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Impacts of wetland cultivation on plant diversity and soil fertility in South-Bench District, Southwest Ethiopia

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Wetlands provide enormous socioeconomic and environmental values. However, wetlands are threatened by conversion for agricultural land in southwestern Ethiopia. The study aims to assess the impact of wetland cultivation on plant species richness, composition and soil fertility. Plant species richness and composition was investigated for 30 plots in each site of adjacent uncultivated and cultivated wetlands sites and total of 60 sampling plots were used. Soil samples were collected from 18 sample plots (9 in each site) selected using simple random method from plots used for plant survey. The results showed that cultivated sites have significantly higher ($P<0.05$) species richness, diversity and evenness indices than uncultivated wetlands. Though, this seems positive biological integrity in cultivated site, some ecologically and socioeconomically valuable wetland plant species were lost. Similarity of species (index 30.51%) between two sites was low. Moisture content, clay, organic carbon, total nitrogen, available phosphorous, cation exchange capacity (CEC), exchangeable K^+ and Na^+ were significantly ($P<0.05$) lower while silt, pH and electric conductivity (EC) were significantly ($P<0.05$) higher for cultivated site respect to uncultivated site. However, bulk density, sand, exchangeable Mg^{2+} and Ca^{2+} were not significantly ($P>0.05$) affected. Hence, planning wise use strategy for sustainable management of wetlands is essential.

Key words: Wetland cultivation, species composition, soil physico-chemical properties, South-Bench District.

INTRODUCTION

Wetlands are diverse in types and hence defined differently across the world. The most commonly used definition is that of Ramsar Convention which defines wetlands as ‘areas of marsh, fen, peatlands or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters’ (Ramsar Convention Secretariat, 2011). Wetlands contribute in diverse ways to the livelihoods of millions of people (Rebelo et al., 2010) and providing fundamental ecological services such as food, water, and recreational benefits for the larger catchment population (Ayalew, 2010; McCartney et al., 2010). In recent decades, agricultural use of wetlands has increased significantly in many developing countries, particularly in Africa (McCartney et al., 2010). This

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increase is driven partly by increasing number of population, deterioration of upland soil, economic and financial motivation (Schuyt, 2005) and increasing issues of food security in developing countries (Taiwo, 2013). It also supplements the upland soils where soil productivity and crop yields have declined due to improper land use and management, soil erosion and degradation (Ogban et al., 2011). Though, the continuous use of wetlands for cultivation has the potential to degrade their fragile ecosystems and undermine their capacity to provide ecological services (Morardet et al., 2010).

In Ethiopia, wetlands cover about 2% the total area (13,699 km^2) of the country (Ayalew, 2010). Like other developing countries most of Ethiopian wetlands are under the risk of degradation and loss due to drainage for cultivation, overstocking, offsite and underlying causes related to policy issues (Afework, 2007). Some researchers indicated that, farmers in the country were encouraged and often enforced to drain and convert available wetlands into agricultural land because they are considered as underutilized potential agricultural lands. During the past decade, this trend of wetland conversion during the past decade in the country shows faster increase than ever. For instance, Legesse (2007) reported that in Illu Abba Bora zone the percentage of wetlands converted to agricultural land was 12.7% in 1996 and 65.6% in 2006, which is more than five times within ten years. Besides, many wetland ecosystems are regarded as unproductive and unhealthy ‘wastelands’ with no useful purpose to society or as a source of disease and a threat to public health and they continue to be depleted at an alarming rate throughout the country (Yilma, 2003; Legesse 2007). Dixon and Wood (2003) also showed that many small wetland areas in eastern Africa have been drained for agriculture and now pose a real threat to their continued existence.

Wetland drainage and cultivation have resulted in major impacts on wetland hydrology (Dixon, 2002) which is one of the strongest determinants for wetland vegetative and composition, diversity and for soil (Collins, 2005). Disturbance to wetlands especially from agricultural activity was the causes for elimination of native species and introduction of weedy species due to hydro-period regime shift (Zedler and Kercher 2004; Handa et al., 2012) which generally reduces the value of the wetland for wetland dependent species (Collins, 2005). Besides, an alteration to water regimes has notably affect on wetland dependant species composition and contributed to a loss of wetland biodiversity (Legesse, 2007). Anthropogenic activities such as cultivation also affect self-organization in wetlands and affecting spatial patterns of soil pH, nutrient concentrations and soil organic matter (SOM) content (Cohen et al., 2008). Cultivation also impacted on soil structure, hence lowering the clay content by promoting the disintegration of soil and leading to precipitation of clay particles into lower horizons and increased accumulation of the fine silt particles on surface (Belay and Hunt, 2000; Igué, 2004; Fungai, 2006; Rezaei et al., 2012). Moreover, the loss of biological diversity, changes in soil characteristics and associated impact on ecological services had serious socio-economic impacts (Legesse, 2007).

In southwestern Ethiopia, cultivation of wetlands is increasingly needed due to growing population associated to shortage agricultural land and decline in crop productivity of the uplands. Although understanding the impact of wetland cultivation on plant diversity and soil properties will be the basis for designing strategies and implementation of a sustainable utilization of wetland resources. However, the study on wetlands degradation has not been conducted and the information on southwest Ethiopia is still lacking particularly in the South-Bench district. Therefore, the objective of this study was to assess the impact of wetland cultivation on plant species richness and composition and on some selected soil physico-chemical properties as fertility indicators.

