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Assessment of land-cover changes in a sub-catchment of the Oti basin (West Africa): A case study of the Kara River basin

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With 4 figures and 5 tables

Abstract: This study is presenting results from the analysis of land-cover dynamics in the Kara River basin from 1972 to 2000 using remote sensing and geographic information system (GIS) techniques. Multi-temporal satellite images – Landsat MSS (1972), TM (1987) and ETM+ (2000) were processed using object-oriented classification and post-classification comparison methods. The classification results showed a good agreement with overall accuracies of 77.1% for 1972, 85.34% for 1987 and 88.22% for 2000, the respective Kappa statistics being 0.7, 0.81 and 0.85. Change assessment showed that the basin has experienced important changes in land cover with significant decrease in natural vegetation. Agricultural extension and deforestation appear to be the dominant driving forces. In fact, agricultural land has doubled between 1972 and 2000 by increasing from 19.45% to 43.59% of the total basin area while savannah decreased from 63.41% to 45.19%. Forest land increased by 1.63% from 1972 to 1987 but showed a decrease of 5.87% from 1987 to 2000, while woody savannah decreased by 3.59% and human settlements increased during the same period. The analysis of land cover transition showed that important changes have occurred between 1987 and 2000. The results of this study will be useful for follow-up research such as hydrological and landscape processes modelling in the basin but also many applications including the biomass assessment for greenhouse gases inventories, the REDD+ (Reducing emissions from deforestation and forest degradation-plus) project, the national programs for protected areas redefinition, vegetation resources conservation and sustainable land management, the vulnerability and adaptation studies etc. . Nevertheless, further investigation integrating climatic, hydrological, spatial statistics and socio-economic models would help to better understand and quantify the relationships between different driving forces and their contributions to the changes.

Zusammenfassung: Die Untersuchung zeigt die Veränderung der Landnutzung im Einzugsgebiet des Kara (Togo, Benin) zwischen 1972 und 2000 durch die Analyse von Satellitenbildern. Hierzu wurde die Landnutzung aus Landsat-Satellitenbildern für drei Zeitperioden (MSS 1972, TM 1987 und ETM+ 2000) mit objektorientierter Klassifikation er-

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fasst und die Veränderungen statistisch bewertet. Die Genauigkeit der Klassifikation betrug 77.1% für 1972, 85.34% für 1987 und 88.22% für 2000, die entsprechenden Werte der Kappa Statistik ergaben 0.7, 0.81 und 0.85. Die Differenzanalyse zeigt erhebliche Veränderungen der Landnutzung und hier insbesondere eine deutliche Abnahme der natürlichen Vegetation. Die Zunahme der landwirtschaftlich genutzten Fläche und Abholzungen wurden hier als wichtigste Ursachen für die Veränderungen identifiziert. Beim Ackerbau haben sich die Flächen zwischen 1972 und 2000 von 19.45% auf 43.59% des gesamten Einzugsgebiets verdoppelt, während Waldflächen zwischen 1972 und 1987 um 1.63% zunahmen und zwischen 1987 und 2000 um 5.87% und damit über den Gesamtzeitraum abgenommen haben. Eine vergleichbare Tendenz zeigt sich für die Baumsavanne, die im gleichen Zeitraum um 3.59% abgenommen hat, während Siedlungsflächen zunahmen. Die Analyse zeigt, dass die deutlichsten Veränderungen zwischen 1987 und 2000 in Erscheinung treten, was vor allem auf die Zunahme der Bevölkerung zurückzuführen ist. Die Ergebnisse dieser Arbeit liefern die Grundlage für Folgestudien, insbesondere im Bereich der hydrologischen Modellierung der Wasserressourcen im Untersuchungsgebiet, können aber auch zur Modellierung des Treibhauseffekts im Rahmen der REDD-Initiative (Reducing Emissions from Deforestation and Forest Degradation) sowie für nationale Programme zur Waldbestandsaufnahme oder der Ausweisung von Schutzgebieten, dem Schutz natürlicher Ressourcen, nachhaltiger Landnutzung und Studien zur ökologischen Belastbarkeit verwendet werden.

Keywords: Land-cover changes, driving forces, object-oriented classification, Kara River basin, West Africa.

Stichworte: Veränderung der Landnutzung, objektorientierte Klassifikation, Einzugsgebiet Kara, Westafrika

Introduction

Land cover and land use changes play an important role in the regulation of ecosystems functions (ESF) and services (ESS) for the global environmental change and management aims striving for sustainability (Cojoe 2007, Tan et al. 2011). In fact, changes in land use and land cover as well as land management practices play an important role in changing the carbon cycle and therefore the capacity of ecosystems to sustain food production, freshwater and forest resources availability (Foley et al. 2005). They can also affect regional climate and air quality through changes on net radiation on the one hand and the alteration of atmospheric conditions resulting from changes in emissions on the other hand (Foley et al. 2005). Furthermore land use and land cover changes have an effect on evapotranspiration (Mao & Cherkauer 2009), soil moisture content and infiltration capacity (Costa et al. 2003, Flügel 2011a), surface and subsurface flow regimes including baseflow contributions to streams (Tu 2009), groundwater recharge, surface roughness (Feddema et al. 2005), runoff (Helmschrot 2006) as well as soil erosion and nutrient transport (Steudel et al. 2013) through complex interactions among vegetation, soils, geology, terrain and climate processes (Flügel 2011b). Assessing and monitoring such changes is vital for the integrated land and water resources management (ILWRM). Defined as the coordinated planning and management of land, water, and other environmental resources for their equiTable, efficient, and sustainable use (Calder 2005), the ILWRM is an improved concept of the integrated water resources management (IWRM) widely accepted as the appropriate concept to strive for sustainable management of river basin water resources and to adapt to impacts of climate change (Flügel 2010). The ILWRM particularly recognize the specific inclusion of the land use and land management related aspects that are not strongly enough integrated into IWRM (Calder 2005) and thereby accounts for the hydrological process chain that is generating the quantity and quality of the different types of water resources that are subject to sustainable management in the river basin (Flügel 2010).

