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Biodiversity and Land Systems

PERSPECTIVE

A new focus for ecological restoration: management of degraded forest remnants in fragmented landscapes

Land use and land cover change is the major driver of biodiversity loss in terrestrial ecosystems worldwide, making the management and governance of land systems a key parameter in conserving and sustaining biodiversity. This issue gathers 16 contributions dealing with the relations between biodiversity and land systems from very diverse thematic and regional perspectives.

Photo by: Fabiano M. Scarpa

Jörg **Helmschrot**[1] | Heou Maléki **Badjana**[2,3] | Emma Patricia **Kabore**/ **Bontogho**[2]

Land cover change and its implication for the sustainable management of West African water resources

Abstract

Ongoing land use changes which are primarily driven by population growth and associated demands for food and energy production as well as changing climate pattern in West Africa are considered to vastly affect hydrological dynamics such as runoff generation or groundwater recharge. To contribute to a better understanding of these dynamics, we present our findings from three reference catchments in Burkina Faso, Benin and Togo. Our study reveals that 35% up to over 50% of savannah was severely degraded over the last three decades. However, no significant changes in runoff pattern were observed yet for any of the three basins which is in contrast to other studies in the region. We argue that slightly decreasing rainfall, farm dams and irrigations schemes which have been recently established as well as a growing domestic water use seem to counteract increasing discharges. These interacting dynamics underpin the need for integrated research to povide science-based information to water resources managers.

Introduction

In previous years, most West African countries have experienced considerable land-use changes through deforestation in combination with agricultural expansion, overgrazing and conservation (e.g. Li *et al.*, 2007, Wittig *et al.*, 2007). In addition, changing climate pattern (e.g. Kabore/Bonthogo *et al.*, 2015a,b; Badjana, 2015) and an increasing population caused by migration and high fertility rates (e.g. World Bank, 2011) accelerate the pressure on vulnerable ecosystems across West Africa. These changes are expected to have immediate and long-term impacts on the local and regional water cycle (e.g. Cornelissen *et al.*, 2013, Mahe *et al.*, 2005, Routier *et al.*, 2014). For example, ongoing deforestation of savannah along with projected rainfalls of higher intensities may affect runoff generation mechanisms, and thus support flood generation and reduce baseflow. On the other hand, the expansion of agricultural area and the reduction of tropical forests will presumably increase evapotranspiration (e.g. irrigation agriculture) and possibly alter groundwater dynamics, all affecting local climates and biodiversity in a long-term perspective. However, tremendous land use changes generally do not offset the hydrological effects of climate change (e.g. Ibrahim *et al.*, 2015). Given the relevance of land management and climate change, the monitoring and assessment of such dynamics are essential for water resources managers and decision makers.

We studied land cover changes over the last 30 years in various West African reference catchments, in order to provide reliable data and information on land use pattern and its change at catchment scale. The information is not only being used for hydrological modelling efforts to assess the impacts of such changes on runoff and evapotranspiration, but also to inform interested stakeholder, planers and decision makers on potentially immediate impacts at local and regional scale.

Case studies in Burkina Faso, Benin and Togo

Study Areas, Data and Methods

To assess land use distribution as well as changes in West Africa, our study has been conducted in three study basins in Burkina Faso (Massili Basin: 2.612 km²), Benin and Togo (Kara River Basin: 5.287 km², Binah River Basin: 1.044 km²). All study basins are located in the savannah ecological zone and characterized by a tropical climate with a rainy season from May/June to October with highly variable rainfalls and a dry season during the remaining period of the year. The mean annual rainfall varies between 700 mm and 900 mm in the Massili Basin while about 1250 mm were observed in the Kara and Binah Basins. The population in the region is mostly rural, thus relies on subsistence agriculture.

[1] University of Hamburg, Germany; 2 University of Abomey-Calavi, Benin; 3 University of Lome, Togo
Corresponding author: Dr. Jörg Helmschrot, Biocentre Klein Flottbek, University Hamburg, Ohnhorststr. 18, 22609 Hamburg, Germany, Ph/Fax: +49 40 42816 673/539,
Corresponding author: joerg.helmschrot@uni-hamburg.de

For the analysis and assessment of changes in land cover and land use, multi-temporal Landsat data sets covering selected periods over the previous 30 years were examined. A set of Landsat scenes was acquired for the Massili Basin representing the years 1990, 2002 and 2013. Landsat images were also selected for the Kara River Basin (1972, 1987 and 2000) and for Binah River watershed (1972, 1987 and 2013). All imagery was provided through the Global Land Cover Facility's (GLCF) website and the USGS LandsatLook Viewer. The land cover classification was performed using object-based image analysis which was supported by historic maps and field data. Post-classification change analysis was used to assess changes in land cover between different dates.

