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Wetlands in *Khalong-la-Lithunya* catchment in Lesotho: Soil organic carbon contents, vegetation isotopic signatures and hydrochemistry

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ABSTRACT

There is sparse information on the characteristics of the wetlands in the *Khalong-la-Lithunya* catchment (KLC), Lesotho in terms of physico-chemical properties, soil organic pools and vegetation isotopic signatures and hydrochemistry of surface waters after five years of rehabilitation. At the KLC two transects of length 250 m–700 m were chosen and soil observations made at intervals of 50 m and at these points, piezometers were installed in duplicates and water samples were collected from Jan to Dec for four years (2009–2012). Soil samples were collected in duplicate from excavated mini-pits (0.50 m). Vegetation samples were collected monthly (Jan, Apr and Aug) of 2010 from these transects (upper slope, middle and toe-slopes) on which $\delta^{15}N$ isotope was applied. Samples (soil, water and plant) collected were properly labelled and transported to the laboratory. Samples were analysed after standard method. Results showed that soil organic carbon varied significantly across mini-pits, and transects. These ranged from 15.50 g kg^{-1} with a mean of 28.61 g kg^{-1} (Transect-1) to between 34.60 and 53.50 g kg^{-1} with a mean of 43.24 g kg^{-1} (Transect-2). Majority (or 78%) of the pedons in Transect-1 are strongly weathered, while in Transect-2, majority of the pedons (i.e. 73%) were classified as non- or weakly weathered using soil organic matter: silt + clay ratio. Results of the cluster analysis showed that clusters 1, 2, 3 and 4 were related to the water holding capacity, the soil weatherability, the soil ability to store carbon (carbon mitigation) and the soil's acidity. Results of the $\delta^{13}C$ data for both transects varied slightly with slope positions though not significantly different ($p < 0.05$) but higher negative values of the vegetation −28.13 to −28.90‰ were observed. The results of the $\delta^{15}N$ ranged from −2.52‰ to −2.93‰ with a mean of −2.81‰. Results of the hydrochemistry from the installed piezometers showed that across years and months the following variables (pH, EC, Ca, Mg, Na, K & NO_3-N) were within the normal range stipulated by the WHO (2004), while the phosphate concentrations were beyond the limits of the USEPA/NOAA (1988). It was concluded that more research is needed to identify sources and forms of phosphates in this wetland.

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1. Introduction

The kingdom of Lesotho has a total land area of 30,588 km^2 and is divided into four agro-ecological zones (AEZs): the Lowland, Senqu River valley, Foot-Hills and Mountains. The relative area covered by each AEZ is presented in Table 1. Most soils have low organic carbon contents coupled with low available P and acidic pH (≤3.5). The highest population pressure is in the Lowland AEZ, where the arable land is concentrated. In addition to the high population pressure, there is the problem of serious soil erosion and land degradation as a result of steep slopes, low soil organic carbon and sparse vegetation.

Lesotho has witnessed considerable internal migration in recent years and this pattern of migration has in large part, been from the rural to urban areas and from the Mountains AEZ to the Lowland AEZ. This internal migration is influenced by factors such as unemployment and increasing population pressure on agricultural lands in the rural areas. Despite having only one-quarter of the total land area, the Lowlands, Foot-Hills and Senqu River Valley AEZ holds more than three-quarters of the total population. Lesotho is replete with wetlands of varying sizes and at different levels of degradation.

Wetlands are important reservoirs of carbon, representing about 15% of the terrestrial biosphere carbon pools (Bolin et al., 2000; Gitay et al., 2001). Bolin et al. (2000) observed that when boreal forests and some tropical forested wetlands are included as wetlands, the amount of carbon reservoirs will be approximately about 37% of the total terrestrial carbon pool. The capability of a wetland to store carbon is related to the hydrology, geomorphology, and local climate condition (Patterson, 1999; Sahagian and Melack, 1998). It is estimated that wetland ecosystems have a total C stock of approximately 20–25% of the total stock in terrestrial soils (Zhang et al., 2008) and considered to play an important role in global C cycling. It is reported that the global C cycling directly affects the concentration of atmospheric CO_2, with potential implications for global climate change (IPCC, 2000; Lal, 2004). Native and restored

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Table 1
Agro-ecological characteristics of Lesotho.
Source: Olaleye (2012).

Agro-ecological zones	Altitude (m) above sea level	Topography	Mean annual rainfall (mm)	Mean annual Temperature (°C)
Lowland	<1800	Flat to gentle	600–900	−11 to 38
Senqu river valley	1000–2000	Steep sloping	450–600	−5 to 36
Foot-hills	1800–2000	Steep rolling	900–1000	−8 to 30
Mountains	2000–3484	Very steep bare rock and gentle rolling valleys	1000–1300	−8 to 30

wetlands are generally a sink for atmospheric CO_2, and therefore make an important contribution to global C sequestration (Furukawa et al., 2005; Inubushi et al., 2003; Roulet, 2000). Some authors estimated that the global C stock down to one metre depth in wetlands is approximately 225 Pg (1 Pg $= 10^{15}$ g) (IPCC, 2000). Armentano and Menges (1986) reported that this value compares favourably with the estimated range (180–249 Pg).