Remote sensing in combination with Geographic Information System (GIS) are widely recognized as well-established information technologies that provide potential means for understanding landscape dynamics but also for an effective planning and management of land and natural resources (Jensen 1996, Franklin et al. 2000, Bhagawat 2011). They have been extensively used in many land use and land cover applications including agriculture, forestry, hydrology and environment planning etc. For instance, Casa et al. (2009) used remote sensing and GIS to estimate the crop water demand in a plain where there was a lack of data on spatial crop distribution and their spatial and temporal water requirements. Their results contributed to fill an important gap in the implementation of sustainable water management policies in the agricultural sector in the region. Ngueguim et al. (2009) evaluated logging impacts on tropical rainforest fragmentation and canopy damage in Eastern Cameroon and in a related study, Sakthivel et al. (2010) assessed forest cover change detection with remote sensing and GIS techniques and concluded to their usefulness in forest restoration planning. By combining remote sensing and GIS to assess land cover changes and their patterns in the Volta Basin and Ghana Braimoh & Vlek (2004) could provide useful directives for environmental planning and sustainable soil management in the area. Furthermore, the integration of remote sensing and GIS techniques has been demonstrated to improve the confidence of the accuracy in a wide range of studies focusing on the modelling of catchment characteristics and hydrological processes (Helmschrot & Flügel 2002, Bhuyan et al. 2003, Costa et al. 2003, Krause 2002, Tu 2009).

The Oti basin is one of the sub-catchments of Volta basin (West Africa) where population is mainly rural and strongly depends upon land resources for subsistence agriculture and livestock breeding (UNEP-GEF 2012). During recent decades, variations in seasonal rainfall distribution, intensity and the duration of the dry season on one hand and the rapid population growth followed by deforestation, agricultural land extension or poor practices in general etc. on the other hand; have led to significant loss in soil and vegetation cover (Braimoh & Vlek 2004). In consequence, this impoverished the physical and chemical properties of soil, altered hydrological processes and led to the reduction in ecosystem productivity and services (UNEP-GEF 2012). Currently, there is still a lack of an integrated assessment of land cover and land use changes and their patterns over a long period within the basin.

The Kara River basin is one of the tributaries of the Oti River. As a result of population growth triggering increasing need of land for agriculture and settlements and need of wood for energy, the vegetation cover has undergone important changes in the Kara River basin, especially since 1990. Also, agricultural extension based on slash-and-burn and bush fires in the dry season contribute to losses in vegetation and soil qualities each year (Dantsey-Barry et al. 2007, UNEP-GEF 2012). At present, there is no study or statistics available on the land cover and land use changes in the basin.

Under the ongoing population growth and demand for food and income and the subsequent consequences on vegetation resources, there is a need of spatial explicit land cover and land cover maps for a better understanding of these dynamic systems, but also practical guidance towards a sustainable management of natural resources. Remote sensing and GIS are tools that can address this demand and provide information for stakeholders and decision makers.

Moreover, in a basin which appears to be vulnerable to climate change and where water scarcity problems become frequent in some areas and given the direct impact of land cover on hydrological processes, there is a clear need to understand and quantify the land cover changes throughout the basin in order to allow for an effective planning and integrated land and water resources management.

The present study addresses this demand by mapping the different types of land cover and land use in the Kara River basin on different dates and assessing their changes between 1972 and 2001.

Study area

The study is carried out in the Kara River basin at N'Naboupi, a subcatchment of the Oti River basin which itself is a subcatchment of Volta River basin (West Africa). The Kara River basin is located between longitudes 0° 30' and 1° 38'E and latitudes 9°15'and 10° 01'N (see Fig. 1) and covers an area of 5287 km2 covering Togo and Benin. Entirely within the interior savannah ecological zone, it is drained by the Kara River and its tributaries. The geology comprises Neoproterozoic to Paleozoic formations, Buem, Atakora and gneiss-migmatite units, and the basic and ultrabasic massifs (Tairou et al. 2012). Topography and soils are much diversified, consequences of the great diversity of environmental factors such as geological, petrographic and tectonic as well as geomorphologic factors (Faure 1986). The terrain includes hills with the maximum altitude reaching 782 m at Lama-Koumea, depressions, flat plains, plains and plateaus. The soils are ferralsols, leptosols, fluviosols and lixisols (Faure 1986).The climate is of tropical type with two seasons: one rainy season from April to October with high rainfall variations and one dry season on the remaining period of the year. The mean annual rainfall in the basin is 1250 mm with a standard deviation of 214 (Adjoussi 2000).