MATERIALS AND METHODS

Descriptions of the Study Site

The study area is located in southwest of Ethiopia and nearly 586 km away from Addis Ababa, the federal capital of Ethiopia. The geographic location of the study area is between 29°23' 13.401" and 29° 41' 37.004" east latitude and between 6° 43' 55.916" and 6°59' 42.775" north longitude. The altitudes range from 1,000 to 2,200 m above sea level with undulating plains and mountains. The area receives annual rainfall of nearly from 1,000 to 1,452 mm and much of it falling during March to November. The mean annual minimum and maximum temperature is18 and 25°C, respectively.

A study wetland, according to Collins (2005), is valley bottom wetlands. The wetland is seasonally flooded and fed by ground water, as well as spring flow around it. A wetland was stratified into two adjacent land uses: Cultivated and uncultivated (pristine wetland). Cultivated site has been used for cultivation of taro (*Colocasia esculenta*) for about nine years. Clearing of native vegetation, burning of vegetation and crop residues, drainage and soil manipulation through hoe was the common farming activities in cultivated wetland site. Agrochemicals (chemical fertilizers, herbicides, etc) were not used by farmers’ for cultivation. Both sites of the wetland have similar slope of almost flat surfaces with gradients of about zero to 2.6%.

Plant sampling and identification

A plant survey was conducted from December 2012 to mid-January 2013. This period was selected because most species was expected to reach at their full growing stage during end of the rainy season in the area. Seven transects intervals were determined systematically at fixed intervals of 160 m across the direction of water flow in each cultivated and uncultivated wetland sites. Along each transect, sample plots were laid systematically at fixed intervals of 15 m. The plot size of 1m×2m (2 m^2) was used for herbaceous and grass while the plot size of 4×4 m (16 m^2) was used for shrubs (Jefferies et al., 2008). Plots were laid after estimating the boundaries of wetland in each site from the upland. For comparison of change in wetland plant composition due to cultivation, sampling plots were entirely placed inside the wetland. Thus, a total of 60 sample plots (30 sampling plots from each site) were used. In each sample plot, all plant species (excluding agronomic species) were recorded and plant specimens were collected for identification. Identification, assignment and nomenclature of the plant species were performed according to the Flora of Ethiopia (Hedberg and Edwards, 1989; Edwards et al., 1995, 1997; Phillips, 1995).

Determination of species diversity and evenness

Shannon and Wiener Diversity index (H') was used to calculate the species diversity to compare the diversity between cultivated and uncultivated wetland sites using the formula (Help et al., 1998):

$$H' = -\sum_{i=1}^{s} Pi \mathrm{Ln} Pi$$

Where: H' = Shannon-Wiener diversity index, s = number of plant species encountered, Pi = n_i/N = relative abundance of each species, n_i = number of individual of a species, N = total number of all individuals of all species. The evenness (E) component of H´ was computed as follows:

$$E = \frac{H'}{\mathrm{Ln}(S)} = \frac{H'}{H'max}$$

Where: E = Evenness; H'max = Ln(S), S= total number of species in the sample. Jaccard coefficient of similarity index (JCS) was used to assess the similarity of plant species composition between cultivated and uncultivated wetland sites using the formula (Kent and Coker, 1992):

$$JCS = \frac{C}{A + B + C} \times 100$$

Where: C = the number of species in common between sites (cultivated and uncultivated site), A = the number of unique species at uncultivated site, B = the number of unique species at cultivated site. The Jaccard coefficient of similarity index value was converted to percentage to show the percentage similarity between two sites (cultivated and uncultivated wetlands)

Soil sampling and laboratory analysis

Eighteen plots (that is, 9 samples from each site) were used for soil sampling. Soil samples were collected using a soil augur from 0 to 30 cm depth. The samples were collected at five points after removing aside vegetation and litter and pulled into one sample. The soil sampling plots were chosen among the plots used for plant sampling using a simple random method. From 7 transects and 30 sample plots used for vegetation survey in each sites, three transects from each site and 3 plots along selected transect were randomly selected for soil sampling (3 transect*3plot*2site=for a total of 18 samples as a whole).

Particle size distribution was determined by the hydrometer method after destroying OM and dispersing the soil. Soil moisture content was determined using Gravimetric method as the ratio of weight of water to weight of oven dry soil (Sahlemedhin and Taye, 2000). Soil bulk density was determined by core method (FAO, 2007) using core sampler and drying it to constant weight in an oven at a temperature of 105°C for 24 h. Soil pH was measured in 1:2.5 pH-H_2O (soil: distilled water) using the glasscalomel combination electrode whereas electric conductivity (EC) by conductivity meter using suspension of 1:2.5 soil: water ratio.

Organic carbon (%OC) was determined using wet combustion methods of Walkley-Black as described by Nelson and Sommers (1982). Total nitrogen (%TN) was measured by using the Kjeldahl method and available phosphorus was determined by Bray method. Total exchangeable bases were determined after leaching soils with ammonium acetate. The exchangeable Ca^{2+} and Mg^{2+} in the extracts was measured using atomic absorption spectrophotometer (AAS) while Na^+ and K^+ by flame photometer. Cation exchange capacity (CEC) of the soil was estimated from ammonium-saturated samples that were subsequently replaced by sodium (Na^+) from by a percolating sodium chloride solution. The excess salt was removed by washing with alcohol and the ammonium that was displaced by sodium was measured by Kjeldahl method (Chapman, 1965).

