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Fragmentation of wetlands in the south eastern coastal savanna of Ghana

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ABSTRACT

Temporal changes in a wetland were studied over a period of 25 years (i.e. 1990–2015) through the use of satellite images to assess the extent of environmental degradation in the Songor Ramsar Site, with special emphasis on fragmentation in the wetland. The study sought to analyse the wetland fragmentation and loss at the site. The specific objectives of the study were to assess the changes in the wetland classes, analyse the landscape configuration of the wetland classes and finally examine the composition of the wetland landscape. The wetland classes were categorised by employing the Ramsar classification system for wetland types. The validation results were established to be satisfactory after employing standardised accuracy assessment measures and comparison with ground truth data. Eight (8) landscape metrics were selected based on the literature and the potential of each metric to best describe wetland fragmentation. Interview surveys were used to complement data produced by Geographic Information System (GIS) application. During the 25-year period, lagoon/lake and inter-tidal forested wetland experienced a positive change while seasonal/intermittent and permanent marshes experienced a negative change. Further analysis using landscape metrics revealed that the configuration of the wetland types, especially inter-tidal forested wetland, has been fragmented and their ecosystem composition has reduced considerably.

1. Introduction

The coastal savanna area of Ghana hosts a variety of wetlands. The diverse wetlands in this zone provide many socioeconomic benefits and ecological value. Examples of such wetlands in the country include the Songor, Keta, Sakumo and Amazuri. The significance of wetlands lies in their roles as flood retention basins, producers of biomass, and habitats for important wildlife and fish species. They are a source of nutrients for the nearshore marine environment and also serve as pollution filters for water quality improvement (Tijani et al., 2011). Wetlands also serve as "carbon sinks", i.e. they take carbon dioxide from the atmosphere. Thereby they contribute to reducing the impact of global warming (Ramsar Convention Secretariat, 2007). Communities that live around wetlands in many parts of the world depend directly and indirectly on them for their livelihoods. They generate income from activities such as farming, cattle rearing, salt production and fishing.

Unfortunately, wetlands, particularly those in the coastal savanna zone of Ghana, have become more vulnerable as a result of increasing human use such as reclamation for residential and industrial purposes (Ryan and Ntiamoa-Baidu, 2000). Human activities coupled with changes in climate have resulted in fragmentation of wetlands, thus accelerating their degradation and threatening the biodiversity conservation and sustainable ecosystem services that the wetlands provide. Research has shown that fragmentation of wetland landscapes characteristically reduces species richness and taxa diversity and may reduce the efficiency of ecosystem functioning (Opdam and Wascher, 2004). In addition, fragmentation also affects habitat continuity, creating isolated patches which support fewer species and may promote local extinction of species (UNDCP, 2003).

Within the past years, scientists in landscape ecological research have developed landscape metrics methodologies for quantifying landscape fragmentation (O'Neill et al., 1988; Turner and Gardner, 1991; McGarigal and Cushman, 2002). In particular, advances in spatial techniques such as Geographic Information System (GIS) and Remote Sensing (RS) have contributed to the mapping of wetlands (Nyarko et al., 2015), and the development and use of landscape metrics.

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The use of fragmentation metrics as a landscape indicator is gaining governmental and scientific attention because it helps one to understand the complex interactions within a landscape. Therefore, understanding the dynamics of fragmentation in wetland ecosystems and their relation to human activities could improve our understanding of wetland functioning and help decision makers to develop and implement policies based on scientifically-informed management approaches for the protection and conservation of wetlands.

The Songor wetland located on the south eastern coast of Ghana forms an ecologically valuable resource providing numerous forms of support for biological diversity. The shores of the Songor lagoon serve as a feeding and roosting site for water birds while the coastal stretch provides nesting sites for marine turtles and fish species. The mangroves serve as habitat for monkeys and other wildlife species as well. To ensure sustainable use of the site resources by the local communities and to enhance its benefits it was designated as a Ramsar site on the basis of ecological communities, including the water bird populations whose presence relates to the international importance of the site (RSIS, 2015). Despite their relevance, the Songor wetlands are under increasing threat from over-exploitation and degradation. According to Yeboah et al. (2013), there is a perceived loss of the ecosystem services provided by the wetland. A study by the Centre for African Wetlands in 2014 on land use and land cover indicated that between 1990 and 2007 there had been a significant decrease and degradation of healthy vegetation cover from 3087 ha to 1308 ha. Field observations and analysis of recent aerial photographs of the Songor Ramsar Site depict that the wetland landscape shows spatially fragmented patches surrounded and interspersed with a matrix of agricultural fields, saltpans, settlements and drainage ditches. Though fragmentation represents the first step in the process of degradation, unfortunately such information on the extent of fragmentation is overlooked in most ecological studies within the site. Notwithstanding, no research has been conducted on the extent of fragmentation and its effect on the wetland ecosystem. This study sought to analyse wetland fragmentation in the Songor Ramsar Site over a 25-year period (1990–2015) to provide scientific information for the management not only of this site but also for other comparable Ramsar sites across the country.

