the wetlands, the accuracy of the classification of wetland maps of 1973, 1986 and 2011 are assessed by error matrix, over all accuracy and Kappa (K) statics. For this method, ground truthing data were collected by guided and transect walks and GPS.Besides to satellite image mapping, focused group discussions and key informant interviews were conducted with the community having different economic status, age and sex group.In this study lands which are covered by water, sedimented lands and moist lands are classified as wetland.

2.2.2 *Methods and Procedures for Soil Sampling and Analysis*

For this study, biosequential soil sampling approaches was followed. After having these governing soil sampling approach, soil samples were taken from the land which was wetland 20 years ago (sample site 1), land which was wetland 10 years ago (sample site 2) and currently undisturbed wetland (sample 3). A composite soil samples from 0-75 cm were taken in three replication. From one sample site 21 soil samples, totally 63 soil samples were taken. Each soil sample were placed in a plastic zip-lock bag and stored in air drying place. Location of sample points, sedimentation areas, different types of wetlands (disturbed or undisturbed wetlands) and other aspects of wetland were identified on the field during sampling. Finally carbon content of the sample soils was analyzed in laboratory of Oromia Water Works Enterprise in Addis Ababa following ferrous ammonium sulphate using diphenylamine indicator procedure(Schnitzer, 1982).

After laboratory analysis of carbon content of wetlands, statistical analyses were performed by using ANOVA. Data was analyzed using two groupings. Group 1 is reference site (the current undisturbed wetland) and group two is former wetland sites now under other land uses (disturbed site). Then comparison of the mean carbon content in between different state of wetlands was conducted using ANOVA test. This data analysis was performed by SPSS version 16.

2.2.3 *Qualitative Data Collection and Analysis*

These are methods to study the causes of wetland shrinkage and qualitative description of the trend of wetland. Focused group Discussion with youth households group, old aged households group and kebele administration group having a group size of six and key informant interview with 28 informants were performed. The key informants were kebele Development Agents, governmental and nongovernmental organizations, social institutions, religious leaders and others concerned to the management of the wetlands of Fogera plain.For qualitative data analysis, content and comparative analysis methodswere used. For biodiversity study, field observation, interview and review of other studies were conducted.

3. Result and Discussion

3.1 Analysis of Wetlands Shrinkage in Fogera Plain

By using field survey and satellite images of Landsat MSS 1973, Landsat TM 1994 and Landsat ETM+2011, cultivated land , settlements, Wetlands, Grazing lands and Forest and bush lands were identified. These land use and land covers have spatial pattern and subject to change over time. Among these land uses, change in area of wetlands is the objective of this study (see figure 3 and table 1).

The wetlands of Fogera plain showed a significant difference in area from the 1970s to the present. In 1973, 25.73% of the area was wetland while in 2011 it reduces in to 19.59% of the area. In contrast the area of agricultural land and settlement showed an increasing trend. In 1973, the land of agricultural land and settlement was 47.35% while it increases in to 56.64% of the area.

The result of the satellite image analyses described above is also confirmed by the local community. The farmers themselves notice the shrinkage of wetlands. The farmers clearly describe that there is shrinkage of wetlands. The farmers of Shina kebele of Shesher said;

‘‘The area of the land covered by water is decreasing from time to time and this is a good fortune for us to plough. Before 20 years ago, there was a grass grown on the wetlands and that grass was used for cattle forage. During that time diary farming was the main stay. But following the retreat of the wetland water, we plough the

wetland. Owing to this,wechange the former milk cows. Because these cows by nature are big and require more grass. Since 1990s we are practicing farming on this wetland. We drain the water of these wetlands to plough and pump water for irrigation''.