Data analysis

To know the statistical difference in plant diversity indices and soil physico-chemical properties among plots from cultivated and uncultivated wetlands sites, calculated plant diversity indices and soil physico-chemical properties were analyzed using SPSS version 16.0 software. Independent two sample t-test was used to test whether significance ($P \leq 0.05$) difference in these parameters between cultivated and uncultivated wetland sites exist. Relative change (RC) in soil parameter was computed to compare the change in soil properties due to cultivation as:

$$RC(\%) = \frac{Puc - Pc}{Puc} \times 100$$

Where Puc is the mean value of soil property in uncultivated site and P*c* is the mean of a soil property in cultivated site. Pearson correlation analysis was carried out to determine the relationship between soil parameters. Moreover, Principal Components Analysis (PCA) was used explore the relationship between and within plant species and soil variables.

RESULTS AND DISCUSSION

Species composition

A total of 59 different plant species belonging to 20 families were identified in both cultivated and uncultivated wetland study sites. Higher numbers of species were found in cultivated site (Table 1). In cultivated wetlands 48 species classified as in 19 families and in uncultivated site 29 species belonging to 15 families were identified. From 29 plant species observed in uncultivated site, 28 species were identified as wetland plants and 11 species were exclusively observed in uncultivated site. On other hand, of the 48 species observed in cultivated site, 18 plant species were wetland plant species while 30 species were upland plant species or weedy species. About 80% of the plant communities were solely found in cultivated site.

In the uncultivated site, Cyperaceae was the family with the highest number of plant species (5), followed by the family of Gramineae and Lamiaceae each with 4 species. Besides, Fabaceae and Polygonaceae each of them had with 3 species while the remaining 10 families each had

Table 1. Plants species recorded at uncultivated and cultivated wetland sites with their relative distribution.

Family	Species	Study sites		Species category
		Cultivated	Uncultivated	
Acanthaceae	*Hygrophila schulli* (Hamilt)Almeda v Almeda	+	+	w
Amaranthaceae	*Amaranthus spinosa* L.	+	-	nw
	Achyranthes aspera L.	++	++	w
Apiaceae	*Cenetella asiatica* (L.) Urb	++	+	w
	Hydrocotyle sibthorpioides Lam.	+	-	nw
Balsaminaceaeae	*Impatiens ethiopica*	+	-	nw
Caryophyllaceae	*Cerastium octandrum* Hochst. ex A. Rich.	+	-	nw
	Drymaria cordata (L.) Willd	+	-	nw
Commelinaceae	*Floscopa glomerata* (Willd. ex Schult. & Schult. f.) Hassk	+	+	w
	Commelina lantifolia A.Rich	+	-	nw
	Commelina forskalaei Vahl.	++	-	nw
Compositae	*Galinsoga parviflora* Cav.	+	-	nw
	Sonchus asper(l.) hill	+	-	nw
	Galinsoga quadriradiata Ruiz & Pav	+	-	nw
	Bidens pilosa L.	+	-	nw
	Aqeratum conyzoidesL.	+	-	nw
Convolvulaceae	*Jacquemontia paniculata* (Burm. f.) Hall f.	+	-	nw
	Ipomea cordofana R. Br.	+	-	nw
	Convolvulus arvensis L.	+	-	nw
	Ipomea eroiocarpa R. Br.	+	-	nw
Cyperaceae	*Pycreus elegantulus (Steud.) C.B. Clarke*	-	+	w
	Cyperus flavescent L.	-	+	w
	Cyperus mundtii (Nees)Kunth.	-	+	w
	Fimbristy*lis dichotoma (L.) Vahl.* ssp. *Sieberiana*	-	+	w
	Mariscus syperoides L.	+	-	nw
	Cyperus latifolius poir	+	++	w
	Cyperus assimilis Steud.	++	-	
Euphorbiaceae	*Phyllanthus boehmii* Pax. var. boehmii	++	++	w
Fabaceae	*Aeschynomene schimperi* Hochst. Ex A.Rich	-	+	w
	Sesbania dummeri E. Phillips &Hutch.	-	+	w
	Aeschynomene abyssinica (A.Rich.)Vatke	+	+	w
Gramineae	*Sacciolepis rigens* (Mez) A. Chev.	-	+	w
	Panicum sp.	+	+	n
	Cynodom dactylon (L.)pers	+	-	nw
	Sacciolepis africana C.E.Hubb. and Snowden	+	+	w
	Echinocloa colona(L.)Link	+	-	nw
	Snowdenia polystachya (Fresen.) Pilg	++	-	nw
	Eragrostis ciliaris(L.) R. Br.	++	-	nw
	Digitaria ternate (A.Rich.) Stapf	++	-	nw
	Oplismenus spp.	++	-	nw
	Digitaria sanguinalis (L.) Scop.	++	-	nw
	Leersia hexandra SW.	++	++	w
Lamiaceae	*Leucas deflexa* Hook f.	-	+	w

Table 1. Contd.

	Plectranthus argentatus (S.T.Blake)	-	+	nw
	Plectranthus punctatus (L.)L Her	+	+	w
	Ajuga remota Benth.	+	+	w
Melastomataceae	*Dissotis canescens* (Graham) Hook. F.	+	++	w
	Antherotoma naudinii Hook.	+	-	nw
Onragraceae	*Luddwigia abyssinica* A.Rich.	+	+	w
	Ludwigia stolonifera *(Guill. & al.) Raven*	+	-	nw
Polygonaceae	*Persicaria glabra* (Wild.) M.Gomez	+	++	w
	Persicaria senegalensis (Meisn.) Sojak	+	+	w
	Polygala petitiana Meisn.	++	+	w
	Rumex abyssinicus Jasq.	++	-	nw
Rubiaceae	*Oldenlandia lancifolia* (Schumach) DC var. scabridula	+	+	w
Solanaceae	*Solanum anguivi* Lam	+	-	nw
Thelypteridaceae	*Thelypteris confluens* (Thunb.) Morton	-	++	w
Tiliaceae	*Triumfetta spp*	-	+	w
	Triumfetta pilosa Roth	+	-	nw