The population within the Kara River basin is about 460,000 inhabitants, mainly rural and strongly dependent on natural resources (RGPH 2010). The main land use is agriculture with extensive shifting cultivation, followed by livestock husbandry and fisheries. The main crops are yams, guinea corn, corn, rice, millet, and groundnuts. The last decades were characterized by a high population growth with an average rate 2.58% per year (RGPH 2010) which is causing a strong increase in population pressure on vegetation resources. Investigation on population growth showed that the population of Kara region which contributes to 86.88% of the total area of the basin has increased from 235,000 inhabitants in 1970 to 426,651 and 769,940 inhabitants in 1981 and 2010 respectively (Law 2008, RGPH 2010).

Methodology

Data

To analyse the changes in land use and land cover (LULC) over time in the study area, multi-temporal Landsat images (Table 1) were selected on three dates

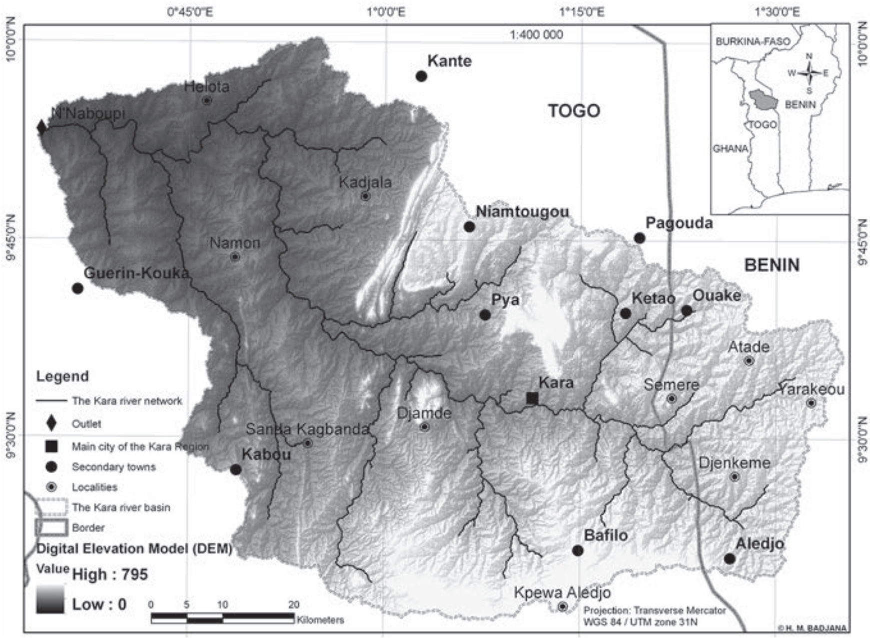

Fig. 1. Map of the Kara River basin.
Data source: Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) subset at 90 meters resolution, http://srtm.csi.cgiar.org/ and http://eros.usgs.gov/products/elevation/

Table 1. Landsat imagery used for the study.

Data type	Spatial reference (Path and row) of scenes	Acquisition date	Pixel resolution
Landsat MSS	207–053	10.11.1972	60 m
Landsat TM 5	193–053 and 193–054	30.10.1987	30 m
Landsat ETM+	193–053	4.12.2000	30 m

Landsat MSS = Landsat Multispectral Scanner, Landsat TM 5 = Landsat Thematic Mapper 5, Landsat ETM+ = Landsat Enhanced Thematic Mapper Plus.

The Landsat MSS images consist of four spectral bands while the Landsat TM and ETM+ consist of seven and eight spectral bands respectively, with one thermal infrared (band 6) and one panchromatic (band 8) especially for ETM+. All the bands were used during the classification, except the thermal and panchromatic ones.

depending on the temporal and spatial availability of the scenes. The selected periods are 1972, 1987 and 2000. Images have been acquired from the Global Land Cover Facility (GLCF), University of Maryland and U.S. Geological Survey LandsatLook Viewer.

In order to better distinguish the different vegetation classes, Landsat MSS and ETM images from 1972 and 1987 were selected between October and November, a transition period between the rainy season and the dry season and on which vegetation still remains active. For the year 2000, an image was selected in from December because of a limited availability of accepTable and cloud-free Landsat Enhanced Thematic Mapper Plus (ETM+) images.

The pre-processing of the data was not necessary because (i) a post-classification change detection was implemented and (ii) each of the classifications was performed separately based on specific training data.

In addition to the satellite images, existing maps of vegetation and topography as well as other field maps containing information on past and recent land use and land cover of different parts of the area were used for training and validation purposes. They were primarily collected from the National Mapping and Cadastre Services, libraries and the Mapping Service of the Research Institute for Development of France (IRD – Institut de Recherche pour le Developpement).

The field surveys comprised the collection of reference sites for different LULC classes by means of GPS (Global Positioning System) throughout the study area. In total, 206 reference points for 6 LULC classes, namely forest land, woody savannah, savannah, agricultural land, human settlements and water bodies (Table 2) have been sampled using a stratified random sampling method. The field surveys were accompanied with social surveys in order to be ensure that each recorded class was the same in 2000.

The classification scheme adopted is shown in Table 2 and was based on the West African vegetation classification system (Hahn-Hadjali et al. 2011) and the typical land cover classes defined on the national vegetation map.