Results and Discussion

The analysis of the classification results clearly show that savannah vegetation dominated the landscape in all three study areas at the beginning of the respective time series. In 1972, 71 % of the Kara River Basin and 68 % of the Binah River Basin were identified as savannah vegetation and forest covered about 9 % and 16 % resp. A similar pattern was found for the Massili River basin at the beginning of the time series in 1990 when 69 % of the basin were classified as savannah, followed by farm and fallow land (22 %). Gallery forest (4 %), settlement (3 %), bare soil (1 %) and water bodies (1 %) were less dominant in the watershed (Fig.1).

In all the three basins, savannah has undergone severe changes, mainly due to agricultural expansion. In the Kara River Basin, the results show an increase in agricultural land from 19 % in 1972 to 26 % in 1987 and 43 % in 2000 while the area of savannah decreased to less than 45 % of the catchment in 2000. In the Binah River watershed, only 33 % of catchment remained as savannah in 2013, while agricultural land has significantly expanded from 15 % (1972) to 24 % in 1987 and 43 % in 2013 (Fig.2). Some smaller areas of cultivated land were converted to savannah which is caused by the common fallow agriculture. The land cover assessment for the Massili River Basin showed that between 1990 and 2002 about 33 % of savannah was converted to cultivated land which covered 54 % of the basin in 2002. At lower conversion rates, this trend was continuing to 2013 when 27 % of the watershed were identified as savannah and 59 % as agricultural area (Fig.1). However, the results indicate that the extensive cultivation of savannah started more than a decade later in the drier Massili Basin (Burkina Faso) compared to the two catchments in Togo and Benin.

Besides these large-scale land use changes, additional, but less dominant conversions were found in all three catchments. Those are either caused by ongoing degradation of forests or in some cases conservation efforts like reforestation (Badjana *et al.*, 2014, 2015). For example, vast awareness-raising campaigns of reforestation and projects of protected areas rehabilitation in Togo led to the reforestation of woody savannah which increased from 1,000 ha in 2002 to more than 3,000 ha in 2008 (MERF 2002, 2008).

As shown in all case studies, there is a significant conversion of vegetation especially savannah to agricultural land which is strongly related to the increase of population. In fact, during recent decades, there has been a significant population growth throughout the region (López-Carr *et al.*, 2014) leading to an increasing demand for food and energy. The expansion of agricultural land is the main strategy to secure sufficient food production, and the need for energy, i.e. mainly charcoal and firewood, notably adds to the devastation of woody vegetation. Although some recent case studies refer to the impacts of climate change on vegetation, the main changes in land cover are generally socio-economically driven, i.e. population growth and the associated demand for food and energy are the major drivers. Our results also reveal that the changes in land use have a similar spatial dimension in all catchments, but vary regarding the beginning of vast land conversion which confirms that land use changes are rather human-driven in these basins.

Implications for water resources and its management

Various studies have demonstrated that the transition of savannah to agricultural land, deforestation, thinning and overgrazing affects runoff generation. As stated by Li *et al.* (2007) for the Niger and Chad Basins, the hydrological response to large-scale land cover change is non-linear and exhibits a threshold effect, i.e. little impact on the water yield and river discharge can be observed as long as deforestation (thinning) percentage remains below 50 %. Any exceeding of this threshold is expected to significantly alter the runoff pattern. Li *et al.* (2007) simulated that a complete removal of savanna results in an increase in annual streamflow by 33–91 %. Similar results are presented by Cornelissen *et al.* (2013) who compared four model applications in the Ouémé catchment, Benin. They found that an expansion of cultivated area by 30 % will significantly increase discharge and, in particular surface runoff.

When transfering these findings to our reference basins, the loss of savanna exceeding these thresholds in all basins refers to significant changes in runoff generation during recent decades. As argued by Giertz *et al.* (2005) for the Aguima catchment (Benin), lower infiltration rates