+Represent species with abundance <2% while ++ represent ≥2%; (-): absence, (+): present, (++) dominant, w= wetland plant, nw =non wetland plant (upland plant), n=habitat not identified.

one species (Table 1). In the cultivated site, Gramineae was the family with highest number of plant species which is 10 species followed by Compositae with 5 species, Convolvulaceae and Polygonaceae each with 4 species, Apiaceae and Cyperaceae each with 3 species, Caryophyllaceae, Amaranthaceae, Commelinaceae, Melastomataceae, Onragraceae and Lamiaceae each with 2 species while the rest 7 families each had one species (Table 1). Family Thelypteridaceae was not observed in cultivated site. Furthermore, in cultivated wetlands, the species in family Cyperaceae, Fabaceae and Lamiaceae were decreased because of draining the land for agricultural use while species in families Amaranthaceae, Apiaceae, Balsaminaceaeae, Caryophyllaceae, Commelinaceae, Compositae, Convolvulaceae, Gramineae, Melastomataceae, Onragraceae, Polygonaceae and Solanaceae was increased because of drainage and cultivation created conducive environment for their invasion.

Among plant species in uncultivated site, 7 plant species dominant the plant community with relative abundance more than two percent. These plant species were *Leersia hexandra* (46.35%), *Cyperus latifolius* (23.79%), *Thelypteris confluens* (3.96%), *Phyllanthus boehmii* (3.73%), *Persicaria glabra* (2.71%), *Dissotis canescens* (2.58%) and *Achyranthes aspera* (2.09%). These 7 plant species were accounted for 85.21% of the community while rest 22 species had relative abundance less than 2% which accounted for 14.79%. From 48 plant species, 13 species such as *Commelina forskalaei* (15.6%), *Leersia hexandra* (12.96%), *Digitaria sanguinalis* (12%), *Oplismenus* spp. (9.71%), Digitaria ternate (8.02%), *Cyperus assimilis* (3.54%), *Phyllanthus boehmii* (3.3%), *Rumex abyssinicus* (2.89%), Cenetella asiatica (2.6%), *Eragrostis ciliaris* (2.59%), *Achyranthes aspera* (2.44%), *Snowdenia polystachya* (2.16%) and *Polygala petitiana* (2.11%) with relative abundance more than two percent were accounted for 79.92% of the plant community in cultivated sites of which 56.61% them were upland plant species.

On other hand, wetland plant species such as *Thelypteris confluens, Cyperus mundtii, Leucas deflexa, Cyperus flavescens, Cyperus elegantulus, Sesbania dummeri, Fimbristylis dichotoma, Plectranthus argentatus, Aeschynomene schimperi, Sacciolepis rigens* and *Triumfetta* spp were not observed in cultivated site. The result revealed that other important species such as *Leersia hexandra* and *Cyperus latifolius* were decreased significantly due to cultivation. The local community is using *Cyperus latifolius* for thatching; *Leersia hexandra* for thatching, fodder and plastering; *Aeschynomene abyssinica* and *Sesbania dummeri* for construction and fuel wood; *Triumfetta spp*. for fodder and rope making. Due to conversion of wetland into agricultural lands some of these species are declining and hence the socioeconomic benefits obtained by local community from these plants were significantly reduced. A research report by Dixon (2002) indicated that conversion of natural wetland by drainage and cultivation may be causes for loss of wetland vegetation which area

Table 2. Species diversity measured using transects in uncultivated and cultivated wetland sites.

Parameter	Study wetland sites	
	Uncultivated	Cultivated
Species richness(S)	29	48
Shannon-Wiener diversity(H')	1.90	2.99
Evenness(E)	0.58	0.78
Jaccard's coefficient of similarity (JCS) (%)	30.51	

Table 3. T-test for diversity measured using plot based in uncultivated and cultivated wetland sites.

Parameter	Mean ± Std. deviation		t-test	P-value
	Uncultivated	Cultivated		
Species richness(S)	7.3±1.44	10.33±2.06	-6.61	0.000***
Shannon-Wiener diversity(H')	1.24±0.20	1.85±0.22	-11.45	0.000***
Evenness(E)	0.59±0.09	0.80±0.08	-9.41	0.000***

*** Very highly significant P<0.001.

important to local communities livelihoods.

The Jaccard coefficient of similarity index (30.51%) showed low similarity in plant species composition between cultivated and uncultivated wetland sites. This confirms the change in wetland plant composition and invasion of the wetlands by upland plants species due to wetland drainage and cultivation. Fungai (2006) also observed that cultivation influences community structure and species composition. According to Dixon (2001), disappearance of natural wetland vegetation and invasion of non wetland (upland) vegetation or weedy species is the sign of environmental degradation in wetlands. This is because of the fact that each plant species has a limited tolerance to their habitat requirement. Thus change in composition and loss wetland plant in cultivated site could be change in habitat condition of the wetland or alteration of water regimes by wetland drainage for cultivation (Zerihun and Kumlachew, 2003; Barakagira and Kateyo, 2008; Dube and Chitiga, 2010). Besides, drainage cultivation could cause undesirable environments to the wetland plants and resulted in their disappearance. In line with this, Collins (2005) also reported that the degree of harshness decreased as wetlands were drained for cultivation which could create conducive environments for increasing diversity of upland species in cultivated site and loss/degradation of wetland plants. Temporary the evading species use the opportunity that is why the diversity of cultivated site increased. However, as time goes this situation will change results in decreasing species diversity in cultivated site.

