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Land Cover Dynamics in Wa Municipality, Upper West Region of Ghana

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Abstract: Land cover change is pervasive in urban areas and can destabilise the ecosystem with negative consequences. To manage land effectively and to protect its cover, there is the need for a reliable inventory. GIS and remote sensing technology has become a standard in producing land cover maps worldwide. Therefore, in this study GIS and remote sensing was used to map the land cover of Wa Municipality of the Upper West Region of Ghana. Two Landsat 5 images of 1986 and 2011 were used. The images were pre-processed, subset to the study area and classified using the maximum likelihood classification algorithm. The map accuracies for the classes of interest; built-up, bare land and vegetation were not less than 70%. The land cover maps generated indicated that built-up area has increased by 34% whiles total size of bare land has increased by 47% from 1986 to 2011.These increases have reduced the total area of vegetated land by 10%. Therefore, if the current rate of degradation is not controlled, biodiversity of Wa and its surrounding areas would be lost in the near future. Also the degradation can intensify floods and droughts and other effects of climate change. The current study has demonstrated the effectiveness of GIS and remote sensing in studying environmental changes taking place in semi-arid regions. The application of remote sensing technologies should be intensified especially in the developing world to continue to provide vital data needed to manage the environment in a sustainable manner.

Keywords: GIS, land cover, landsat, remote sensing, wa

INTRODUCTION

Land cover change continues to destabilise the ecosystem despite growing evidence in changes in the climate such as erratic rainfall pattern and its consequential flooding in many cities globally (Weaver, 2003). Land cover change is pervasive and the cumulative effect at the global scale disturbs the ecosystem functioning (Lambin *et al.*, 2001). Thus land cover change continues to present a dilemma for Governments and stakeholders of the ecosystem because, on one hand many land use practices such as farming and expansion of settlements are necessary for the survival of mankind. On the other hand, some of the land use practices damage the life-supporting ecosystem (Foley *et al*., 2005). Increasing population, migration in search of greener pastures in urban centres, urbanisation and expansion of agricultural frontiers through slash and burn farming practices still make land cover change a very dynamic and difficult issue to solve (Robson and Berkes, 2011; Rudel *et al*., 2005; Wilbanks and Kates, 1999; Carlson and Arthur, 2000). The frequency and the dynamics in land cover couple with the need to monitor the ecosystem balance make land cover research very relevant despite numerous researches on the matter (Lambin *et al.*, 2001; Robson and Berkes, 2011; Rudel *et al*., 2005; Briamoh, 2006; Park *et al.*, 2005; Pabi, 2007; Pontius *et al.*, 2004). The changes in land cover partly determine the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson *et al.*, 1995) such as flooding, drought, migration and land conflicts. Wilbanks and Kates (1999) is of the view that due to the complex nature of land cover change and its effects, a cross range of disciplines, linking the local and the global scale integrating issues of culture, population, economy and the feed-back effects of climate change helps in deeper understanding of land cover change. The current dynamics in the land cover has been explained (Lambin *et al*., 2001) from different but interrelated viewpoints with the needs of mankind at the centre of the changes. Some explained it in terms of uneven distribution of job opportunities compelling people to migrate to urban areas in search of jobs thus increasing the dynamism of urban land cover. The land cover change is also explained in terms of energy for domestic and local food industries. Many people in the urban centres of Northern Ghana use

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fuel wood which is sourced from woodlands and forests in the rural and peri-urban areas for their domestic energy needs. This is so because alternative energy such as Liquefied Petroleum Gas (LPG), kerosene and electricity is either expensive or unreliable in terms of supply. High demand for fuel wood in urban areas makes fuel wood harvesting a major economic activity in some rural communities (Aabeyir *et al*., 2011) which also keeps changing the land cover of such communities. The expansion of agricultural frontiers is looked at from the resources of farmers and market opportunities for farm produce. Lack of resources to improve soil fertility of existing farms compels farmers to clear new farms in forests and woodlands which are more fertile than existing farms. Rudel *et al.* (2005) explained that areas that have the capacity to export food to urban areas and gain from the exportation experience expansion in farm sizes. The increasing warnings of eminent food insecurity is enticing investment in food crop farming in the rural and peri-urban areas which leads to expansion of farms and clearing of woodlands and forests for new farms (Rudel *et al*., 2005).