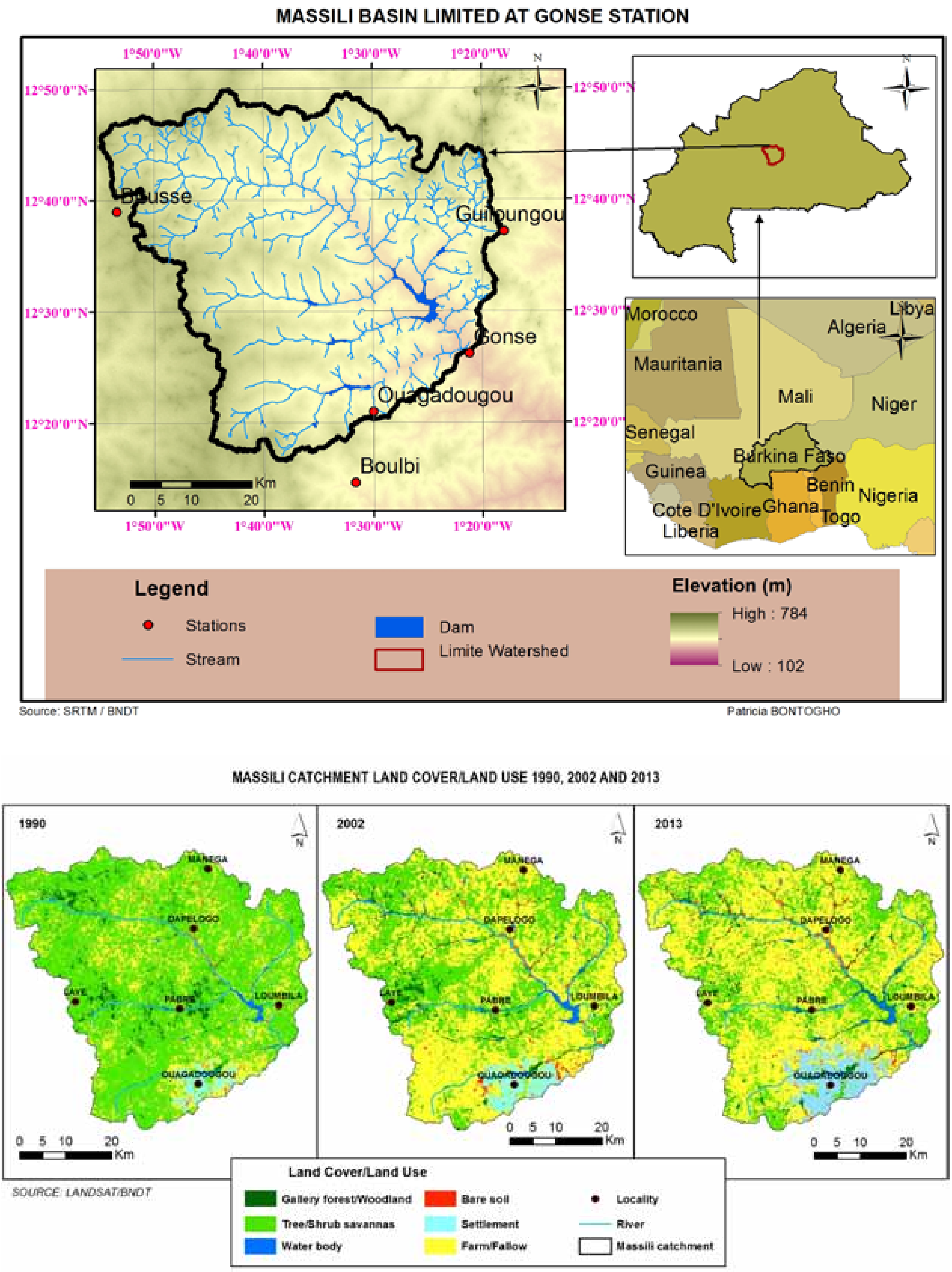

Figure 1: *Land cover change in Massili basin, Burkina Faso between 1990, 2002 and 2013.*

and altered storage capacities of the soils along with more intense rainfall events as found for the Massili Basin (Kabore/Bonthogo *et al.* 2015) may cause stronger surface runoffs on arable lands, and thus may support flood generation. On the other hand, given that this water is rapidly transfered through surface runoff, it will only shortly be available for agricultural purposes or domestic use. Thus, the establishment of small dams, the intensification of agricultural production as well as increasing land cultivation are strategies to ensure food production in West Africa (Sakurai, 2006). Since no significant increase in discharge was observed yet for any of the three basins, slightly decreasing rainfall, farm dams which have been recently established

Figure 2: Degraded savannah in the Binah River Basin in Togo (Photograph: Badjana, 2013)

along with agricultural expansion as well as a growing domestic water use seem to counteract increasing discharges over the previous 30 years (e.g. Kasei, 2009). However, little attention was given to other economic and environmental implications of these dynamics as for example the impact on yields and markets or investments in infrastructures like dam constructions or irrgiation schemes. Such developments underpin the need for integrated research taking these interacting dynamics into account, all in order to provide reliable information and assessments to assist decision makers and planners accordingly.

Conclusion and further needs

The observed changes in land cover and land use have many consequences on natural systems including the loss of biodiversity, the degradation of physical and chemical properties of soil, alteration of hydrological processes and the reduction in ecosystem productivity and services. Under the ongoing population growth, agricultural expansion and the vulnerability of the region to climate change, there is a need to develop and support integrated land and water resources managements plans in order to support future water security and food production.

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