Species diversity and evenness

High species diversity (H') (2.99) and species evenness (E) (0.78) were measured at cultivated site than uncultivated site (H' = 1.9 and E = 0.58) which showed that cultivated site had more number of species and more even distribution of plant species than uncultivated site (Table 2).

The diversity result indicated that cultivated site had significantly higher (P<0.001) mean species richness (10.33) than uncultivated site (7.3) (Table 3). Similarly, cultivated site had also significantly higher (P<0.001) mean species diversity (1.85) than uncultivated (1.24) site. The result of this study is in agreement with Zerihun and Kumlachew (2003) and Handa et al. (2012) where they reported that drainage and the disruption of vegetation creates an increased number of ecological niches or conditions which suit a wider range of plants or favorable environments for the survival of upland plants species to invade the disturbed area. Fungai (2006) also reported that, shortened hydroperiods, the use of fire in land preparation can induce the domination of weedy species in cultivated site. Cultivated site also significantly higher (P<0.001) mean species evenness (0.80) than uncultivated site (0.59). This indicates little dominance but more number of species with few individual per plot in cultivated site. It also showed that cultivated site has more species diversity than uncultivated site (Table 3).

Soil physico-chemical properties

Conversion of wetland into agricultural land may cause the alternation of soils physico-chemical properties which in turn can influence the soil fertility status of a given area. Hence, soil samples collected from the study site at the depth of 0 to 30 cm were analyzed for some selected soil properties. The soil of uncultivated and cultivated site were clayey and clay loamy respectively. The soil contained

Table 4. Soil physical properties of cultivated and uncultivated wetland sites.

Parameter	Mean ± Std. deviation		t-test	P-value	Relative change (%)
	Uncultivated	Cultivated			
%Sand	34.22±5.83	36.11±5.90	-0.68	0.504^{ns}	-5.52
%Clay	49.44±5.50	34.78±8.86	4.22	0.001**	+29.7
%Silt	16.33±3.81	29.11±7.29	-4.66	0.001**	-78.23
Bulk density(g/cm^3)	0.20± 0.043	0.22±0.02	-1.12	0.287^{ns}	-8.84
%soil moisture content (SMC)	15.54±0.24	11.05±0.25	10.08	0.000***	+28.85

***very highly significant P<0.001; **highly significant at P<0.01; * significant at P<0.05; ns = not significant at P>0.05 whereas (-) decrease in soil properties; (+) increase in soil properties from cultivated to uncultivated site.

Table 5. Soil chemical properties of cultivated and uncultivated wetland sites.

Parameter	Mean ± Std. deviation		t-test	P-value	Relative change (%)
	Uncultivated	Cultivated			
pH-H_2O	4.26±0.18	4.49±0.13	-3.17	0.006**	-5.48
Available P(ppm)	3.62±0.46	3.03±0.42	2.81	0.013*	+16.22
%TN	2.31±0.73	1.06±0.23	4.9	0.000***	+54.02
%OC	28.19±5.8	12.33±2.68	7.45	0.000***	+56.26
CEC(meq/100gm)	41.31±11.78	28.19±9.72	2.58	0.021*	+31.77
Mg^{2+}(cmol(+)/kg soil)	3.31±1.66	3.96±1.11	-0.98	0.342^{ns}	-19.67
Ca^{2+} (cmol(+)/kg soil)	26.83±11.28	26.17±9.89	0.13	0.899^{ns}	+2.41
K^+(cmol(+)/kg soil)	0.714±0.17	0.56±0.028	2.58	0.020*	+21.1
Na^+(cmol(+)/kg soil)	0.057±0.03	0.025±0.003	2.91	0.019*	+56.38
EC (dS/m)	0.10±0.01	0.22±0.14	-2.58	0.032*	-120.29

***very highly significant P<0.001; **highly significant at P<0.01; *significant at P<0.05; ns = not significant at P>0.05 (-) decrease in soil properties; (+) increase in soil properties from cultivated to uncultivated site.

acidic in reaction with a pH value ranged from 4.26 to 4.49, and high organic carbon varied from 12 to 28%. The cation exchange capacity (CEC) of the soil also ranged from 28 to 41 meq/100 g in which the dominant cation being Ca^{2+} followed by Mg^{2+} and K^+ was the dominant exchangeable cation (Table 5)

Soil physical properties

Clay and silt content of the soil samples analyzed from uncultivated and cultivated wetland sites were significantly different (P<0.001) while the sand content was not significantly different (P>0.05) (Table 4). Uncultivated site had higher mean value of clay (49.44) than cultivated site (34.78). On the contrary, cultivated site had high mean value of silt (29.11) and sand (36.11) than uncultivated site (silt 16.33, and sand 34.22). The relative change result indicated that clay content of the soil decreased by 29.7% while silt and sand was increased by 78.23 and 5.52% respectively due to change of wetland into cultivated land. The possible reason for this lower content of clay in cultivated site could probably due to the removal of clay soil from surface by erosion and translocation of clay fraction down to a lower horizon. This result are in agreement with the findings of Lgué (2004), Fungai (2006) and Rezaei et al. (2012), in which they reported that cultivation of land cause accumulation of silt and sand particles in upper horizon and high clay content in lower horizon due to translocation of clay fraction from surface layer to subsurface layer. Besides, Igué (2004) and Wakene and Heluf (2004) reported that the removal of clay by accelerated soil erosion (sheet erosion) in rainy season as cultivated site was less vegetation cover and bare during rainy season could be the cause for lower clay content in cultivated site. Similarly, Wakene and Heluf (2004) indicated that clay content can be decreased by land use change as the management practices that may contributed indirectly to the changes in particle size distribution particularly in the surface layers by removal of soil by sheet erosion and mixing up of the surface and the subsurface layers during continuous cultivation.