Wa Municipality is one of the urban areas in Ghana that has seen a significant increase in population in the past 12 years partly due to the establishment of the Wa Polytechnic and the University for Development Studies. These institutions have attracted investors in the hospitality and real estate sectors who compete with other interest groups and individuals for land. The above has contributed greatly to making the municipality one of the fastest growing communities in Ghana. This is a source of worry from the ecosystem point of view. In the Municipality, land cover change is greatly shifted towards the expansion of settlements and other physical structures at the expense of natural vegetation. It is not surprising that Datta and Sarkar (2010) noted that development in many resource-dependent countries has been synonymous with degradation of their natural resources.

The importance of the vegetative cover in keeping the balance in the ecosystem is usually downplayed. Currently the trend in the physical development in the municipality is to clear trees and build without any consideration of replacement of trees to maintain the balance in the ecosystem. However the situation is disturbing because the long term effects are expensive to reverse. As noted by Wilbanks and Kates (1999), land cover changes at the local scales contribute to global changes and are affected by them.

Assessing the spatio-temporal dynamics of land use/land cover change is the first step in developing strategies for effective environmental management and land use planning. Therefore this study was conducted in November 2011 to assess the land cover dynamics of Wa Municipality in Ghana.

MATERIALS AND METHODS

Study area: Wa Municipality is one of the nine municipal assemblies that make up the Upper west region of Ghana. The Municipality shares administrative boundaries with Nadowli District to the north, the Wa East District to the east and the Wa west district to the west. The Municipality lies between latitudes 9º50′ N to 10º20′ N and between longitudes 9º40′ W and 10º15′ W (Fig. 1). It has an area of approximately 234.74 km^2, about 6.4% of the area of Upper West Region. The climate of Wa is made up of long dry season and short raining season. The dry season is normally from November to April while the remaining months experiences the raining season with its peak in August and September. The dry season records high temperatures ranging between 40-45ºC in the months of March and April. Total annual rainfall in the area ranges from 910 to 2000 mm with an average humidity of 95 mm.

The vegetation cover of the area is guinea savanna woodland, which is made up of grasses and tree species such as *Butylosternum Paradoxum* (Shea tree), *Parkia biglolosa* (Dawadawa), *Adansonia Digitata* (baobab), *Anarcadium occidentale* (cashew), *Acacia*, Ebony, Neem and Mango among others. There is a marked change in the plant life of this vegetation zone during different seasons of the year. The vegetation in this area is thus open and dominated by short grasses. In the wet season, the area looks green and in the dry season, the grass dries and most of the trees shed their leaves and prone to bush fires. Human activities such as firewood harvesting, charcoal burning, farming, quarrying, construction etc. are all combined to modify the natural environment.

The Municipality lies in the Savanna high plains, which generally, is undulating with an average height between 160 and 300 m above sea level (Fig. 1) and has two main drainage systems, Sing-Bakpong and its tributaries to the South and Billi and its tributaries to the North. The streams dry up during the long dry season thereby reducing available water for agriculture, domestic, industrial and construction users. Currently (2011) the population of Wa is approximately 127,284. This constitutes l.6% change over estimated population for 2006 and gives a population density 542 person/km^2 compared to 509 in 2006.

Data collection: The research was based on two Landsat 5 images for January 18, 1986 and February 8, 2011 and field data obtained in November 2011. The fieldwork consisted of the following activities: visual identification of training and test classes, determination of sample point classes and measuring of their coordinates using Global Position System (GPS).

