Short communication

Pattern of land-use and land cover changes in Driefontein Grassland Important Bird Area, Zimbabwe

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Abstract
We assessed land cover and land use change in Driefontein Grasslands Important Bird Area (Driefontein IBA), Zimbabwe, after the land reforms that took place in 2000, using remotely sensed satellite land cover images of 1995, 2000, 2005 and 2010. A drive transect was done for ground truthing. Data were analysed spatially in a Geographical Information System environment. Changes in land cover and land use proportions were recorded from 1995 to 2010 throughout the Driefontein IBA. The land cover classes of grassland and wetland showed a decrease, whereas land area under cultivation increased during 1995–2010. However, the woodland area marginally remained constant over the same time. We concluded that changes in land cover in the study area were largely driven by land use change, i.e., increase in cultivation, following the resettlement of people within the Driefontein IBA. It is likely that with increasing human population the natural habitat of the study area will be degraded further, negatively impacting key sensitive habitats such as wetlands, bird species, and other biodiversity. Threats to birds and wetlands habitats are also threats to human livelihoods because people in this semi-arid area depend on wetland ecosystem services for their survival. The study recommends continuous monitoring of Driefontein IBA for conservation of birds and their habitats.

Key Words: bird habitat, Driefontein, human, land cover, land-use

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Introduction

Important Bird Areas (IBAs) located outside protected areas of Africa generally contain a high proportion of mosaic woodland and open water, suggesting that such habitats are under-protected and generally threatened [1-3]. IBAs are places that are rich in bird species and other biodiversity and are therefore of international significance for the conservation of birds at global, regional and sub-regional levels [4]. Despite their biodiversity value, many IBAs are threatened by habitat degradation, and a high proportion of IBAs still lack legal protection [1, 5]. Land use and vegetation changes in savanna landscapes can affect ecosystem productivity and the conservation value of IBAs [6]. Accordingly, land use change due to human activities in Africa has influenced the transformation of habitats [7, 8]. Severe conversion of natural grasslands and wetlands to agriculture, forestry and human settlement has been reported in Africa [9-11], thus likely threatening the conservation value of some of the IBAs.

One such IBA occurring outside a strictly protected area is the Driefontein Grasslands IBA (hereafter, Driefontein IBA) in Zimbabwe, which was designated as an Important Bird Area because of the presence of threatened bird species. This IBA supports three globally threatened bird species: Wattled Crane (*Bugeranus carunculatus*), Grey Crowned Crane (*Belearica regulorum*) and Secretary bird (*Sagittarius serpentarius*) which use wet grasslands as habitat [12]. The wetlands are key habitats for these indicator bird species and other biodiversity. In addition, the wetlands in Driefontein IBA provide the main sources of water for the rivers that originate from this central watershed, supporting a significant number of people and biodiversity downstream. Driefontein IBA has experienced land use changes since 2000, following the Zimbabwe Government resettlement programme [11]. Prior to 2000, Driefontein IBA was well divided into large commercial cattle ranges compatible with wetland habitat, with a bird richness of about 365 species in the entire IBA [11].

In many parts of Zimbabwe, land use has changed from commercial agriculture to small scale farming characterized by mixed crop and livestock production, following the government's 'fast track' resettlement programme of 2000 [13, 14]. This programme was initiated by the Government of Zimbabwe and resulted in the resettlement of most commercial land. It was aimed at land redistribution to the vulnerable landless people for empowerment as well as to de-congest the communal areas. However, the country witnessed spontaneous farm invasions, and as a result of the fast track nature of the resettlement program, farms were occupied regardless of whether or not they had been formally allocated for resettlement [14]. Previous studies have revealed that vast tracts of land were cleared for cropping following land resettlement in Zimbabwe and in some cases, abandoned, while areas reserved for animal grazing were threatened by continuous grazing, tree cutting, and veld fires [11, 15]. As the human population continues to increase in Zimbabwe, more land is likely to be opened up for settlement and cultivation [16].