The mean bulk density of the soil of study sites ranged from 0.20 g/cm^3 (uncultivated wetland) to 0.22 g/cm^3 which is less than the bulk density of mineral soils (fine silt:

1.0 to 1.3 g/cm^3, and sandy soil: 1.3 to 1.7 g/cm^3) (FAO, 2007). This wetland soil has lower bulk densities than mineral upland soil because it was rich in organic matter (OM) and water-saturated. Similar bulk densities were reported, for instance; 0.11 to 0.23 g/cm^3 by Bruland et al. (2003), as low as 0.2 g/cm^3 in the very organic rich soils by Powell (2008). Moreover, Mitsch and Gooselink (2000) indicated that, organic soils (Organic carbon >12-20%) have low bulk density due to high porosity and usually had bulk density of ranging between 0.2 and 0.3 g/cm^3. Otabbong and Fristedt (2005) reported the bulk density lower than 0.12 g/cm^3 in almost entirely not decomposed wetlands soil and 0.27 to 0.35 g/cm^3 in highly decomposed peat soil. This indicated that the level of decomposition of OM had effect on bulk density of wetlands soils.

The t-statistics revealed that bulk densities were not significantly different ($P>0.05$) in the two sites. The change of organic matter from cultivated to uncultivated wetland was high, though the soil bulk density not changes. This might be due to the variation of bulk density by contribution of tillage practices is higher that organic matter. Farmers in the study wetland used hoes for soil preparation could have insignificant impact on risk of increasing bulk density of the soil in cultivated site. Fungai (2006) and Collins (2005) also reported that tillage by hand had less risk of soil compaction in wetlands soils.

Soil moisture content (SMC) between the cultivated and uncultivated site was significantly different ($P<0.001$). The mean SMC of uncultivated site was higher (15.54) than cultivated (11.05) site. Relative change in SMC indicated that it was decreased by 28.85% by to cultivation. The higher SMC in the uncultivated sites may be due to the presence of high vegetation cover and high OM of the soil. Correlation result showed there was positive and significant correlation between OC and SMC ($r=0.81^{**}$). On the other hand, clearing vegetation cover, soil tillage and redaction in organic matter of cultivated wetlands could reduce water holding capacity of cultivated soil. This was similar with the findings of Dube and Chitiga (2011); they showed there was a significant correlation between the amount of total organic carbon and moisture content. In addition, high clay content of uncultivated wetland site may leads to have high water holding capacity. There was positively and significantly correlation between clay and SMC($r=0.744^{**}$) which explain the direct relationship between clay and SMC. This result agrees with earlier findings of Fungai (2006) and Powell (2008) who reported that soils with high clay content tend to have high water holding capacity.

Soil chemical properties

Soil pH, organic carbon (OC), total nitrogen (TN) and available phosphorous Soil pH level was significantly different ($P<0.01$) between the cultivated and uncultivated wetland sites. The mean pH value of cultivated site was higher (4.49) than uncultivated (4.28). Cultivation increased the pH of the soil by 5.48%. The removal of vegetation for cultivation and exposure of soils to wind and sunny could increase aeration and temperatures of the soil may facilitate rapid decomposition of OM and prevents the accumulation of acids and increase in pH in cultivated as indicated by Fungai (2006).

On other hand, the lower pH in uncultivated site could be due to the release of organic acids from organic matter decomposition (Collins, 2005; Dube and Chitiga, 2011; Tariku and Abebayehu, 2011).

Organic carbon (OC) content was significantly different ($P<0.001$) between cultivated and uncultivated site. The mean of OC content of uncultivated sites was higher (28.19) than that of cultivated (12.33) site. The relative change indicated that OC was decreased by 56.26% due to the conversion of wetland to cultivated land. Similarly, Belay and Hunt (2000), Fungai (2006), Dube and Chitiga (2011), Tariku and Abebayehu (2011), measured low amount of OC in cultivated wetlands. Belay and Hunt (2000) and Zoltán (2008) also indicated that the low OM was due to the rapid decomposition of OM that was facilitated by excessive drainage of wetlands, ploughing of soil for cultivation, low coverage and clearing of vegetation in cultivated site. Besides, decreased in OM inputs to the soil due to burning of plants and crop residues for cultivation (Pantami et al., 2010; Verma and Jayakumar, 2012) and removal crop and plant residues as indicated by Jie et al. (2013) could be the causes for the lower OC content in cultivated wetland. On the contrary, high OC levels in the uncultivated sites could be the reduced decomposition rate as a consequence of less soil residue contact, lower aeration and lower soil temperature (Figure 1).

The total nitrogen content (TN) was significantly different ($P<0.001$) between cultivated and uncultivated wetland site. A cultivated site was lower (1.06) mean levels of TN than uncultivated site (2.31). TN was increased by 54.02% due to wetland uncultivated (Table 6). The TN contents was positively and significantly correlated with the amount of OC($r = 0.74^{**}$) (Table 6). This is obvious reason to expect an increase level of nitrogen content in increased OM content of a soil as OM is essentially the main source of nitrogen (Brady and Weil, 2000). The lower level of TN in cultivated site was because of decrease in litter and vegetation cover, soils preparation and wetland drainage in cultivated site. Moreover, nitrogen can be lost due to crop removal and burning of plant and crop remains in cultivated site. Several works (Burdt, 2003; Zoltán, 2008; Liu et al., 2010; Dube and Chitiga, 2011) also reported similar results that cultivation of wetlands increased soil aeration and temperatures which were the causes for rapid decomposition and mineralization of plant materials and this indirectly lower the content of nitrogen in cultivated site.

