Land Cover Changes and Conservation Effectiveness of Protected Areas: Evidence from Landlocked Developing Countries in Sub-Saharan Africa

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Abstract: It is evident that some existing protected areas (PAs) were established prior to the call for more effective management of PAs. This study looked at the conservation effectiveness of three selected PAs in landlocked developing countries (LLDCs) in sub-Saharan Africa prior and after the Strategic Plan for Biodiversity (2011-2020) using spatial analysis. The results indicated Zemongo Faunal Reserve (Central African Republic) and Central Kalahari Game Reserve (Botswana) had better conservation effectiveness compared to Harar-Wabi Shebelle (Ethiopia). Although there was also human activity in the form of cropland in the three protected areas, this was limited in 2020. The exception was Harar-Wabi Shebelle (Ethiopia). This study reiterates the need for continued effective management strategy and policy making for protected areas in sub-Saharan Africa.

Keywords: land use land cover; spatial analysis; protected area; landlocked developing countries; sub-Saharan Africa.

1 Introduction

The importance of protected areas (PAs) is gaining traction as seen from the numerous efforts from organizations developing various programmes to address the biodiversity decline and ecosystem service protection (CBD 2011). Hence, programmes like the Aichi Target 11, requires protecting 17 % of terrestrial and 10 % of marine areas by 2020. Additionally, the United Nations Sustainable Development Goals (UN-SDG) reiterate their commitment to see life below water (SDG 14) and life on land (SDG 15) safeguarded as to maintain nature's contribution to human well-being, as the ecosystem environment must be conducive for it to thrive (Krkoška lorencová et al. 2016). However, anthropogenic activities lead to biodiversity loss and impair ecosystem functions (Cardinale et al. 2012, Yang et al. 2022). Therefore, to ensure the protection of biodiversity and the environment, protected areas and other effective area-based conservation measures (OECMs) are being initiated in light of the threats that population growth, urbanization and climate change pose to ecosystem services (Hassan et al. 2016, Arowolo et al. 2018).

Interestingly, about 13% of Africa's land area is designated as protected areas and 8,000 of these protected areas are officially registered in the World Database of Protected Areas (WDPA) (Miranda et al. 2016, Parks 2023). The African continent is therefore not left out when it comes to achieving its goals, as the target is to protect 30% of terrestrial and coastal areas (Parks 2023). Conversely, there are reports of poor management and lack of monitoring of existing protected areas in both terrestrial and coastal areas in Africa (Parks 2023). As part of the Convention on Biological Diversity, a study examined the impact of the Strategic Plan for Biodiversity (2011–2020) on the protection of biodiversity in protected areas in nine selected countries. The study found that although the program had resulted in an expansion of protected areas, the countries studied were inadequately protected by 2020 (Jantke et al. 2024).

Nevertheless, in the context of location/ecoregion, this study assumes that the situation is different in coastal and terrestrial areas, especially in landlocked developing countries (LLDCs). For instance, an estimated one-third of the world's population lives in the coastal areas (Barbier et al. 2008), which contributes to more human pressure for food and livelihood, while LLDCs are considered geographically disadvantaged compared to other countries in terms of economic growth and sustainable development efforts, etc., and studies are yet to ask whether the geographical constraints common to LLDCs affect their environment and biodiversity. Hence, this study will specifically address the research gap on the site-specific status of protected areas in landlocked developing countries in sub-Saharan Africa before the start of the Strategic Plan for Biodiversity in 2011 and after its end in 2020. This will provide more precise evaluation of the protected areas considering the influence of its location on its conservation effectiveness. This is significant as researchers have questioned the call to expand protected areas to meet the mandate without considering the conservation effectiveness of existing areas (Watson et al. 2014), amidst intense human pressure (Jones et al. 2018). This is crucial to avoid efforts in futility considering the numerous benefits protected areas offer to human-wellbeing and environment (Watson et al. 2014, Tang 2020). Hence, monitoring PAs conservation effectiveness is the key to conservation efforts and biodiversity protection (Duncanson et al. 2023).

Various studies have analysed the conservation effectiveness of protected areas using human pressure data and discovered half of the world's protected areas are under severe human pressure, particularly in Africa, Western Europe, and South Asia (Jones et al. 2018). Others used a metric score to assess protected area performance (Jantke et al. 2019), weighted least squares regressions (Heino et al. 2015), questionnaires (Laurance et al. 2012) and opportunity costs (Venter et al. 2014). Their observations ranged from higher forest loss within the boundaries of protected areas to the integrity of protected areas being compromised by surrounding areas. Also, based on location, biodiversity hotspot areas are not given much attention (Venter et al. 2014). However, there are paucity of studies looking into PAs conservation effectiveness among landlocked developing countries (LLDC) in sub–Saharan African. This raises the question if land cover drivers and PAs conservation effectiveness are location specific. Also, knowing the particularities surrounding LLDC, as 16 out of 44 in the world are in Africa, such as geographical constraints, access to coastal waters etc., does it affect the conservation effectiveness of their protected area. To fill this research gap, this study uses spatial analysis to assess land use change of existing PAs in landlocked developing countries (LLDC) in sub-Saharan African that were established prior the Strategic Plan for Biodiversity (2011–2020) to see their conservation effectiveness.