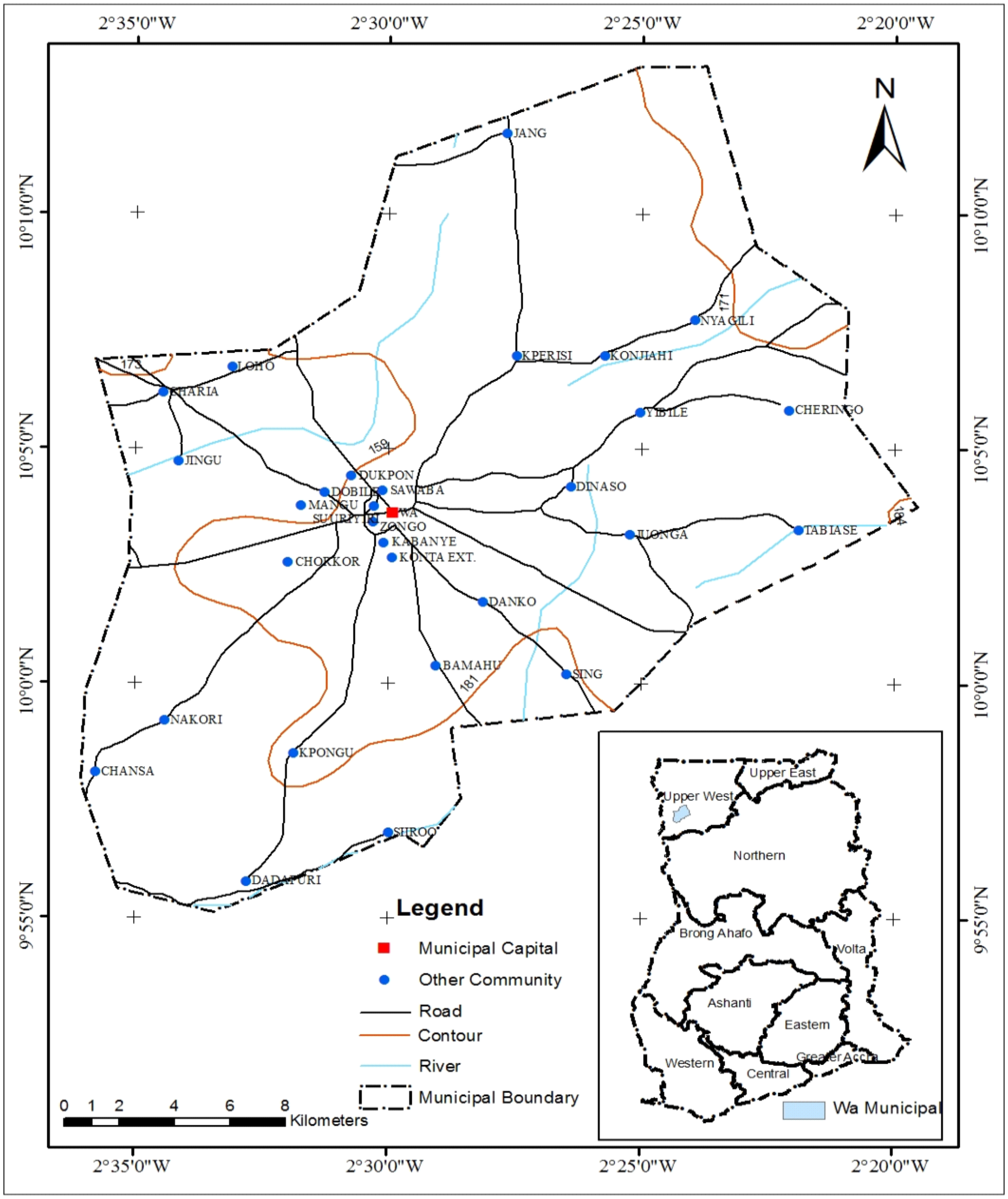

Fig. 1: Map of ghana showing the location of the study area

Image pre-processing: Pre-processing was executed to correct for errors in measured reflectance due to changes in the electromagnetic radiation recorded by the Landsat 5 sensor (Lunetta and Elvidge, 1999). The images were already orthorectified, therefore they were not geo-referenced. However, since the study area is smaller than the Landsat scene, sub-setting was done to limit the image to the boundaries of Wa Municipality. This was done in GIS by using the map of Wa as the area of interest.

Image classification: Classification of the remotely sensed images was executed to convert the digital numbers to real world thematic classes (Campbell, 2002). The objective of image classification was to categorize each image pixel according to the classes they represent on the ground. The spectral pattern within the remotely sensed image was the basis for the categorization (Lillesand and Kiefer, 1994). The images were classified into (7) classes initially using the maximum likelihood classification algorithm. These classes were woodland, shrubs, forest, built-up, water, bare land and rock. The 7 classes were merged into 4 broad classes: vegetation (forest, woodland and shrubs), built-up, bare land (bare land and rocks) and water. This is because the objective of the study was to study changes that have occurred between vegetation, bare land and built-up areas. Therefore details of vegetation types are not necessary for the study. Accuracy assessment of the current land cover map (i.e., 2011) was carried out using part of the field data. The over all accuracy as well as the mapping accuracy for each land cover was computed using the confusion matrix generated.