Table 2. Classification scheme.

Land cover class	Description
Forest	Tree cover > 60%, generally closed woodland including riparian forest
Woody savannah	40 to 60% tree cover
Savannah	Tree cover < 40%, mixture of shrubs and grass with sometimes dominance of grass or shrub
Human settlements	Cities and villages, roads and other buildings
Agricultural land	Farms with crops and harvested croplands
Water	Rivers, inland waters and reservoirs

Methods

Classification

The methodological classification approach used in the study is a hybrid approach that combines both automated and manual methods to integrate our expert knowledge of the area. It has been implemented with ILMS*image* developed at the Department of Geoinformatics, Hydrology and Modelling of Friedrich-Schiller University of Jena, Germany. ILMS*image* is a remote sensing software component of ILMS (Integrated Land Management System), a modular software platform for an integrated assessment of complex environmental systems that integrates different modules for remote sensing, Geographic Information System and hydrological modelling. Based on a modular implementation as a QGIS plug-in, ILMS*image* offers functions for object-oriented image segmentation and classification in a user-friendly, step by step workflow (Kralisch et al. 2012).

Object-oriented classification based on image segmentation analysis is one of the innovative classification approaches. The image is subdivided into meaningful regions with broadly similar pixels or "cells" based on spectral properties as well as geometric attributes such as shape, texture, size and other features, and organizing them hierarchically into image objects or segments (Mather 2004, Jensen et al. 2009). It has the advantage of integrating more object-related features compared to pixel-based approaches, to speed up the processing and to reduce "salt and pepper" effects of classifications (Walker & Horning 2010, Jensen et al. 2009).

The overall classification procedure in ILMS*image* followed in the current study consists of the following three main tasks:

1. In the first step, the image is segmented into statistically homogenous and meaningful objects called cells or segments using a generic algorithm. This process is often called 'segmentation' and in the context of ILMS*image* 'cell creation';
2. In the second step, attributes or features such as color, size, shape, texture etc. are assigned to the delineated cells.
3. The third step is the process of thematic classification which include three sub-tasks:
   i. An unsupervised classification during which cells with broadly similar image features are clustered using *k-means*, one of the frequently used algorithms for self-organization.
   ii. The definition of reference classes which is needed in each classification. In ILMS*image*, a polygon shape or point shape is used to set up a suiTable class definition and classify other appearances of the defined class. While a polygon shape is used to combine various cells into a reference area, a point shape can be used to mark a single cell type or cluster as a reference area. In this work, point shapes were used because of the big size of the clusters. The reference class definition was based on existing maps available for the images recorded in 1972 and 1987, and ground truth points for the image on 2000. The integration of our expert knowledge of the area, the spectral plots and the Normalized Difference Vegetation Index (NDVI) (Tucker 1979) as additional information were integrated to reduce misclassifications, but also to overcome the influence of shadows and topography that sometime make certain vegetation features appear like two different classes. The NDVI is a numerical indicator that is obtained by subtracting the red reflectance values from the near-infrared and dividing it by the sum of near-infrared and red bands (Tucker 1979). Its values range from –1 to +1, with negative values corresponding to water, value around zero representing the soils and value between 0.1 and 0.7 the vegetation formations. Higher values represent dense green vegetation.
   iii. The actual thematic classification which is based on the results from the

clustering and the reference classes definition. In fact, the object classes are created by spatial combination of cluster cell type and by taking the created references areas as examples. The use of minimum object size has allowed excluding small cell combinations when classifying objects.

Accuracy assessment

Accuracy assessment can be defined as the evaluation of the level to which a map corresponds to 'real world' conditions. It is a key indicator on the quality of the classification product (Khorram et al. 2012). Since every thematic map contains errors, it is important to minimize these errors and inform the users about the confidence of the thematic information before being used in follow-up studies and decision making processes. In the current study, the accuracy of the classification products was assessed according to Congalton (1991), Stehman & Czaplewski (1998), Stephen & Foody (2009) by applying the error matrix also called the confusion matrix or contingence Table which is one of the most common method used in thematic classification accuracy assessment (Foody 2002, Khorram et al. 2012). An accuracy assessment consists mainly of three key components that are the sampling design, the response design, and the analysis and estimation protocols (Stehman & Czaplewski 1998). According to Stehman & Czaplewski 1998, the sampling design is the protocol of selecting a sample of individual pixels or polygons (depending on the representation of the map) considered as units of a population which is the area or region represented by the land cover map. The response design is the process of determining the ground reference of the sampling unit and assigning it a label that can be compared to the map label (Stephen & Foody 2009). Sources of ground reference data include ground truth points from field surveys, higher resolution satellite images, maps derived from aerial photo interpretation etc.

To assess the accuracy of the classified maps, a stratified random sampling is used by generating a minimum of 30 points per class, the number of points depending on the spatial extent of each class and compared with the ground reference data. The random points for the recent image (2000) were generated from the ground reference points acquired in 2000 in field surveys, the updated vegetation map of Togo in 2007 and raw image in 2000. For 1972 and 1987 the random points were generated from high resolution maps (in 1969 and 1989) and raw images that are useful in detecting water bodies, forest etc. (Congalton & Green 2009).