There are diverse causes for the shrinkage of wetlands. Among these, the sediment deposition on Shesher wetland which is transported by river Rib is one. This river carried sediment from the upstream areas and deposes it to the wetlands of Shesher. Following sediment the wetland lacks its pristine nature and following this farmers plough. Due to unsustainable farming activities by local farmers, the existence of these floodplain wetlands and associated ecological services as well as socioeconomic importance is under threat. It was observed that the local farmers were draining and pumping the water to expand cereal crops cultivation. Now these wetland are under extensive cultivation of Teff*(wukro teff*), *Guaya, Shinbira, Rice, Misir, and Suf.*

The lands in these wetlands have a problem of ownership. That means some farmers have not land book, they are not registered and even they didn't pay tax for this lands. Since 2011, the government tried to protect these wetlands from intrusion and ploughing. By the year 2012, the government aimed to construct boundary for communal grazing lands and wetlands, control free grazing and identify the farmers who have no title book for the land they are ploughing. Astonishingly the farmers accept the government strategy of control grazing but not ploughing. There are also measures taken for the conservation of the up land to trim down sedimentation. Ethio Wetlands and Natural Resources Association intended to reduce sedimentation from the uplands by taking mainly biological conservation measures.

3.2 The result of wetland shrinkage and its causes in this study is in agreement with other studies[5,6,7,8,9]. In contrast thereare studies disclose the rate of wetland loss was decreased since the 1970s[10,11]. **Carbon Content of Wetlands of Fogera Plain**

Sample soils were collected from natural undisturbed wetlands, sedimented wetlands, semi disturbed wetlands and from agricultural land. Undisturbed wetlands are currently in the pristine state mainly found in the shore of Lake Tana. The wetlands which are termed as sedimented are currently covered by sediments transported from the upstream watersheds by Rib River and are undisturbed. These kinds of wetlandsare found in the shore of Lake Tana.

There is a significant difference on the carbon content among natural, sedimented, semi disturbed wetlands and agricultural land. There is lowest content of carbon on the soils of sedimented wetland followed by semi disturbed wetlands and better content of carbon on the soils of undisturbed wetlands.

In Fogera plain, sediment is transported from the upstream watershed by Rib River and deposited on the wetlands. The top layer of the soil is sediment and the wetland soil is under this layer. Owing this, the pristine nature of wetlands is lacking. On thesesedimented wetlands, lower carbon content of soils was identified. In line to this, it is fair to conclude the sediment transported by Rib River is very poor in organic carbon. Better soil carbon is found in wetlands which are found in the shore of lake Tana..

Concurrent to this study, age of wetlands, location of wetlands, climate and sediments storage are factors regulate carbon content of wetlands soil[12, 13, 14, 15]. Not only has the supply of the sediment, but also the nature of the sediment determined the carbon content of wetlands. Carbon sequestration is variable depending upon the nature of sediments that are building tidal wetlands[13]. In contrast[13], discover carbon accumulation in wetlands is nonlinearly related to the supply of sediment. Soil erosion acts as a transport agent and adding carbon through sediment accumulation to alluvial storage and to the fluvial system[14]

4.Conclusion

The wetlands of Fogera plain are among the largest flood plain wetlands of the country. But the local community is practicing unsustainable use on these wetlands. Sediment deposition on the wetlands from the nearby upstream watersheds by Rib River caused the wetlands to loss their pristine nature and trigger farmers to plough. Problem of ownership of lands in this area is another factor that contributes for the conversion of wetlands in to agricultural land. The area of wetlands was 25.73% of the area in 1973 while it reduced in to 19.59% of the area in 2011. The farmers themselves notice the shrinkage of wetlands.

The wetlands on which there is deposition of sediments, lower content of soil carbon was identified. From this it is fair to conclude; there is low carbon content of sediments transported from the surrounding watershed. While from the wetlands which are less disturbed better content of soil carbon is measured.Generallyit can be concluded that sediment deposition(landscape variable) and further farmers farming practice weaken wetlands ecological role in carbon sequestration. This study recommends further upstreamwatershed conservation efforts and payment for the ecosystem services and benefits for such like ecosystems is to be started.