Land cover change detection: Land cover Change detection is a process of determining changes in the land cover between two time lines. This is achieved by comparing images of the same geographic location acquired in different dates. There are two broad categories of change detection techniques; post classification and pre-classification techniques (Lunetta and Elvidge, 1999). Post classification schemes are based on the differences between classified images (land covers) of different dates. The method relies on accurate registration of the images to the same coordinate and projection systems. However, since the images were classified independently there is no need to do atmospheric correction (Song *et al*., 2001). The need to achieve acceptable classification accuracies for each image is therefore important though it is often not possible to obtain accuracy estimates for images captured in the past. On the other hand, pre-classification change detection methods focus on spectral changes between images of different dates. This also requires that the images be co-registered accurately. Many pre-classification and post classification change detection techniques have been developed. Lunetta and Elvidge (1999), Lu *et al*. (2004) and Coppin *et al*. (2004) described in detail these methods and their relevance. Post classification comparison was applied in this research on the basis that it generates more accurate results than the pre-classification technique. Lu *et al*. (2004) and Coppin *et al*. (2004) are of the view that the method generates accurate results and is widely used.

GIS in change detection: The land cover maps generated after image classification were overlaid on each other and the change map between 1986 and 2011 extracted using GIS spatial analysis techniques. This was done based on an assumption that the land covers in 1986 are the same as those in 2011, only that their sizes might have changed. The change map was therefore used to compute areas of land cover that changed and those that did not change over the 25 year period. Also areal statistics of the individual land cover maps for 1986 and 2011 were calculated and compared. This represents a direct comparison without any consideration of the direction of spatial change.

RESULTS AND DISCUSSION

In Table 1 the confusion matrix generated from the land cover classification for 2011 is presented. The overall accuracy of the land cover map was 68%. Smaller overall classification accuracy suggests that the land cover classes exhibit similar spectral patterns and in such situation separability is often difficult. For instance the spectral signature of bare land and built-up areas are similar and were difficult to map. Therefore, the mapping accuracy, an indication of the accuracy of mapping each cover class is also presented. The land cover classes of interest, i. e. built-up and vegetation were mapped with accuracies not less than 70% (Table 1). This gives credence to the method adopted in mapping the land cover for 2011. The accuracy assessment for the 1986 land cover was not carried out since ground truth data was not available. Furthermore, in Fig. 2 and 3 land cover of 1986 and 2011 as well as land cover changed map (1986 to 2011) are presented respectively. Also in Table 2 and 3, land cover statistics and land cover change statistics are presented respectively:

$$Over\ all\ accuracy = \frac{(5+20+28+31)}{123} * 100\% = 68.29\% \quad (1)$$

It can be observed from Fig. 2 and Table 2 that the built-up area has increased by 34% from 1986 to 2011, a considerable increase. It is also clear from Fig. 3 and Table 3 that most of the new built-up area was taken from land that was previously bare. Also vegetated land has reduced considerably within the period. Most of the vegetated land has been converted to bare land (Fig. 2 and 3 and Table 3) increasing the total size of bare land by 47% (Table 2). The total reduction in vegetation size is however nearly 10% (Table 2). Nonetheless, in Fig. 2 and Table 3, it is interesting to note that some portions of the bare land in 1986 have been vegetated in 2011. A total of 47 km^2 of vegetated land has been added, more than 53% of the original bare land (Table 2). Also small areas of water and built-up have been converted to vegetation but these increases are not significant. Hence, the overall bare land has increased while vegetation has reduced (Fig. 3).

The above statistics indicates the presence of a disturbing phenomenon since conversion of vegetation to

Table 1: Confusion matrix for February 8, 2011 image

		Ground truth					Mapping accuracy
		Water	Bare Land	Builtup	Vegetation	Total	(%)
Land	Water	5	0	0	0	5	45.45
Cover	Bare Land	0	20	1	8	29	51.28
Map	Builtup	5	5	28	1	39	84.85
	Vegetation	1	14	4	31	50	77.50
	Total	11	39	33	40	123	

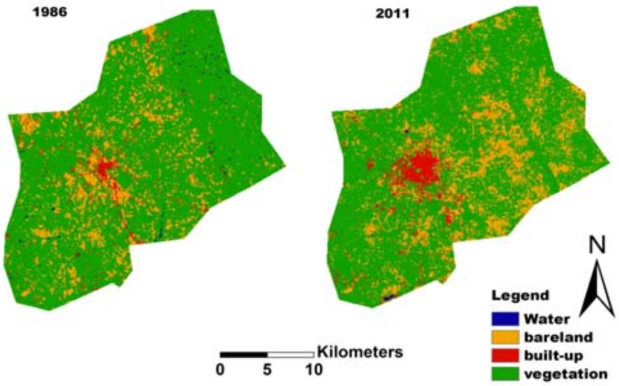

Fig. 2: Land cover (1986 and 2011)