Land use and land cover changes analysis

After classification, all the three outputs were resampled into the same resolution for changes assessment (Serra et al. 2003). Changes in LULC have been assessed by post-classification comparison, one of the most widely applied approaches for LULC change detection (Yuan et al. 2005, Kumar & Kaur 2013). Post-classification comparison consists of classifying the rectified images independently with the same number and type of LULC classes and then overlaying and comparing the resulting LULC maps on a pixel-by-pixel basis. The result is a LULC map with statistics that can be summarized in a 'from-to' change matrix also called transition matrix (Jensen 2005). The comparison has been performed between the classification outputs of first 1972 and 1987, second 1987 and 2000 and finally between 1972 and 2000. The advantages of post-classification results comparison is the minimization of the effect of atmospheric and environmental disparity between input images (Khorram et al. 2012), thus radiometric normalization is not required (Warner et al. 2009).

Results and discussion

Classification accuracy

The overall classification accuracies for the three images are 77.17%, 85.34% and 88.22% respectively, with Kappa statistics of 0.70, 0.81 and 0.85 for Landsat MSS 1972, TM 1987 and ETM+ 2000 (Table 3). These values of Kappa show an agreement for the three classification results. Nevertheless, it can be seen that the producer's accuracy is low for water and human settlements, especially in 1972 (17.65% and 46.67% respectively). In fact, the water bodies that were present in the area at this time were only those from the Kara River and its small tributaries. The relatively small width of the river and the lower resolution of the Landsat MSS (60 m) make it difficult to identify the real water bodies and leads to confusion with their surrounding features like forests or savannahs.

Moreover, most of the human settlements, except Kara city which is the main town of the region, are generally rural with small areas. Thus, the small size of these rural cities which are generally surrounded by agricultural lands caused sometimes their mixture with the agricultural land which explains their low classification accuracy.

Also, we can find out from the error matrix shown in Table 3 that for the three dates, savannah has been classified as agricultural land or vice-versa. In the Kara basin, and this applies for Togo in general, some of the agricultural land is farm parklands which are croplands that are associated with trees and commonly called agro-forestry systems. The source of the misclassification can therefore be explained by the association of trees with crops which sometimes caused some agricultural lands appearing as savannah which is related to the relative high amount of trees that makes the area reflect as a natural vegetation of savannah.

Table 3. Classifications accuracies: PA = Producer's accuracy, UA = User's accuracy.

	1972		1987		2000	
	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)
Forest	85.48	74.65	84.91	69.23	92.16	78.33
Woody savannah	83.87	98.11	79.63	93.48	93.88	93.88
Savannah	93.23	68.51	94.53	82.88	95.93	88.06
Agricultural land	75.96	79	85.19	87.62	93.55	89.23
Human Settlements	46.67	100	75.68	100	77.5	91.18
Water	17.65	100	72.22	100	31.03	100
Overall accuracy	**77.18**		**85.34**		**88.22**	
Kappa statistic	**0.7**		**0.81**		**0.85**	

Land cover and land use changes

The classification results, however, show that the most dominant vegetation type is savannah (Fig. 2, Table 4) which well agrees with the ground truth information as well as information found in the literature. It can also be noticed *a priori* that the increase in agricultural land constitute the most important change that has occurred in land cover (Fig. 2).

Estimations show an increase in the proportion of agricultural land from 19.45% in 1972 to 26.93% in 1987 and 43.6% in 2000 while the proportion of savannah decreased from 63.41% in 1972 to 53.91% and 45.19 in 1987 and 2000 respectively (Table 5). Also the proportion of woody savannah decreased from 7.69% in 1972 to 7.15% in 1987 and 4.09% in 2000 while human settlements increased from 0.39% in 1972 to 0.78% in 1987 and 1.75% in 2000. Moreover, forest land which increased from 9.05% to 11.13% in 1987 has decreased to 5.27% in 2000 (Table 5). The land cover transition maps (Fig. 3) show that only a little space remains untouched by human influence.

The decrease in savannah and woody savannah is the consequence of the extension of agricultural land as it is shown in Figure 3. In fact, the main socio-economic activity in Kara basin is agriculture which is of subsistence and generally extensive (Djagni 2003). The increase in population during recent decades has obviously led to the transition from savannah to agricultural land, all in order to satisfy the increasing needs of population for food. This transition is also reflected by the change matrix which shows that 15.97% of the savannah land in 1972 was transformed to agricultural land in 1987 of which 21.49% became agricultural land in 2000. Altogether 27.96% of savannah has been transformed to agricultural land between 1972 and 2000 (Table 2). Djagni (2003) found that agricultural practices still remain extensive despite the dense mentoring in 1970s and 1980s. He reported that these extensive practices associated with strongly increasing population growth led to environmental degradation. According to Djagni (2003), fertilizers are not used sufficiently by farmers to compensate the loss of nutrients extracted by crops from soil. In case they are used, chemical fertilizers are more dominant than organic compost while harvest waste are burned

Table 4. Summary of the areas of different classified land-cover classes.