2 Materials and methods

This study utilized spatial analysis to assess the land cover changes of three selected PAs located in a landlocked developing country (LLDC) of sub–Saharan African, namely, Harar-Wabi Shebelle National controlled hunting area (Ethiopia), Zemongo Faunal Reserve (Central African Republic) and Central Kalahari Game Reserve (Botswana). This study examined their conservation effectiveness from 2001 to 2020, i.e. before and at the end of the Strategic Plan for Biodiversity (2011–2020). A major criterion for selecting the protected areas were based on their extent (size), designation as a national enterprise and most importantly, established prior to the Strategic Plan for Biodiversity (2011–2020).

The protected areas boundary was clipped from the land cover data in order to analyze the conservation effectiveness of the three selected PAs. Thereafter, the land cover inside the PA was determined after raster projection and image processing on ArcGIS 10.6, using MODIS International Geosphere-Biosphere Programme (IGBP) classification to delineate the land cover classes. The subsequent area changes were determined using Equation (1).

$$\mathrm{LULC}_{\mathrm{change}} = \mathrm{LC}_{n2020} - \mathrm{LC}_{n2001} \quad (1)$$

where, end year and start year are land covers for 2020 and 2001, respectively, while n represents the individual land cover class.

The protected area extent and land cover images were collated from the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and Moderate Resolution Imaging Spectroradiometer (MODIS) (Table 1).

Table 1. Summary of the data source information.

Data Source	Data	Year
UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)	World Database on Protected Areas	2023
Moderate Resolution Imaging Spectroradiometer (MODIS)	500m Land Use Land Cover images	2001 and 2020

3 Results

The land use cover classification showed 7 land cover classes namely; forest, shrubland, savanna, grassland, cropland, built-up area and barren but varying among the three PAs (Figure 1). In Harar-Wabi Shebelle (Ethiopia), shrubland decreased significantly from 49% to 34% between 2001 and 2020, while grassland and cropland increased from 51% to 66% and from 0.02 to 0.12%, respectively. The Zemongo Faunal Reserve (Central African Republic) had a significant increase in forest cover from 10% in 2001 to 28% in 2020. However, other land covers in the protected area decreased. In the Central Kalahari Game Reserve (Botswana), on the other hand, there were only minimal changes in land cover. The land cover area changes in hectares are given in Table 2. Furthermore, n/a means the land cover class is not available (not detected).

Based on the land cover transition matrix, which indicates how the different land covers changed from one state to another, it is observed that apart from the built-up area, which was only present in Harar-Wabi Shebelle (Ethiopia), cropland was common among the three PAs, but was converted to other land cover classes in Zemongo Faunal Reserve (Central African Republic) and Central Kalahari Game Reserve (Botswana), while cropland increased in Harar-Wabi Shebelle (Ethiopia). This implies more effective management of protected areas in the Central African Republic and Botswana compared to Ethiopia.

To explain the presence of human activities that can have profound impact on biodiversity and climate, this study considered the individual land cover changes. The study observed that in Harar-Wabi Shebelle (Ethiopia), shrublands and grasslands were converted to croplands. While in Zemongo Faunal Reserve (Central African Republic) and Central Kalahari Game Reserve (Botswana), croplands were restricted in 2020 and later converted to shrublands, grasslands and savannas.

