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Biophysical and anthropogenous determinants of landscape patterns and degradation of plant communities in Mo hilly basin (Togo)

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ABSTRACT

In mountainous areas, biophysical settings and human disturbances strongly influence landscape patterns and dynamics requiring a permanent understanding of their combined influence. In this study, we investigated the diversity and patterns of wild landscapes in relation to ecological factors, human disturbances and land protection regime in the Mo river basin (Central Togo). First, we used geographical information systems (GIS) and remote sensing techniques to quantify and spatially explicit the major land cover types occurring in the area. We performed a supervised classification of Landsat 8 image from 2014. Next, we used vegetation ordination and classification methods to detect vegetation group types and their similarity level from forest inventory data collected at 75 sites. Data from soil samples at the 75 sites and DEM-based topographical indices were used as biophysical variables to analyze factors of current landscape structure. Both satellite image classification and the outputs from ordination methods indicated that three major vegetation types (forestlands, woodlands and savannahs/shrubs) occurred in protected (PA) and unprotected (UPA) areas. Image classification showed that savannahs/shrubs are the most widespread vegetation types (54.4%) while forestlands and woodlands cover 10.4% and 26.4% of the total area, respectively. UPA showed high rates of human disturbances that shaped the occurrence of a fourth vegetation type made up mainly by degraded savannahs and woodlands. Along the land protection gradient, the landscapes are driven by soil nutrients and moisture, in combination with the influence of topography and human disturbances. In both PA and UPA, and along protection gradient, majority of features exhibited significant differences among plant communities. The spatial analyses combined with the field data providing information on vegetation cover, species richness, and human footprint indices suggested that some areas outside protection still exhibit high potentials for land conservation. In multifunctional landscapes of Mo basin, conservation strategies could also be encouraged in the wild landscapes of community common lands to promote both biodiversity conservation and sustainable provision of ecosystem services.

1. Introduction

Diverse landscapes are host of biodiversity and provide a wide range of ecosystem services, requiring knowledge on the social-ecological interactions. Understanding the interactions between human imprints and biophysical components defining the landscape heterogeneity has been considered as a fundamental for landscape management and biological conservation (Ali et al., 2014). In tropical regions, natural landscapes, especially woodlands and forests provide many functions and services, such as biodiversity conservation, climate regulation and livelihood support to millions of people (Zeleke and Hurni, 2001; Shackleton et al., 2007; Tindan, 2015). In majority, population depend on these natural resources that they manage and conserve according to their usage and resources (Appiah et al., 2009; Pare et al., 2010; Pouliot et al., 2012; Ouedraogo et al., 2013; Steele et al., 2015). This situation led to management options through protected areas and community forest zones in order to serve as guards for landscape conservation. Unfortunately, increasing human pressures on land resources

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affect these protected areas, aggravating the failure of their biological conservation role (Folega et al., 2010a; Wala et al., 2012; Damnyag et al., 2013; Dimobe et al., 2014; Folega et al., 2014b). It hence appears that human disturbances are taking over natural ecological factors in shaping and changing the functions, structure and aesthetics of the landscapes. This broad-scale human-related disturbance and destruction of native vegetation is considered as landscape fragmentation and degradation (Bennett and Saunders, 2010).

Globally, landscape fragmentation and heterogeneity changes are primarily induced by increasing human disturbances, especially agriculture, wood extraction of timber and charcoal production (Pare et al., 2009b; Norris et al., 2010; Pare et al., 2010; Onojeghuo and Blackburn, 2011; Wale et al., 2012; Vu et al., 2014; Wampembe et al., 2014). Landscape heterogeneity is most often driven by complex mechanisms being the result of a natural dynamic phenomenon influenced by human imprints, policy response, climate change, market, and poverty (Appiah et al., 2009; Zhang and Zang, 2011; Appiah, 2013) at a given time and location. In Togo, especially in the Central region covered by mountainous ecosystems, numerous human pressures are shaping and disturbing the landscape patterns, even in protected areas. In these areas, intensive wood extraction of timber, firewood and charcoal production, and small scale farming system strongly affect the landscape structure and induce degradation of natural ecosystems (Dourma et al., 2009; Wala et al., 2012). In this context, land resource availability and location are changing following these human footprint gradients, calling for the spatial mapping of the landscape patterns in order to provide an understanding of how certain factors influence these changes at landscape level.

While earth observation technology provides insights to assess the spatial patterns of the landscapes, field surveys are required to provide stand characteristics of each landscape component, especially vegetation types and soils. Interestingly, a combination of both methods could provide more understanding of the factors governing landscape structure for targeting options of sustainable use and management of resources (N'da et al., 2008; Hoffmann et al., 2012). Such information on intrinsic and exogenous factors can contribute to managing a more sustainable the landscapes considered as commons that are life-support systems on which people undeniably depend (Shackleton et al., 2007; Thondhlana et al., 2012; Tieguhong and Nkamgnia, 2012). Landscape planning needs not only knowledge of the nature of factors causing the dynamic of land cover, but also necessitate spatial information to target areas likely or not to undergo changes.