		Area in km^2		
		1972	1987	2000
Land cover classes	Forest	478.48	588.52	278.6
	Woody savannah	406.38	378.04	216.38
	Savannah	3352.52	2850.44	2389.32
	Agricultural land	1028.37	1423.96	2304.87
	Human settlements	20.67	41.33	92.37
	Water	0.590	4.70	5.46
Total		5.287	5.287	5.287

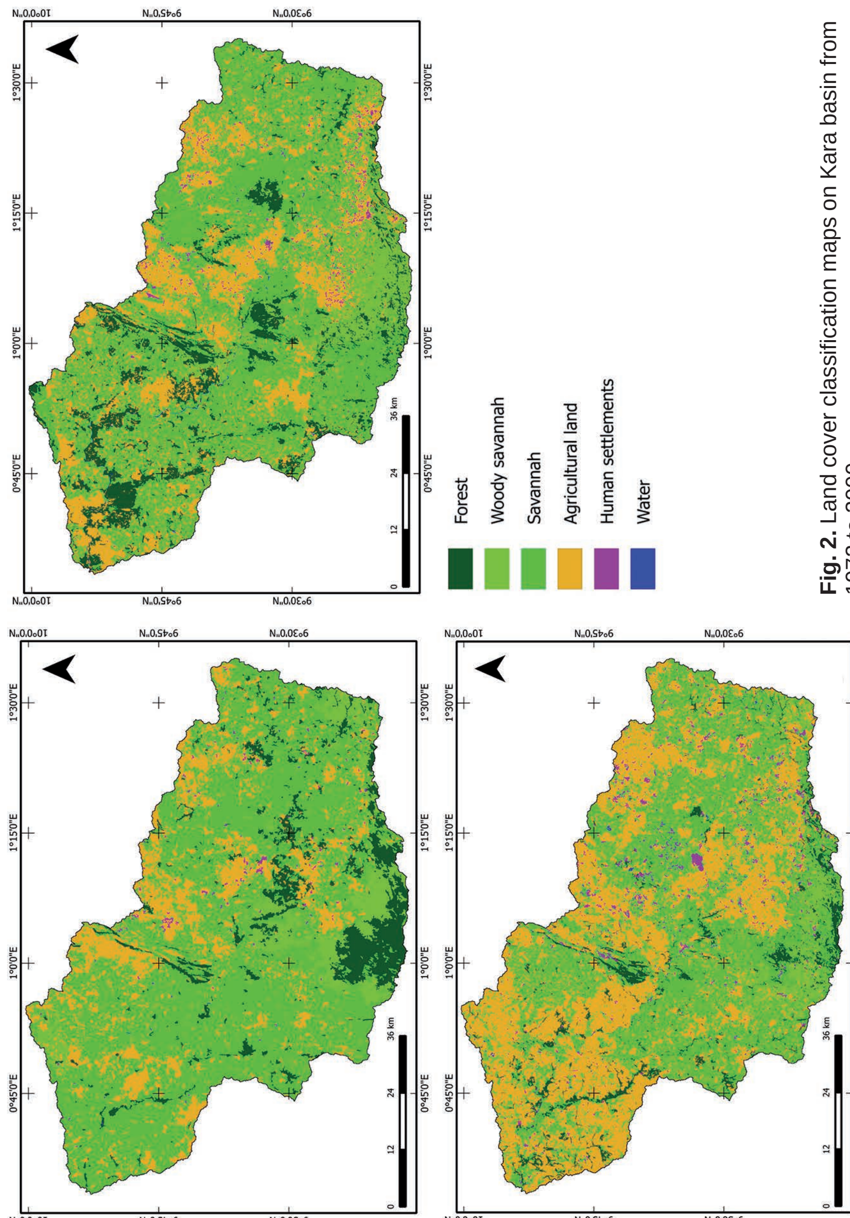

Fig. 2. Land cover classification maps on Kara basin from 1972 to 2000.

