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A rapid assessment of anthropogenic disturbances in East African wetlands

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A B S T R A C T

The use of East African freshwater wetlands for agriculture has increased in recent decades, raising concerns about potential impacts on wetlands and the long-term sustainability of such land use trends. WET-health is an indicator-based rapid wetland assessment approach developed in South Africa. It allows determining the conditions of wetlands in four assessment modules (hydrology, geomorphology, vegetation, and water quality) by observing the degree of deviation of a wetland from its anticipated natural reference state. We tested the transferability of the WET-health concept for East African inland valley swamps and floodplain wetlands based on 114 assessment units at four study sites. Due to large wetland areas and different environmental settings in East Africa, we modified the original approach using a random selection of assessment units and an assessment scheme based on disturbance types (Appendices A and B). Estimated WET-health impact scores were matched with biophysical and socioeconomic variables using a generalized linear mixed model. Land use included largely undisturbed wetland units occurring side by side with seasonally cropped or grazed units, and drained, permanently cultivated units. A strong differentiation of impact scores between the four assessment modules was apparent with highest scores for vegetation and lowest scores for geomorphology. Vegetation and water quality responded most sensitively to land use changes. The magnitude of wetland disturbance is predominantly determined by management factors such as land use intensity, soil tillage, drainage intensity, and the application of agrochemicals and influences vegetation attributes and the provision of ecosystem services. The proposed modification of WET-health enables users to assess large wetland areas during relatively short periods of time. While further studies will be required, WET-health appears to be a promising concept to be applied to wetlands in East Africa and possibly beyond.

1. Introduction

Agricultural production in wetlands is increasingly considered to be a potential solution to food security challenges in Africa (Frenken and Mharapara, 2002; UNEP, 2009). Wetlands are characterized by generally nutrient-rich soils and high moisture availability, enabling smallholder farmers to produce crops all year-round (Sakané et al., 2011). Furthermore wetlands contribute a wide range of additional ecosystem services, including the provision of pasture land for livestock grazing during dry seasons (Dixon and Wood, 2003), the regulation of floods and local climate, the

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removal of pollutants, and being habitats of wildlife (Cui et al., 2012). At global scale wetlands cover about 9.2 million km^2 with 1.3 million km^2 being located in Africa (Lehner and Döll, 2004). In Uganda, Rwanda, Tanzania, and Kenya alone, wetlands cover an estimated area of about 0.15 million km^2 (Amler et al., 2015). This study defines wetlands as land surfaces that are/were flooded with freshwater or where the soil is/was saturated permanently or seasonally. Wetlands are thus primarily characterized by the influence of the amount and the spatial–temporal availability of freshwater and of its effects on soil and vegetation.

The use of such freshwater wetlands for agricultural purposes has increased in recent decades (Dixon and Wood, 2003). These land use changes are mainly driven by economic and demographic growth, climate change, and globalization effects (Van Asselen et al., 2013; Wood et al., 2013), but are also related to changed national policy environments and local governance structures (Wetlands International, 2014). The agricultural productivity of upland fields has declined as a result of degraded soils, extreme land fragmentation and increased variability of precipitation (Symeonakis and Drake, 2010). These factors, combined with emerging market opportunities have further fueled the shift from upland to wetland based agricultural production (Sakané et al., 2011; Wood and Van Halsema, 2008). However, in conjunction with non-adapted agricultural uses, wetland conversion into arable land frequently curtails the capacity of wetlands to provide the above mentioned important ecosystem services. Thus, a sustainable increase in food production from wetlands needs to be reconciled with environmental protection. Striking the balance between maximizing benefits of wetland agriculture while minimizing adverse impacts on other ecosystem services has been described as the main dilemma of current wetland policies and management (McCartney et al., 2010). Against this backdrop, there is a need to quantify the current state of disturbance from human impacts in East African wetlands and to identify major hazards to the condition ("health") of wetland ecosystems. This is imperative given that "healthy" wetlands are likely to be robust in playing the role of providing ecosystem services that are important in sustaining people's livelihoods such as food production resources, clean water, livestock pasture, building materials, fiber, esthetic benefits and hosting organisms that provide pollination services. Through these services, wetlands play an important role in assuring food and nutrition security, securing water supply, preserving plant and animal biodiversity and acting as a storm buffer. Disruption of wetland ecosystems through anthropogenic activities is therefore likely to be associated with tremendous economic costs as a result of the lost capacity to provide ecosystem services.