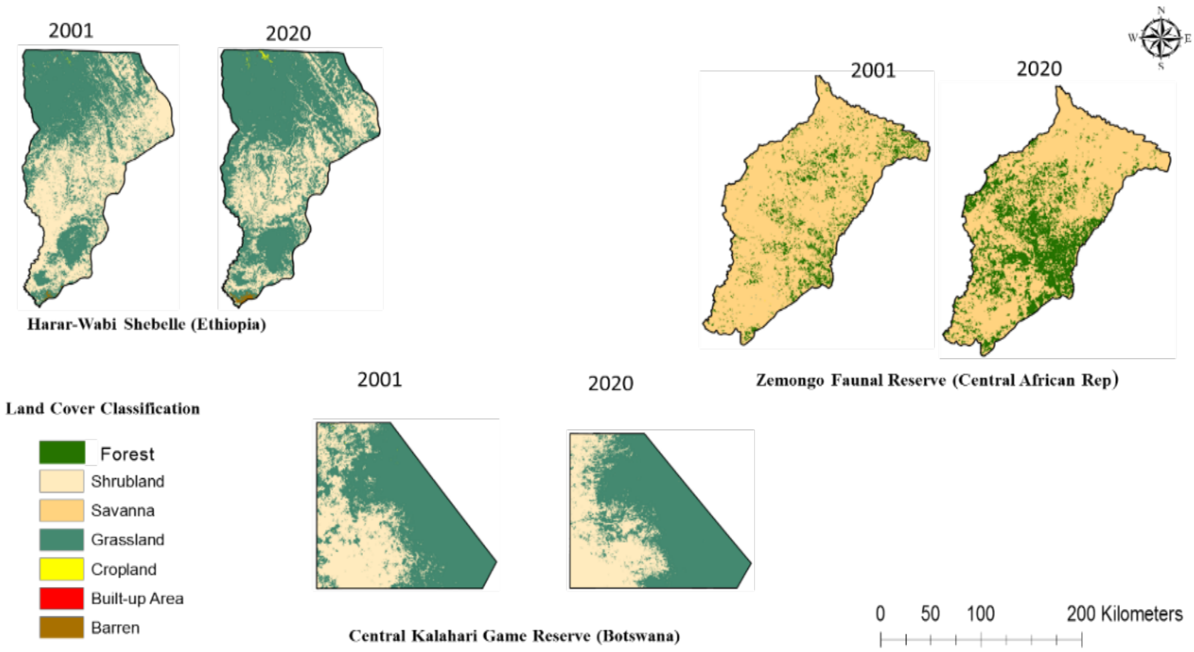

Figure 1. Land cover of the 3 Protected Areas located in Landlocked Developing Countries of Sub-Saharan Africa.

Table 2. Land use cover changes [Ha] across the PAs in Landlocked Developing Countries.

	Harar-Wabi Shebelle			Zemongo			Central Kalahari		
LULC	**2001**	**2020**	**Change**	**2001**	**2020**	**Change**	**2001**	**2020**	**Change**
Forest	n/a	n/a	n/a	143,729	379,618	235,889	n/a	n/a	n/a
Shrubland	1,632,322	1,116,421	-515,901	n/a	n/a	n/a	1,906,896	1,878,372	-28,524
Savanna	226	330	104	1,228,598	993,094	-235,504	3,321,957	3,351,337	29,380
Grassland	1,673,830	2,175,800	501,971	663	29	-604	0	29	29
Cropland	764	4761	3997	57	0	-57	1245	0	-1245
Built-up	65	65	No change	n/a	n/a	n/a	n/a	n/a	n/a
Barren	4126	13,184	9058	n/a	n/a	n/a	n/a	n/a	n/a

4 Discussion

The idea of nature conservation is to protect the natural ecosystem from degradation. Thus, considering the land use land cover changes in the three PAs analyzed, Zemongo Faunal Reserve (Central African Republic) and Central Kalahari Game Reserve, had a better conservation management effectiveness as they restricted cultivation by 2020, to stem degradation associated with agriculture. This shows conservation management efforts are effective as land use management plays a crucial role, even for ecosystem functions (Burkhard et al. 2012). In addition, their individual designation may have contributed to the rate of land cover changes. This is because appropriate management plans and strategies contribute to the sustainability and functions of protected areas (Yoo et al. 2024).

The goal of protected areas is the conservation of ecosystems. However, there were presence of human activities, like croplands in 2001 but was restricted in 2020 in some PAs. This further demonstrates PAs land use management system are different in countries. In addition, the difference in conservation approach has been known to be due to the management aims for the PAs and most importantly the authorities and stakeholders behind their establishments (Dudley 2008, Meli et al. 2019).

This study has highlighted the potential of spatial analysis in the assessment of the management of PAs in the three LLDCs and their outcome indicates their priority and management effectiveness as minimal ecological changes was observed specifically in Botswana and Central African Republic. However, crux of conservation effectiveness may seem to depend on the country's priority and subsequent conservation approach. Nevertheless, the establishment of protected areas remains crucial for the conservation of habitat quality and biodiversity (Geldmann et al. 2013).

5 Conclusions

In this study, the use of spatial analysis was utilized to assess the conservation effectiveness of PAs in some selected Landlocked Developing Countries (LLDCs) in sub-Saharan Africa prior the start of the Strategic Plan for Biodiversity in 2011 and after its end in 2020. As a result, the study observed the following: Zemongo Faunal Reserve (Central African Republic) and Central Kalahari Game Reserve (Botswana), had a better conservation management effectiveness as they restricted cultivation by 2020, to stem degradation associated with agriculture. Human activity was present in the three PAs in form of cropland activities but were restricted in 2020. The exception was Harar-Wabi Shebelle (Ethiopia), which was meant to be a National controlled hunting area, implying a low conservation effectiveness and land use management. Management objectives of PAs may not solely lie on its designation, but from the land use management of the National or regional authority and stakeholders behind their establishments. In sum, the study contributes to advocacy for continued effective management strategy and policy-making related to management of protected areas in sub-Saharan African and the world at large.

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