2. Study area

The study area is the Songor Ramsar Site (5° 45′0″N 0° 30′0″E) located in the Dangbme East District in Ghana, as shown in Fig. 1. It is about 79 km from the national capital, Accra, and is the second largest Ramsar site along the coast of Ghana. The Songor wetland covers an estimated area of 51,133.3 ha and is the only natural point where the Volta River enters the sea. The boundaries of the site include the West Bank of the Lower Volta River estuary and the Songor lagoon. It was designated a Ramsar wetland site of international importance number 14 in August 1992. In 2011, UNESCO approved the Songor Biosphere Reserve as part of the World Network of Biosphere Reserves (UNESCO, 2011). Among several other important functions, the Songor Ramsar Site acts as a habitat and breeding ground for several notable species of water birds such as black winged stilt. Major land use activities in the Songor area include farming, livestock grazing, fishing, salt collection, recreation and settlement.

3. Methods

3.1. Data sources, collection and processing

Two types of data were utilised in this study. They included data from the field and those from secondary sources. Examples of data that were obtained from the field include: the people's perception of wetland fragmentation and Global Positioning System (GPS) coordinates of the wetland types to construct rules for classification and accuracy assessment. In addition to these data, secondary data such as satellite images, aerial photographs and topographic maps of the study area were used. Landsat images from 1990, 2003 and 2015 were freely downloaded from the United States Geological Survey (USGS) website and formed the spectral data sources for mapping the wetland landscape of the Songor Ramsar Site (Table 1). Orthophotos and topographic maps of the study area were also obtained from the Department of Geography and Regional Planning (DGRP) of the University of Cape Coast.

Two visits were made to the study site in 2015 (5th–8th March and 11th–13th December). The first was to obtain first-hand information and collect training samples for classification and the second was to collect true world points for validation of classification results and to conduct interviews. A semi-structured interview schedule was developed to assess the people's perception of wetland fragmentation. In total, 60 sets of the semi-structured interviews were administered to respondents from 4 communities within the Ramsar site. These communities and the number of respondents were Obane (7), Osaya (10), Otrokiper (18) and Pute (25). These communities were purposively selected for the survey on the basis of noticeable changes in the wetlands around them, as revealed by the satellite image analysis and their accessibility. The number of selected respondents varied between communities because of the differences in their populations The survey targeted residents in the communities who have lived in the site for at least 25 years. Most of these individuals were elderly people who had a lot of information about the environmental changes occurring in the site. Image processing operations in the form of radiometric and geometric corrections were performed on the Landsat images. In radiometric correction, haze and noise were corrected for each band of the Landsat datasets. The images were then subsetted using the boundary polygon of the Songor Ramsar Site. The subset images were then geometrically registered to each other before all other image processing and analyses were performed.

3.2. Wetland classification

The study employed both unsupervised and maximum likelihood supervised classification algorithms in ERDAS 2013 software. Unsupervised classification was done to aid in the exploration of the wetland classes. High-resolution images from Google Earth software, topographic maps and ground-based knowledge after a detailed field survey were used to select training samples. This option is the most common method in satellite image data analysis and it identifies and locates land cover types by combining the previous personal experience and fieldwork (Jensen, 2005). Thereafter, four wetland classes were identified on the three images based on the Ramsar classification of wetland type (Ramsar Convention Secretariat, 2013). The wetland classes include: lagoon/lake, inter-tidal forested wetland, seasonal marshes, permanent marshes and non-wetland.

3.3. Wetland landscape fragmentation

To quantify wetland landscape configuration and composition, FRAGSTATS™ 4.4 software was applied, because this spatial statistic program offers a comprehensive choice of landscape metrics. Understanding the components of a landscape cannot be done using a single metric (Ning et al., 2010). For this study, eight metrics were selected based on the literature and the potential of each metric to best describe wetland landscape fragmentation.