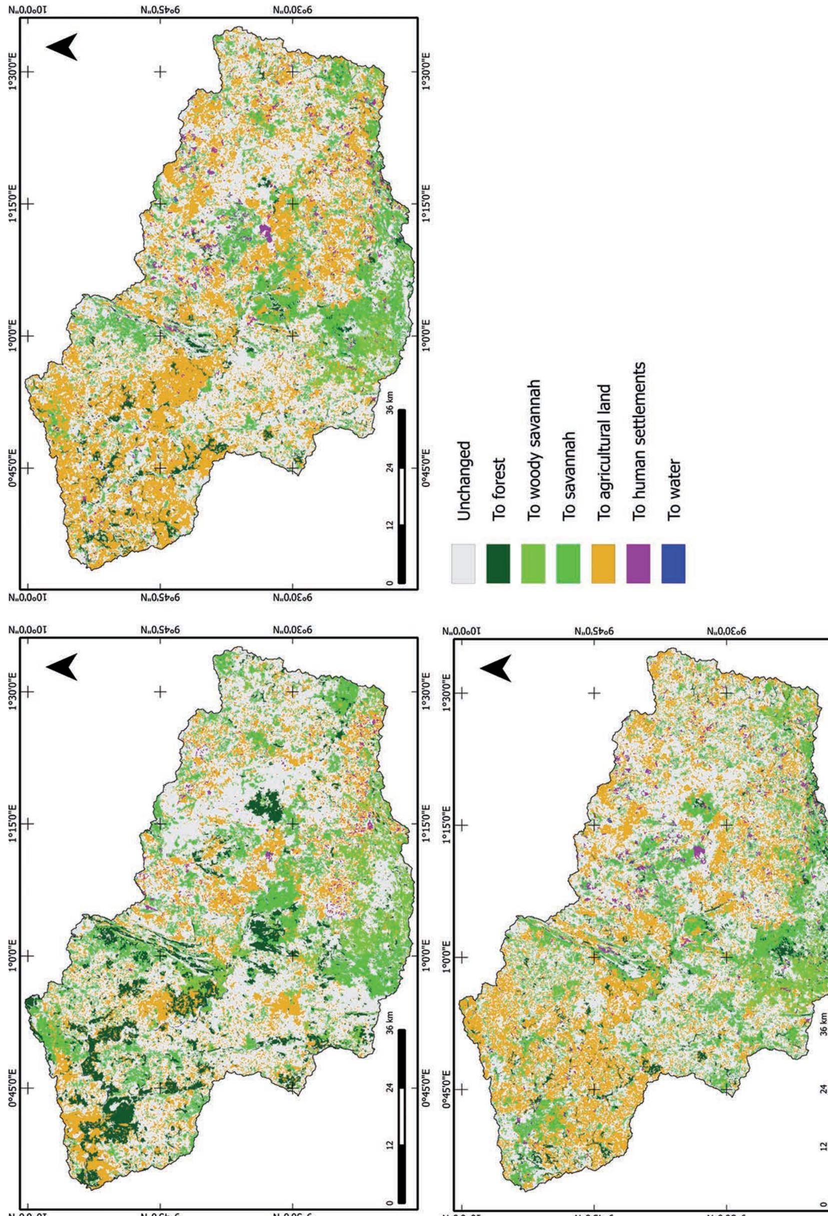

Fig. 3. Land cover transition maps.

or exported for household uses. This exploitation of soils leads to the reduction of soil fertility and consequently in the reduction of crop yields (Djagni 2003) which in turn motivates farmers to adapt to lower crop yields by extending their farms and thereby increasing the pressure on natural vegetation.

Although an important part of natural vegetation has been converted to agricultural land; some of these agricultural lands however have changed to savannah from 1972 to 1987 as well as from 1987 to 2000 (Table 5). This agricultural land transformation to vegetation can be explained by the influence of shifting cultivation and fallows systems (Djagni 2003, MAEP 2003).

The decrease in vegetation cover did not affect only the savannah but also the woody savannah and the forest especially from 1987 to 2000. In fact, 5.37% of forest land in 1987 has been converted to savannah and 3.45% to agricultural land in 2000 while 3.32% and 1.14% of woody savannah were transformed to agricultural land on the same period. The decrease of these vegetation types from 1987 to 2000 is a consequence of deforestation for mostly domestic fuel or charcoal production, but also to establish agricultural fields. For instance, the Sirka forest (9° 32’ 48.26’’ N and 1° 16’ 52.46’’ E) has been heavily destroyed for charcoal and fire wood production and currently remains in the form of a small island. It is also important to mention the socio-political problems that the country witnessed from 1990s which led to the loss of government control over protected areas.

According to a study on the strategy of biodiversity conservation in Togo, the Kara region has been identified among the three of the 5 regions in Togo where vegetation degradation has accelerated with the increasing demand of firewood and charcoal. With an estimated mean annual consumption 347 kg/person for firewood and 59 kg/person for charcoal, both products are the main sources of energy for 80% of the population (MERF 2003). In addition to the causes related to energy, softwood lumber manufacturing has also been identified as an important cause for vegetation degradation. Its relevance has significantly increased with the introduction of chainsaws which continuously replaced traditional tools such as machetes and axes since 1975 (MERF 2003).

Moreover, the deforestation is aggravated to slash-and burn agriculture management and the increasing practice of rural irrigation and off-season farming that sometimes involves the destruction of gallery forests (Diwediga 2012). In fact, the soils impoverishment during recent decades and the consecutive low yield products drive people towards river banks which are generally fertile but also allow for two farming seasons, one during the normal rainy season and the second one during dry season on river banks with local irrigation. Driven by the variance of rainfall distribution which sometimes generates the flooding of the river banks, there is an increasing practice of off-season farming which consists of ploughing on river banks based waters withdrawn from the river. The crops will benefit from the flooding until the harvest. Since this practice has produced good yields, the destruction of riparian forests is increasing.

Even if the losses in vegetation are mainly due to human activities, the climate influence can not be neglected. Recent decades have been characterised by a high spatio-temporal variation of rainfall, causing a shortening of the rainy season and an increase in temperature (MERF 2009, Badjana 2011). These changes obviously influence the vegetation development by reducing the vegetation period and increasing its vulnerability to bush fire.

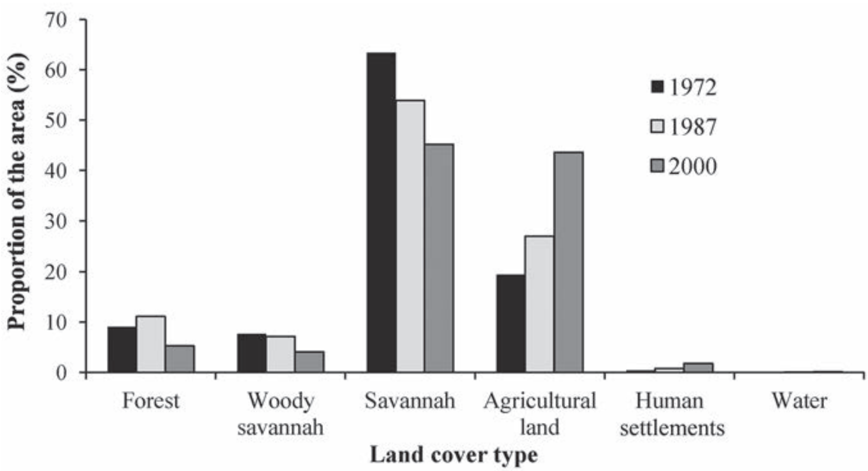

Fig. 4. The proportions of different land cover classes from 1972 to 2000.