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Figure 1 Map of Fogera Woreda

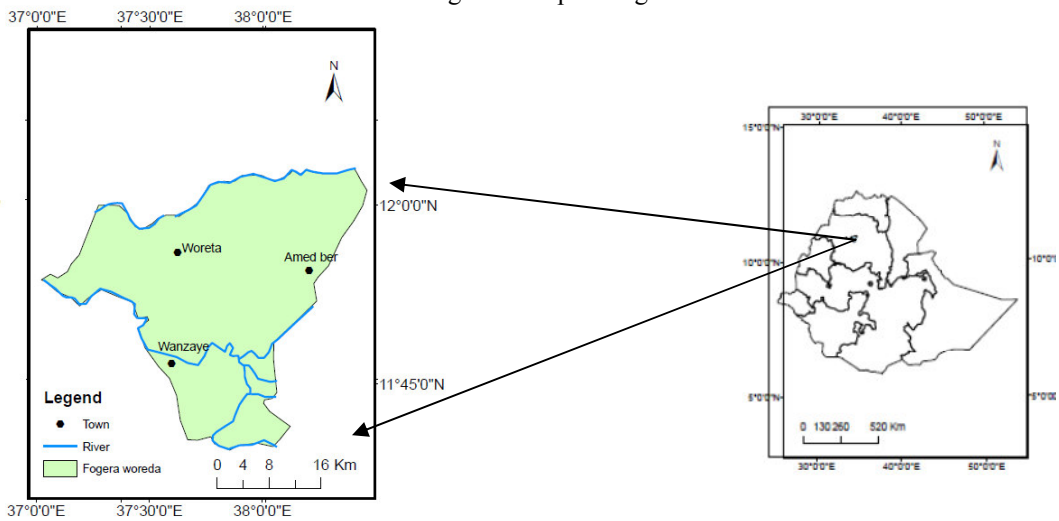

Figure -2 soil map of the area

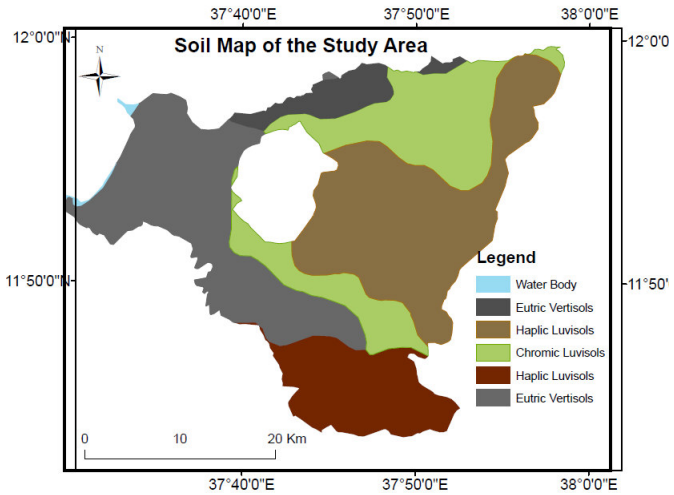

Figure 3. Distributions of Sample Points

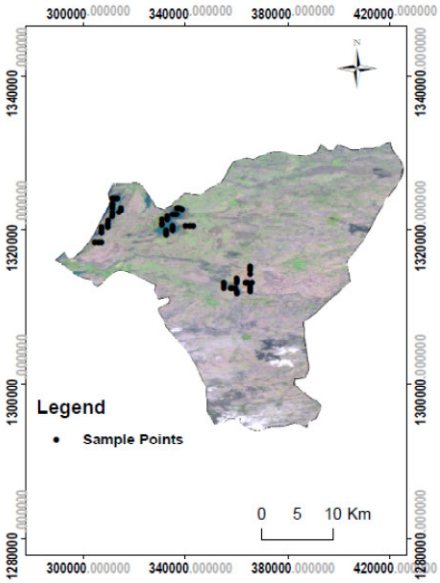

Figure 4. Land cover map of Fogera Woreda in 1973, 1994 and 2011

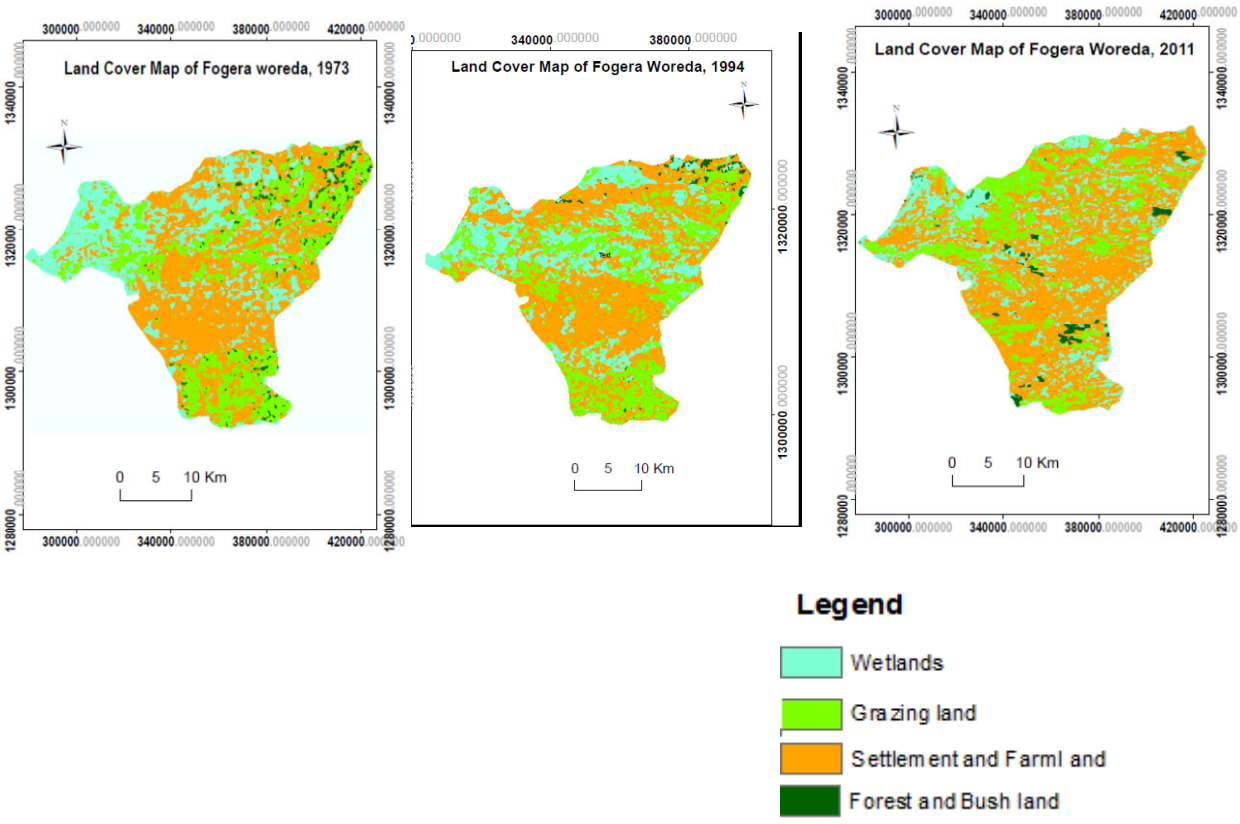

Table- 1 Area f wetlands in1973, 1994 and 2011

Land use and land cover types	Area in ha			Area in percentage		Change in area in ha
	1973	**1994**	**2011**	**1973**	**2011**	**1973-2011**
Wetland	25254.56	24981.87	19235.4	25.73	19.59	-5246.26
Settlement and Farmland	46502	49709.19	55615.4	47.35	56.64	+9113.4
Grazing land	24254.1	22337.29	20704.4	24.7	21.08	-3550.1
Forest and Bush land	2179.34	1162	1861	2.22	1.89	-318.34
Total area	**98190**	**98190**	**98190**	**100**	**100**	

Table 2- Organic Carbon and Organic Matter in different state of wetlands (Mean and Std. Deviation)

Wetlandtype		OC	OM
Sedimented	Mean	.7443	1.2843
	N	21	21
	Std. Deviation	.32329	.55976
Semidisturbed	Mean	1.3157	2.2714
	N	21	21
	Std. Deviation	.57741	.99588
Disturbed	Mean	1.2529	2.2662
	N	21	21
	Std. Deviation	.36521	.67516
Total	Mean	1.1043	1.9406
	N	63	63
	Std. Deviation	.50080	.88709

Table- 3 ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	4.124	2	2.06	10.828	.000
	Within Groups	11.426	60	.190		
	Total	15.550	62			
OM	Between Groups	13.570	2	6.78	11.559	.000
	Within Groups	35.219	60	.587		
	Total	48.789	62			

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