At the onset of the resettlement programme, villagers moved into Driefontein IBA, opening up the natural habitats for crop production [11]. Presently, Driefontein IBA has a total population of about 17,000 people with a population density of 33 people per km^2, and the population growth was 1.1% during the period 2002 to 2012 [16]. To date, little is known about the extent of human activities and land use changes in Driefontein IBA, or the resulting implications on this important wetland area. The objective of this study was to quantify the land use land cover changes between 1995 (pre-land reform and resettlement programme of Zimbabwe) and 2010 (post-land reform and resettlement) in Driefontein IBA, Zimbabwe.

One major challenge in monitoring land use and land cover changes in African IBAs when using remote sensing is the general inability to afford expensive high spatial resolution satellite images for mapping and monitoring [1]. The National Aeronautics & Space Administration (NASA), however, provides free and daily LANDSAT TM images or composites suitable for mapping purposes.

Methods

Study area

Driefontein IBA (about 20,000 ha) is located on Zimbabwe's central plateau; its central coordinates are 30^{o} 47.00' E 19^{o} 23.00' S (Fig. 1) [17]. The landscape in the Driefontein IBA is characterized by extensive expanses of open wet grasslands where soaks, seeps and depressions collect water and form many vleis as a result of the flat terrain [17]. There are few streams such as Nyororo and Shashe. The soils are sandy and fast-draining, except where water runs into shallow clay-lined depressions called vleis which support dense reed beds [11, 17]. Two distinct seasons occur, a wet season from November to March, and a dry season from April to October [17]. The Driefontein IBA is a semi-arid low-rainfall area with a mean annual rainfall of about 650 mm and a mean annual temperature range from 12 °C in winter to 32 °C in summer, with frost being common in winter [17]. The area is not well-suited to cultivation [18] and therefore was divided into large commercial cattle ranches until the onset of the land redistribution program in 2000. Livestock pastures and pens were watered from mechanically-powered boreholes, which enhanced the wetland environment [18].

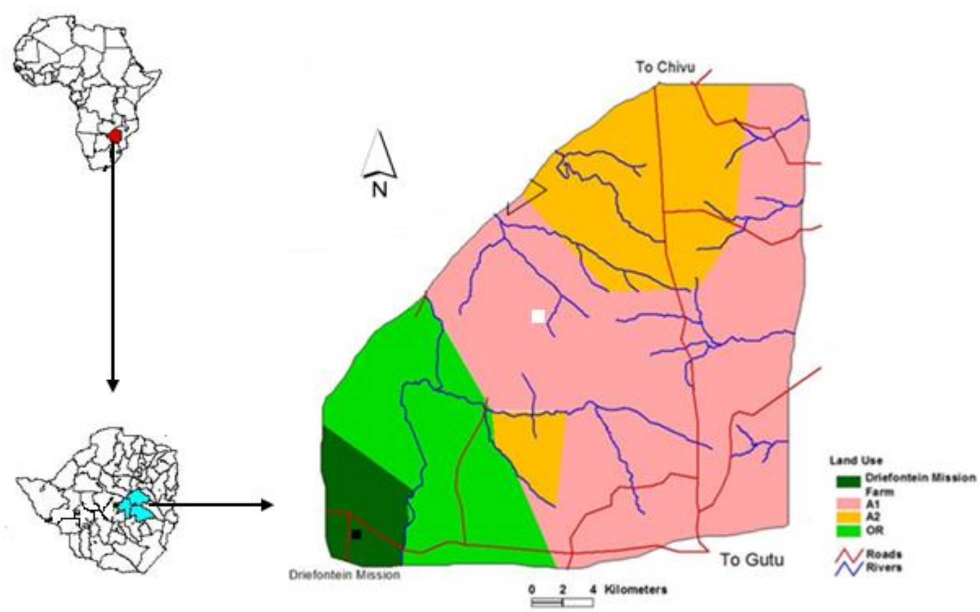

Fig. 1. Map of Driefontein Important Bird Area, Zimbabwe; A1 = communal resettlement area, A2 = commercial farm resettlement area, OR = old resettlement.