As shown in Figure 4 between 1972 and 1987, a slight decrease in woody savannah and an increase in forest land can be observed. These changes can be explained by the reduced population numbers and relatively less human influence in these areas. Also the protection of natural resources especially protected areas by public administration was more rigorously enforced.

Since the human influence was less, the natural succession of vegetation may also have contributed to the changes. In fact, savannah can gradually be transformed to woody savannah which can itself be transformed to forest if the ecosystem I not disturbed by human activities. Analysis of transition matrix shows that 6.99% of savannah was transformed to forest and 2.21% to woody savannah between 1972 and 1987 (Table 5).

Human settlements, which have been underestimated due to their small sizes and therefore are misclassified as agricultural land, showed an increase over the three periods and even doubled from 1987 to 2000 (Table 4). Such an increase is also resulting from population growth during recent years which led to the sprawl of both rural and urban areas throughout the basin. According to the last population census in Togo, population density has increased from 37 to 66 inhabitants per square kilometre from 1982 to 2010 with an urbanisation rate of 24% in Kara region in 2010 (RGPH4, 2010).

As far as water bodies are concerned, their small size makes it difficult to accurately assess their changes. A better assessment will therefore require high resolution satellite images.

Conclusion

The use of object-oriented analysis of remotely sensed data and GIS techniques allows for classifying LULC at good accuracies and assessing LULC changes in the Kara River basin where statistics on land-cover evolution were lacking.

Table 5. Land cover and land use change transition matrix.

From 1972 to 1987 (Change in % of overall area)		1987					
		Forest	Woody savannah	Savannah	Agricultural land	Human Settlements	Water
1972	Forest	1.89	2.26	3.91	0.96	0.03	0.01
	Woody savannah	1.06	2.41	3.48	0.75	0	0
	Savannah	6.99	2.21	37.79	15.97	0.34	0.06
	Agricultural land	1.18	0.28	8.61	8.98	0.39	0.01
	Human Settlements	0	0	0	0.26	0.11	0.02
	Water	0	0	0	0	0	0.04
From 1987 to 2000 (Change in % of overall area)		2000					
		Forest	Woody savannah	Savannah	Agricultural land	Human Settlements	Water
1987	Forest	1.78	0.37	5.37	3.45	0.13	0.03
	Woody savannah	1.14	1.43	3.32	1.14	0.08	0
	Savannah	1.85	2.09	27.75	21.49	0.69	0.04
	Agricultural land	0.49	0.2	8.51	16.94	0.77	0.02
	Human Settlements	0	0	0.18	0.52	0.08	0
	Water	0.01	0	0.04	0.02	0	0.07
From 1972 to 2000 (Change in % of overall area)		2000					
		Forest	Woody savannah	Savannah	Agricultural land	Human Settlements	Water
1972	Forest	1.88	1.22	4.1	1.7	0.13	0.01
	Woody savannah	0.54	1.72	3.62	1.69	0.1	0.01
	Savannah	2.59	1.1	30.69	27.96	0.95	0.06
	Agricultural land	0.25	0.05	6.61	11.99	0.54	0.02
	Human Settlements	0	0	0.12	0.24	0.03	0
	Water	0	0	0	0	0	0.08

The results demonstrate that the basin has experienced noTable changes in LULC between 1972 and 2000. One of the important driving forces of the LULC changes is the extension of agricultural land which increased from 19.45% of the basin's size in 1972 to 43.56% in 2000. At the same time, the vegetation cover including savannah which is the dominant vegetation type, woody savannah and forest has significantly decreased. This reduction in vegetation cover reflects the devastating human impact through agricultural extension or bad practices, and deforestation for firewood and charcoal production as well as softwood lumber manufacturing. These land cover changes are supposed to cause a loss in biodiversity, the increase in soil erosion and sediment transport, river silting, a reduction in forage production service, the alteration in hydrological processes in general etc.

Under the current situation of changing climate and the generally high vulnerability of the region due to the strong dependence of the population on natural resources, an urgent development and implementation of measures to reduce the rapid vegetation degradation are required as a prerequisite for a sustainable ILWRM, an appropriate option to better adapt to climate change impacts. Some of these measures could be a better regulation and control of agricultural practices and vegetation resources conservation policies, a raising awareness of the local population and their integration in the management and conservation of land and water resources, the improvement of farming practices in intensively and extensively used agricultural fields or a wider access of the rural population to renewable energies.

This study provides useful information for other applications such as hydrological processes modelling in the basin but also for environmental planning and natural resources conservation policies. Nevertheless, further investigations need to be carried out to better understand and quantify the relationships between different driving forces. This calls for the integration of spatial statistical and socio-economic models.

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