Mo river basin, embedded in one of the richest landscapes in Togo covering three protected areas, is undergoing continuous transformation. Despite its importance, the ecological status and appropriate conservation management remain poorly understood. Furthermore, as in the whole Togo, there is no master plan aiming at promoting the sustainable allocation of land resources. Though protected areas are erected in the region to ensure biological conservation, the public policies failed due to weaknesses in law enforcement and illegal incursions (Wala et al., 2012). Attempts to propose pathways for sustainable management of landscapes were undertaken fundamentally on the characterization of vegetation structure and floristic composition in relation to environmental variables and human disturbances (Woegan, 2007; Dourma, 2008). Acute attention has only been paid to the use of species composition, and vegetation stand structure as evaluation indicators of land performance and landscape heterogeneity. No insight is provided on the spatial patterns of the evaluated land resources in order to inform about the potential resource availability. Furthermore, potentials of the soils in terms of chemical contents are not well understood, although correlations between soil conditions and vegetation influence the landscape patterns (Galal and Fahmy, 2012).

In the context of insufficient information to tackle landscape fragmentation issues, further researches that integrate spatial dimensions still need to be undertaken at local and national levels. Therefore, in this study, we used an approach that integrates geographical information systems and remote sensing combined with field measurements in order to spatially explicit landscape patterns and assist the sustainable management of the multifunctional landscapes of the Mo river basin. The specific objectives of the study were to (i) provide a spatially explicit map of the current landscape heterogeneity in natural and semi-natural landscapes of both protected and unprotected areas of Mo basin; (ii); analyze biophysical and human disturbances prevailing at the landscape level, and (iii) determine the stand characteristics as well as soil chemical conditions in each vegetation type. By hypothesizing that protected areas exhibit better indicators of land conservation performance than unprotected areas, we investigated on the structure and stand characteristics as well as edaphic-ecological variables according to land protection regimes. The outputs of the study are suggested as potential indicators of landscape configuration, threats to land conservation and land characteristics that could help in re-addressing poor land management issues and landscape planning in the Central Togo.

2. Methodology

2.1. Study area

Mo watershed is a sub-unit of the Volta basin (West Africa) located in the Central Region of Togo (Fig. 1). With a total area of 148,592 ha, the basin is particularly sensitive as it contains great parts of the Fazao-Malfakassa National Park (FMNP), the Aledjo Wildlife reserve, and Kemeni Forest reserve. Due to the increasing demand for land resources, these protected areas are likely to undergo more human pressures (Woegan, 2007; Wala et al., 2012). The Mo basin is embedded in the Ecological Zone 2 of Togo, characterized by a mosaic of dry and riparian forests, woodlands, guinea-soudanian savannahs. Dominant land uses within the human-dominated landscapes (non-protected zones) are small scale agro-systems (Woegan, 2007). The predominant plant species in the area are *Isoberlinia doka* Craib & Stapf, *Isoberlinia tomentosa* (Harms) Craib & Stapf, *Monotes kerstingii* Gilg, *Detarium microcarpum* Juss. and *Uapaca togoensis* Pax., etc. (Woegan, 2007; Dourma, 2008; Dourma et al., 2009). The climate is tropical subhumid characterized by a rainy season from April to October (Petit, 1981). Mean annual rainfall is between 1200 and 1300 mm with an irregular spatial-temporal distribution. Mean minimal and maximal temperatures reach respectively 19 °C in January with the Harmattan winds and 30 °C in April. Evapotranspiration is generally high, especially during dry season and can reach 1600 mm per annum. Some parts of the hilly lands have elevation above sea level higher than 800 m, especially in Aledjo Mounts. Other mounts are of variable heights, comprising the massifs of Mazela (704 m), mount Akitili (861 m), mounts Kouzé (625 m) and Kpeya (652 m). Mounts Malfakassa composed of Ouassi (568 m), Zandebou, Tchakouya, Timbou et Balankan (Woegan, 2007). The rivers/streams network is heavily developed in accordance with the mountainous relief. Mo, Loukoulou, Kamasse, and Bouzalo are the most important streams of the basin. On morpho-structural angle, the Mo basin is dominated by sericite and muscovite dominant quartzites. Lithosoils and ferruginous tropical soils are the dominant soil types with some patches of ferralitic soils (Lamouroux, 1969). Foremost of the land uses in the area is small-scale subsistence farming, pasture lands, protected areas and built-up areas. The prominent environmental issues are land degradation due to overgrazing, unsustainable agricultural land use, fuel wood harvesting