The available phosphorous (Av.P) concentration was significantly ($P<0.05$) different between uncultivated and cultivated sites. Cultivated site was lower (3.03) mean levels of available phosphorous than uncultivated site

Figure 1. Ash added by burning of plants and crop residues during cultivation in cultivated wetland site.

(3.62) sites. It was relatively decreased about 16% due to cultivation. The lower concentration of available phosphorus in cultivated site could be the result of continuous loss of phosphorous through crop harvesting, plant and crop residues removal. On other hand, continuous application OM through litter fall and dying of plant in uncultivated site could increase soil phosphorus availability by decomposition and mineralization of organic phosphorous (OP) and reduce phosphate adsorption in the soil colloids (Yusran, 2010).

Exchangeable bases and CEC

There were significant difference ($P<0.05$) in exchangeable K^+ and Na^+ between cultivated and uncultivated sites. Cultivated sites had lower mean content of exchangeable K^+ (0.57 cmol (+)/kg soil) and Na^+ (0.025 cmol (+)/kg soil) than uncultivated site (K^+ = 0.714 cmol (+)/kg soil and Na^+ = 0.057 cmol (+)/kg soil). The relative change result indicated that K^+ and Na^+ content were decreased by 21.1 and 56.38% respectively due to cultivation. There were no significant difference ($P>0.05$) in exchangeable Ca^{2+} and Mg^{2+} between uncultivated and cultivated sites. However, the mean exchangeable Ca^{2+} content in cultivated site was slightly lower (26.19 cmol (+)/kg soil) than uncultivated site (26.83cmol (+)/kg). The probable reason for lower contents of exchangeable K^+, Na^+ and Ca^{2+} could be leaching due to clay because of low vegetation cover of cultivated wetlands which expose the soil to direct contact of high amount of rainfall of the area which was similar with the finding of Gebeyaw (2007) and Adamu (2011). Moreover, lower K^+ in cultivated site might be continuous losses though harvested crops and crop residue removal.

The CEC values was significantly different ($P<0.05$) between uncultivated and cultivated sites. Uncultivated site had higher mean CEC value (41.31 meq/100 g soil) than cultivated site (28.7 meq/100 g soil). The relative change indicated that CEC was decreased by 31.77% by cultivation. High clay and OM might be the reason for high CEC value in uncultivated site. There was general relationship between clay and colloidal OM with CEC value (Raseem and Bhatti, 2000; Brady and Weil, 2001; Gebeyaw, 2007). This is because clay and colloidal OM had high surface area and negative electrical surface charges to absorb and hold positively charged ions. Hence depletion of OM as a result of continuous cultivation could result for reduced CEC under cultivated site. This result was agreed with the observations of Belay and Hunt (2000), which indicated that the capacity of the wetland soils to contain nutrients (CEC) is adversely affected by cultivation.

Species and soil property relationship

Principal Component Analysis (PCA) performed for soil and plant species had extracted more than 32.1% of the variance of data set. PCA 1 provides 19.74% of the variance of data set while PCA 2 takes about 12.38% of

Table 6. Pearson correlation matrix among soil properties.

	Clay	Sand	Silt	BD	OC	TN	%SMC	Av.P	Ca^{2+}	Mg^{2+}	CEC	EC	pH	Na^+	K^+
Clay	1														
Sand	-0.553*	1													
Silt	-0.830**	-0.003	1												
BD	0.048	-0.441	0.236	1											
OC	0.630**	-0.125	-0.673**	-0.279	1										
TN	0.655**	-0.286	-0.594**	-0.036	0.740**	1									
SMC	0.744**	-0.199	-0.761**	-0.233	0.813**	0.765**	1								
Av.P	0.302	0.181	-0.483*	-0.396	0.485*	0.130	0.553*	1							
Ca^{2+}	0.092	-0.344	0.119	0.377	0.005	0.425	-0.101	-0.466	1						
Mg^{2+}	0.102	-0.147	-0.025	-0.122	-0.194	0.149	-0.111	-0.235	0.067	1					
CEC	0.160	0.406	-0.462	-0.550*	0.538*	0.362	0.478*	0.326	-0.023	-0.166	1				
EC	-0.198	-0.044	0.267	0.272	-0.344	-0.283	-0.522*	-0.714**	0.056	0.206	-0.233	1			
Ph	-0.501*	-0.032	0.624**	0.546*	-0.586*	-0.291	-0.566*	-0.357	0.335	-0.045	-0.644**	0.480*	1		
Na^+	0.551*	-0.316	-0.450	0.050	0.575*	0.894**	0.613**	0.134	0.518*	0.328	0.298	-0.291	-0.131	1	
K^+	0.502*	-0.309	-0.397	0.062	0.543*	0.879**	0.578*	0.073	0.561*	0.336	0.291	-0.282	-0.089	0.99**	1

* Significant at the 0.05 level; ** significant at the 0.01 level.