Sampling design and data collection

Data were collected between April and June 2013. The study adopted a two-step approach: (1) remote sensing for quantifying land use and land cover changes; and (2) field work which used ground truthing to verify land use categories. Land use and land cover changes were quantified throughout the study area using remotely sensed satellite images acquired from NASA (LANDSAT TM, path 170 raw 73) [19]. Because significant land use and land cover change in Driefontein IBA were initiated by the onset of land reforms and land resettlement (post year 2000), the land cover images were taken before land reform (1995), at the time of the land reform (2000), and after resettlement (2005 and 2010). We selected land cover images taken after the rainy season when leaf growth is at its peak. We preferentially selected images taken during cloudless days of April, May and June for the years 1995, 2000, 2005 and 2010.Land cover images were taken on 2 February 1995, 23 February 2000, 15 March 2005, and 24 April 2010. We then geo-referenced and co-registered the acquired images to each other. Co-registration was done so that corresponding pixels from different dates were matched, which aided in the comparison of specific land cover units over time. Geo-referencing of all land cover images was based on the Ground Control Points (GCPs) collected using hand-held Geographical Positioning System (GPS) and was done using the exact location of permanent land features such as dams, rivers and road junctions. As part of ground truthing, guided by permanent features as referral points, a vehicle traversed the selected roads across Driefontein IBA, and notable land use type and land cover were recorded as sighted on either side of the road.

Most sensors including LANDSAT record reflected electromagnetic radiation by earth features in the form of Digital Numbers (DN). These pose difficulties when comparing multi-temporal images due to differences in sun angle, sensor angle and flight height, among other factors. We solved this problem by changing DN values to radiance and then radiance to reflectance [19], using the following formula:

DN to radiance = $(LMAX - LMIN) / 255 \times DN + LMIN$, as presented [20].
Radiance to reflectance: $\rho p = (\pi \times L\lambda \times d2) / ESUN_\lambda \times COS(\Theta s)$

where:

ρp = planetary reflectance,
L_λ = Spectral radiance at sensor's aperture,
$ESUN_\lambda$ = band dependant mean solar exoatmosphereic irradiance,
Θs = solar zenith angle, and
d = earth-sun distance, in astronomical units

Data analysis

Land cover images for the study area were classified based on three techniques: unsupervised K-means [19], supervised Spectral Angle Mapper (SAM), and visual interpretation. The Spectral Angle Mapper (SAM) is a physically-based spectral classification that uses an n-dimensional angle to match pixels to reference spectra. The spectra for different land cover classes were compared to typical spectra of known land features and verified by ground truthing in order to separate ambiguity features. This comparative approach was necessary because the different land covers are always a mixture of different plant and grass species with distinct soil cover, especially in semi-arid areas. Visual aids were also employed following SAM analysis for further habitat feature identity based on the features' sites, locations, arrangements, and shapes. We used spatial analysis in a Geographical Information System (GIS) environment to produce land cover maps of the study area over time for all four satellite land cover image dates. Changes of land cover classes were determined by comparing land cover images of earlier dates against later date images to establish percent changes.