Stable isotopes are increasingly being used to detect and understand causes of environmental change. They have been used both to monitor ecosystem change and to make specific connections between ecology, land use, and geochemistry (Fry, 2006). In aquatic ecosystems, carbon (C) and nitrogen (N) isotopic signatures of organic matter (OM) have been used to detect changes in plant and microbial processes related to anthropogenic disturbance gradients. Studies employing natural abundance carbon (C) and nitrogen (N) isotopes have provided important insights into plant ecophysiology, organic matter cycling, and biogeochemical processes (Ewe et al., 2007; Troxler, 2007; Troxler and Richards, 2009) in wetland ecosystems. All these information may provide insight into their degradation and maintenance. Physiologically mediated variations in C isotopic composition in wetland plants can result from a number of sources, including the photosynthetic pathway, the nature of the primary inorganic C source (atmospheric vs. dissolved), the available carbon form and subsequent mode of assimilation (CO_2, HCO_3), and the limits on diffusion imposed by plant life form or conditions of the aquatic environment (Troxler and Richards, 2009). Similarly, variations in N isotopic composition can reflect differences in N source and processing (Dai et al., 2005; Mitsch and Gosselink, 2007). There is sparse data on the morphology and physio-chemical characteristics of wetlands in *Khalong-la-Lithunya* catchment, soil organic carbon pools and the vegetation isotopic signatures and surface water chemistry in the wetlands of Lesotho. Hence, investigations were conducted between 2009 and 2012 on the soil characteristics, hydrochemistry of the surface waters and vegetation isotopic signatures in order to assess the extent to which conservation and rehabilitation practices have allowed the wetlands to return to its former status.

2. Materials and methods

2.1. Site description

The study was conducted in a Lacustrine wetlands located in the *Khalong-la-Lithunya* catchment (KLC) in the Mountains AEZ of Lesotho in Butha-Buthe district. The KLC is located at points latitude 28° 53 S, 28° 47 E at an altitude between 3100 and 3200 m above sea level (asl) (Fig. 1a and b). The catchment of this wetland forms a part of sub-catchments of a main quaternary catchment draining into Motete River. The reference site has a total area of 3280 ha while the restoration catchment size is approximately 1332 ha (or 40.61%) (Department of Environment, 2009). Restoration efforts started in 2007, though there is no documented evidence that the wetlands have actually been restored. According to Chipps et al. (2006), the intensity of anthropogenic pressures such as mining, smelting, and industrial pollutions could be low, when wetlands has little (<5%) or no agricultural activity within 150 m of the wetland boundary, while high impacted wetlands had agricultural activities, within 10 m of at least one-third (≅33%) of the wetland boundary. The medium impacted wetlands will have agricultural

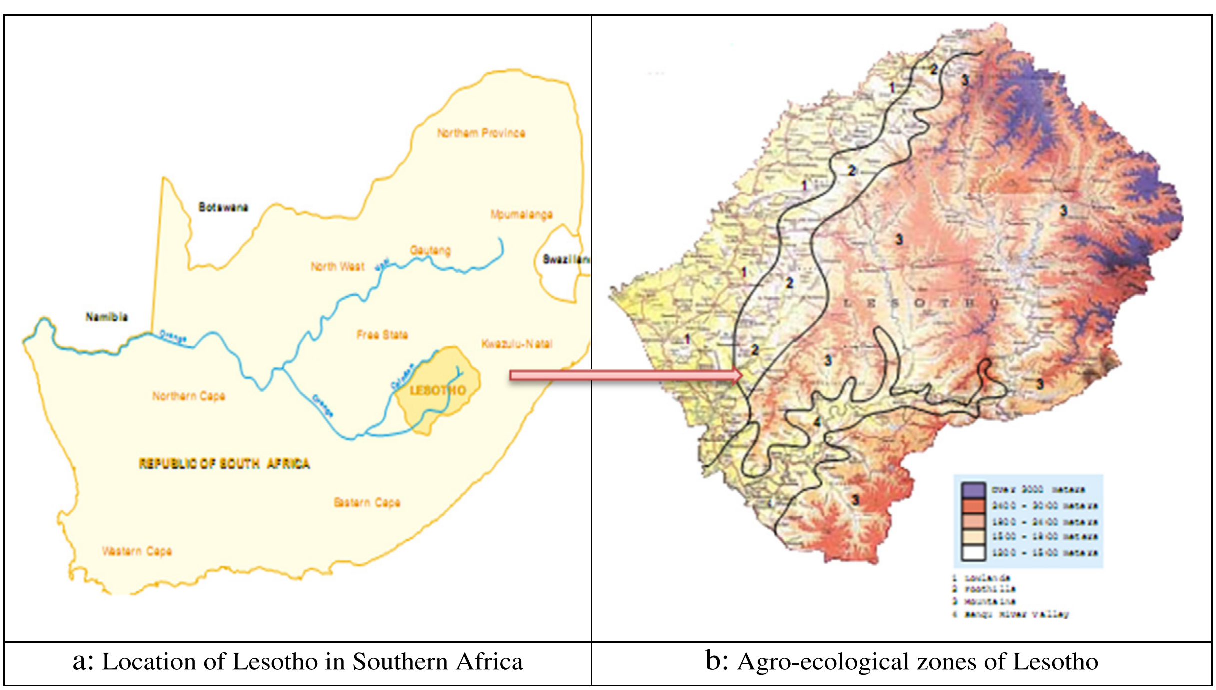

Fig. 1. a: Location of Lesotho in Southern Africa. b: Agro-ecological zones of Lesotho.

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