the variance. Scatter plot for species and soil parameters indicated three major groups of data set (Figure 2). In first group *A. abyssinica, L. hexandra, C.elegantulus, A. schimperi, C. latifolius, L. deflexa, A. aspera, P. punctatus, P. argentatus, P. senegalensis, T. confluens I. ethiopica, S. dummeri and D. sanguinalis* were associated with available phosphorous, SMC, TN, OC, CEC and Clay. Except *I. ethiopica and D. sanguinalis,* they were wetland plants. Similarly, in second group, *O. forskalaei, S. polystachya, C. assimilis, H. schulli, M. syperoides, I. cordofana, D. ternate, P. boehmii, L. stolonifera and C. dactylon* were associated with sand, bulk density, Ca^{2+}, pH, EC and silt. In this group only *Hygrophila schulli and Phyllanthus boehmii* were wetland species. Furthermore, *C. arvensis, I. eroiocarpa, Sacciolepis Africana, A. conyzoides, E. ciliaris, S. anguivi, D. cordat* and *O.* spp. were associated with Na^+, K^+ and Mg^{2+} in which only *S. Africana* was wetland plant species and the rest were upland species. It also revealed that available phosphorous, SMC, TN, OC, CEC and Clay were associated with each other negatively associated with sand, bulk density, pH, EC and silt. Besides, Shannon-wiener diversity, evenness and species richness were positively associated bulk density, pH, EC and silt. Thus, most wetland plant species were positively associated with clay, SMC, CEC, TN, OC and available phosphorous which measured maximum value in uncultivated wetland site. Similarly, most of upland plant species were positively associated with sand, bulk density, pH and EC measured highest value in cultivated site (Figure 2). This indicated that continuous cultivation can increase EC, pH, silt, bulk density, species diversity and change in the composition wetland plants.

Conclusion

Plant species diversity and evenness were increased in the cultivated site due to wetland drainage and cultivation. Changes in wetland hydrology and wetland cultivation were the most determinant factor for changing in wetland plant composition, diversity and soil characteristics linked to soil fertility. Though this seems positive for biological integrity in cultivated site, cultivation has caused the losses and degradation of wetland plant species vital for ecosystem services and livelihood of local community. Low similarity in species composition between cultivated and wetland sites indicated that changes in environmental conditions of the wetland favor upland plant species. Cultivated and continuous drainage impact on soil phyco-chemical properties such as soil organic matter, water-holding

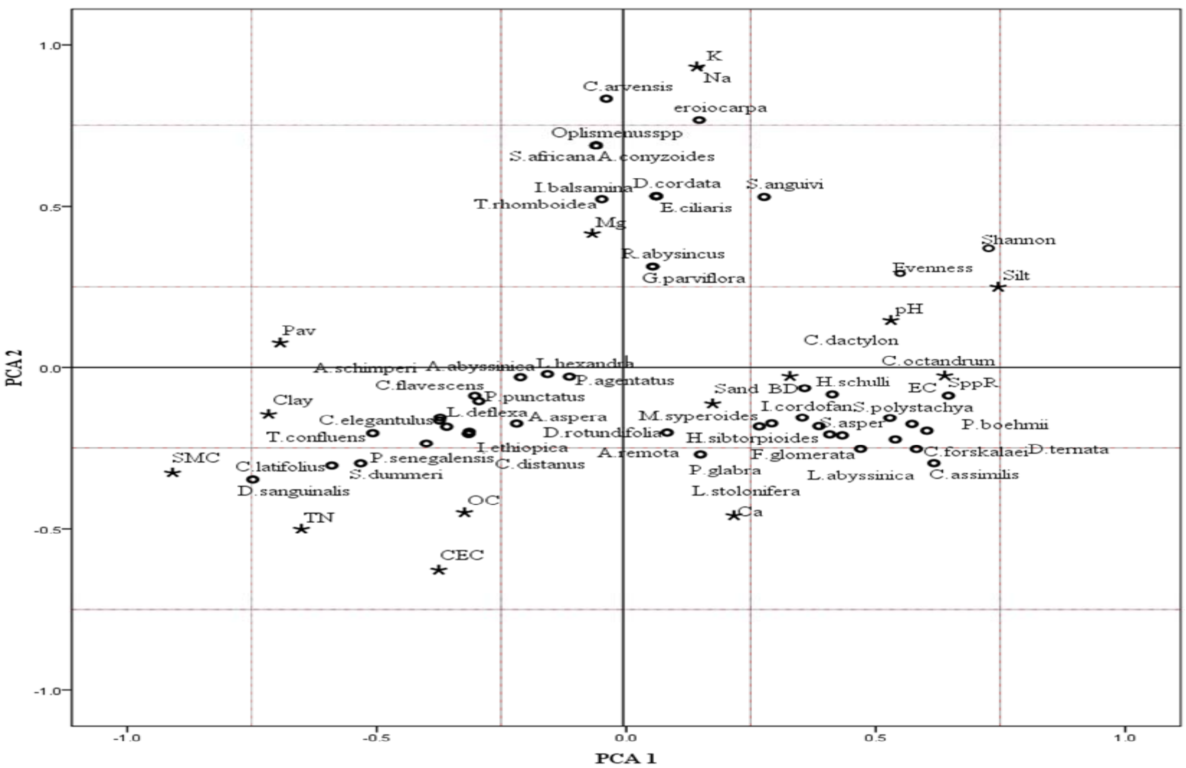

Figure 2. Scatter plot for species and soil parameters relationship in cultivated and uncultivated wetland sites.

capacity of the soils, total nitrogen, available phosphorous and CEC. Thus, the result indicated that in cultivated wetland site there was disturbance of nutrient cycling. Besides, the significant variations in soil physico-chemical properties between cultivated and uncultivated site the result of this study indicated the risk for the sustainable use of wetlands by cultivation. Hence, planning sustainable use strategy that promotes biodiversity conservation, environmental integrity and enhance community benefits from wetland resources is an urgent research and policy agenda.

Conflict of Interest

The authors have not declared any conflict of interest.

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