Results

Land use and land-cover changes in Driefontein IBA

The land cover was classified into five classes: grassland, wetland (grassland low lying), water, woodland, and cultivated land/fields (Table 1). The 1995 land cover classes show land cover percentages before Zimbabwe's Fast Track Land Resettlement programme, and the 2010 classes show percentage land cover after the land resettlement programme. The land cover class of area under wetland (grassland low lying) decreased between 1995 and 2010. The land area covered by grassland was 12,937 ha in 1995 and decreased to 9,214 ha in 2010 (Table 1). The proportion under wetland (grassland low lying) cover was 3,503 ha in 1995 and decreased to 1,938 ha in 2010. The greatest reduction of grassland and wetland cover classes occurred between 2005 and 2010, when 7,640 ha (11.8%) and 1,800 ha (2.8%) were lost, respectively. The land under cultivation increased from 89 ha in 1995 to 4,244 ha by 2010. The greatest increase in land cover under cultivation occurred between 2005 and 2010, when 2,676 ha of land were cultivated (Table 1). The land area under woodland cover expanded by 5% from 1995 to 2000, but remained almost constant from 2000 to 2010. The proportion under water shows very small changes from 1995 to 2010.

Table 1. Land cover classes and land use changes covering Driefontein Important Bird Area (total land size = 20,000 ha), Zimbabwe, from 1995 to 2010. Note: Grassland low lying represents wetland.

Land cover class (ha)	1995	2000	2005	2010
Cultivated	89	585	1,569	4,244
Grassland	12,938	11,900	11,564	9,214
Grassland low lying	3,503	3,036	2,491	1,938
Water	98	108	132	114
Woodland	3,371	4,372	4,244	4,490

Land cover maps of the study area from satellite images of the years 1995, 2000, 2005, and 2010 are shown in Fig. 2a, 2b, 2c, 2d, respectively. The land cover maps of Driefontein IBA over time (1995 to 2010) showed an increase in area of land under cultivation (fields), with a corresponding reduction in grassland and wetland. By the year 2010 more fields of land under cultivation were scattered across Driefontein IBA than in the year 1995. More wetland areas shrank in size between 1995 and 2010. Information recorded through observation (ground truthing) revealed that land use and land cover in Driefontein IBA have changed from commercial cattle ranging to subsistence mixed farming. Two models of resettlement, communal small-scale agriculture (A1) and commercial large scale agriculture (A2) were adopted. The farming system was characterized by transformation of some wet grasslands to cultivated lands. The local farmers cleared wetlands for gardening and cereal production (*T. Fakarayi, personal observation*).

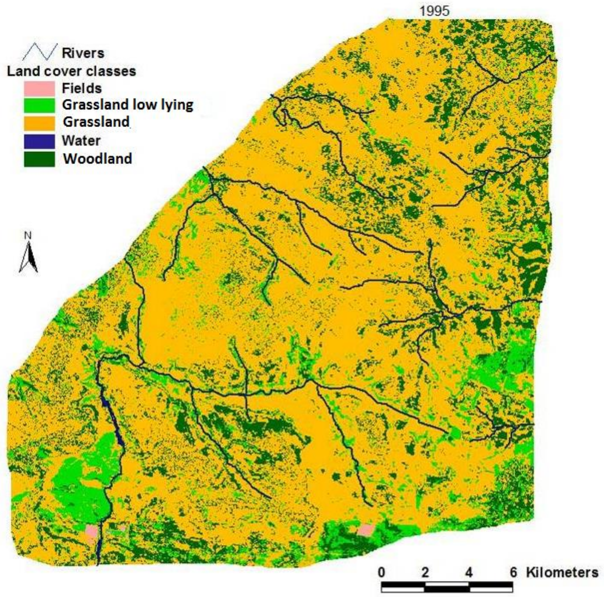

Fig. 2a. Land cover map of Driefontein Important Bird Area, Zimbabwe, in 1995. Note: Grassland low lying represents wetland.