Several studies have explored agriculture-wetland interactions in sub-Saharan Africa in view of developing frameworks able to describe the potential of wetlands for agriculture and the concomitant supply or loss of ecosystem services (Acreman and Miller, 2007; Cui et al., 2012; Dixon and Wood, 2003; McCartney and Houghton-Carr, 2009; Van Dam et al., 2013; Wood and Van Halsema, 2008). One of these frameworks is the WET-health approach, developed for South African wetlands, that is a wetland degradation assessment, describing the degree of deviation of a wetland from its natural reference state (Kotze et al., 2012). This degree of deviation will henceforth be called disturbance. The level of disturbance is assessed for the four "assessment modules" hydrology, geomorphology, vegetation, and water quality. WET-health uses a semi-quantitative estimation of impact at a scale ranging from 0 (no deviation from natural conditions) to 10 (complete transformation and absolute loss of wetland properties) (Macfarlane et al., 2009). It is recognized that the natural reference state of a wetland is often not fixed, but depending on the particular situation may be highly dynamic, e.g. a lake fringe wetland where the level of the lake fluctuates markedly at a decadal scale as a result of climatic cycles. Furthermore, completely un-impacted wetlands are virtually absent in East Africa. Thus there is often no true reference site existing and the reference state has to be anticipated from climate, wetland type, and local information on past uses of the wetland. For instance, the reference condition for vegetation corresponds to the properties displayed by plant communities (diversity, structure, etc.) in absence or removal of human impacts (thus pristine vegetation or late succession stages). While the absolute reference state (vegetation stands with no human impact) is hardly to be found in the field, a hypothetical reference state can be approached by observing stands under low levels of disturbances. Such a reference state is known in ecology as potential natural vegetation (Mueller-Dombois and Ellenberg, 1974). The focus of the approach, however, lies on assessing current functionality of wetlands rather than accurate historical classification of reference sites.

While the four assessment modules are strongly interlinked, the WET-health framework provides an impact assessment of anthropogenic disturbances that attempts to reduce double-counting by assessing each WET-health module separately (Kotze et al., 2012). Thus, we consider WET-health to be a user-friendly and cost-effective approach that was developed for similar land uses as present in the wetlands of East Africa. Prior to this study all wetlands to which WET-health had been applied were relatively small (<10 km^2). In the application of Kotze (2011), for example, all examined wetlands were smaller than 1 km^2. The selected sites for this study, on the other hand, are much larger, with areas ranging from 81 to 537 km^2. These sizes present a particular challenge in terms of field coverage. Thus methodological modifications are required to transfer the WET-health assessment approach to East African wetlands. To reduce the sampling size we characterized randomly-selected assessment units within different localities and land use types. We further assigned WET-health impact scores for hydrology, geomorphology, vegetation, and water quality to these assessment units. In order to further reduce field operations this assignment was modified as well, using an assignment scheme based on disturbance types. Additionally, relationships between WET-health scores and biophysical conditions as well as socioeconomic attributes of the wetlands were determined. The adaption of the WET-health concept for East Africa was based on 114 wetland assessment units at four study sites in East Africa.

2. Methods

2.1. Study sites

The study was conducted at four sites in East Africa, namely Kampala (Uganda), Kigali (Rwanda), Ifakara (Tanzania), and Rumuruti (Kenya) (Fig. 1). The four sites were selected as East African freshwater wetlands used for agricultural purposes and representing primary intervention environments of national wetland policies in the target countries. They are contrasting in their geomorphological, bioclimatic and economical properties and cover the two major geomorphological wetland types, the inland valley swamps and the floodplains. The Kampala (Uganda) study site is located in the humid zone, covering an area of 117 km^2. It comprises a large number of small inland valleys located on transects along an urban-to-rural gradient at a mean elevation of 1100 m a.s.l. At an altitude of 1500 m, the Kigali (Rwanda) site covers 129 km^2 in the sub-humid zone and comprises both inland valleys within the Lake Muhazi catchment and floodplains of the Nyabarongo River. The Ifakara (Tanzania) site lies in the sub-humid to semi-arid lowlands at 250 m altitude, within the Kilombero catchment, covering an area of 537 km^2, and representing a typical lowland floodplain wetland. The Rumuruti (Kenya) site is located on the semi-arid Laikipia