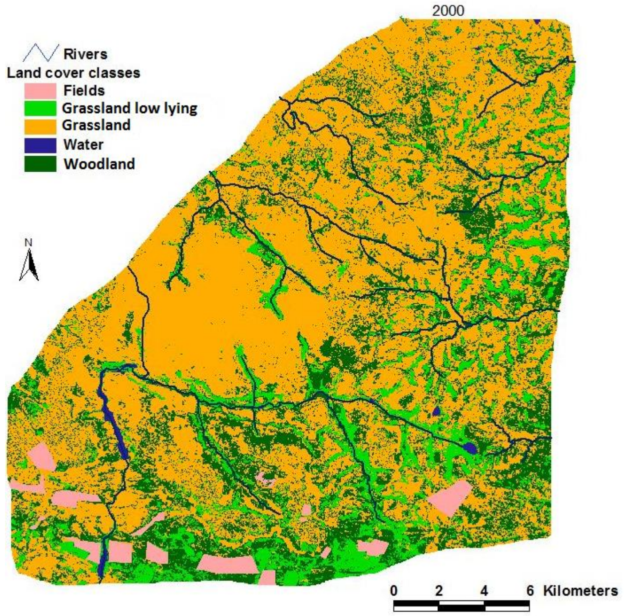

Fig. 2b. Land cover map of Driefontein Important Bird Area, Zimbabwe, in 2000. Note: Grassland low lying represents wetland.

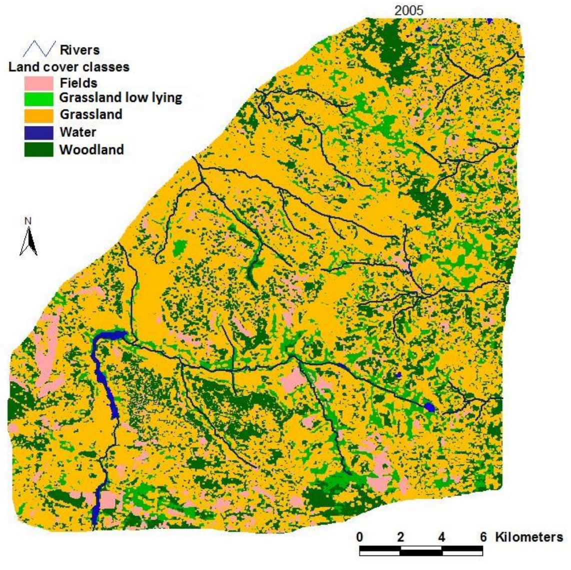

Fig. 2c. Land cover map of Driefontein Important Bird Area, Zimbabwe, in 2005. Note: Grassland low lying represents wetland.

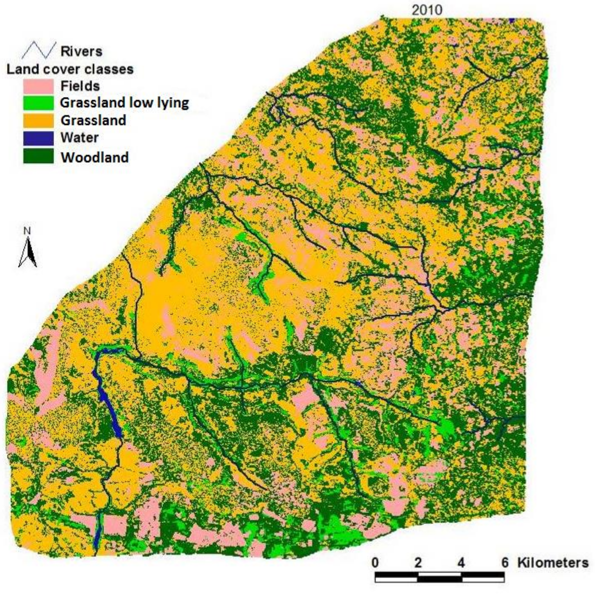

Fig. 2d. Land cover map of Driefontein Important Bird Area, Zimbabwe, in 2010. Note: Grassland low lying represents wetland.

Discussion

In this study, LANDSAT images of land use and land cover changes in Driefontein IBA highlighted significant changes in land use and land cover over the period 1995 to 2010, with a reduction of grassland and wetland habitats and expansion of land area under cultivation (Table 1). These changes have resulted in the transformation and/or loss of habitat for the globally threatened bird species in Driefontein IBAs. For instance, the distribution of Wattled Cranes and the Grey Crowned Crane in Zimbabwe is largely restricted to Driefontein IBA [17]. These two crane species are among the most threatened bird species in Zimbabwe, and Driefontein IBA is no exception: these two cranes are 'Specially Protected' species under the Zimbabwe Parks and Wildlife Act of 1975 as amended in 1996 [21, 22]. Since 2000, there has been a significant reduction of Wattled Crane (wetland trigger species) population in Driefontein IBA [11], a population decline attributed to loss of wetland habitat due to increased cultivation in wetlands following the resettlement programme of 2000 [11].

The wetlands and grasslands of Driefontein IBA were likely to become more exposed to cultivation following the resettlement programme, resulting in increased human densities throughout the study area, which likely explains the exponential growth of cultivated land cover [16].Our findings corroborate earlier reports of significant wetland habitat losses due to cultivation in Driefontein IBA, Zimbabwe [11]. Our findings suggest that land cover changes observed after 2000 were mainly influenced by the Fast Track Land Resettlement programme. Major changes in cultivation occurred between the periods 2000–2005 and 2005–2010, after the onset of Fast Track Land Resettlement programme of 2000. Before 2000, land use in the Driefontein IBA was commercial cattle farming with limited areas under controlled cultivation on the Driefontein Mission Farm and old resettlement village [11, 17, 18]. Changes in land use thereafter are largely a result of the resettlement programme in the Dreifontein IBA. Interestingly, our findings concur with previous studies that projected losses of wetlands and crane habitat due to agricultural activities following the resettlement programme in Zimbabwe [18, 21].

Our study highlights evidence of current land use and land cover changes caused by conversion of more wetland and grassland habitats into cultivated land, indicated by land cover maps of 1995 and 2010, respectively (Fig. 2a, 2d). These are signs of new agricultural land use developments still occurring in Driefontein IBA, reflecting earlier findings of considerable agricultural developments in IBAs in Africa [23, 24]. Given that the soils in the study area are typically poor sand soils not well suited for crop production [25], gardening in Driefontein IBA likely increases demand for wetland resources, especially in areas with poor soils. This implies that more land per unit production is required for cultivation by subsistence farmers in an attempt to maximize crop productivity, which will likely lead to more human encroachment of the unprotected wetlands of Driefontein IBA. Findings of this present study concur with study results that projected losses of wetlands due to agriculture following the resettlement programme in Zimbabwe [17].

Implications for conservation

Changes of land use systems are degrading the important grasslands and wetlands habitats of the Driefontein IBA. This habitat degradation could be negatively impacting certain population of the bird species, especially the cranes which are restricted to Driefontein IBA in Zimbabwe. For instance, the breeding sites (wetlands) and home ranges of cranes [11, 22] are likely constrained by the surrounding land use changes. Wattled Cranes have an average home range of 1,664 ha, including proportions of both wetlands (48.9%) and grassland (51.8%). Pairs are strongly territorial, and each pair requires a territory size of approximately 25 ha [10]. A total of 5,290 ha of both wetlands and grasslands were lost in Driefontein IBA between 1995 and 2010 (Table 1), which translates to a total loss of about 3 actual home ranges and 212 breeding sites of Wattled Cranes lost to conversion of wetlands and grasslands to cultivated land between 1995 and 2010 in Driefontein IBA. Loss of wetlands breeding sites and home ranges increases the risk of local extirpation of specific bird species populations in the medium to long-term in Driefontein IBA [2, 26, 27].

However, if well managed, agricultural land mosaics can support a range of bird species [28]. We recommend further studies to assess the impact of land use land cover changes on the abundance, distribution and habitat use by specific bird species throughout Driefontein IBA [29-31]. We conclude by proposing the development of a proper land use management system backed by a strategic land use plan, in order to reduce the loss of sensitive wetland habitats and biodiversity in Driefontein IBA.

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