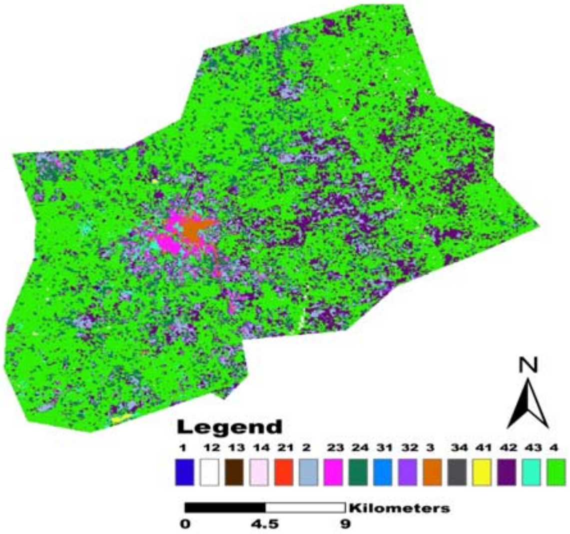

Fig. 3: Land cover changed map (1986-2011) 1: water (unchanged); 12: water to bareland; 13: water to built-up; 14: water to vegetation; 21: bareland to water; 2: bareland (unchanged); 23: bareland to built-up; 24: bareland to vegetation; 31: built-up to water; 32: built-up to bareland; 3: built-up (unchanged); 34: built-up to vegetation; 41: vegetation to water; 42: vegetation to bareland; 43: vegetation to built-up; 4: vegetation (unchanged)

Table 2: Land cover statistics

	Area (km^2)		
Land cover	1986	2011	% change
Water	3.40	0.46	-86.54
Bare land	88.09	130.06	47.64
Built-up	20.05	26.89	34.15
Vegetation	465.92	420.05	-9.84
Total	577.46	577.46	

bare land brings with it many negative environmental consequences. These include loss of productive agricultural lands through erosion, decrease in local albedo resulting in increased local temperatures (Aduah *et al*., 2012) and high evaporation rates which also dries the soil. The conversions of vegetated to bare land can also result in increased stream flows and subsequent siltation and drying of streams and dug out dams. It is

Table 3: Land cover change statistics (1986 to 2011)

Land cover	Area (km^2)
Water	0.043
Vegetation	366.603
Bareland	30.843
Built- up	5.072
Water to bareland	0.419
Water to vegetation	2.049
Bareland to water	0.009
Bareland to built-up	9.569
Bareland to vegetation	47.266
Bulit -up to water	0.001
Bulit-up to bareland	5.163
Bulit-up to vegetation	8.976
Vegeation to water	0.401
Vegetation to bareland	89.587
Vegetation to built-up	11.198
Total	577.456

interesting to note that most of the added built-up areas were taken from bare lands, however, the rate at which the built-up area is increasing (0.27 km^2 per year) mean more vegetated areas will be removed in the future.

The above statistics also indicates the need for extra effort to actively protect the current vegetation and also to implement re-aforestation plans within the Wa Municiplality. The slush and burn agriculture as well as charcoal production would have to be monitored more closely if the Municipality is to protect the land from further degradation. It disturbing to mention that creation of bare lands is the beginning of desertification.

Unmanaged land use change in Wa Municipal (Fig. 4) can therefore intensify effects of climate change and worsen the plight of the local people most of whom are subsistence farmers. The causes of the massive land use change between 1986 and 2011 are partly due to anthropogenic causes (urbanisation, expansion of agricultural and commercialisation of charcoal production) and climate change. For instance, the significant urbanisation can be attributed to the establishment of the Wa Polytechnic and the University for Development Studies which have attracted a lot of people into the municipality.

The current study has demonstrated the effectiveness of GIS and remote sensing in studying environmental changes taking place in semi-arid regions. Studies (Runnström, 2000; Dixon *et al*., 1996) have concluded that the vegetation of the semi-arid regions is disappearing at a rate that can result in desertification in the long term. It is also important to note that rainfall patterns have changed over the study area since the 1980s. The average intensity and duration of rainfall have changed and could also be contributing to the changes in the land cover. The success of the study is a proof of the need to use more current satellite imagery and computer technology to study the landscape since it is more cost effective compared to field based techniques. However, using satellite images for studies in the tropics are often limited by cloud and haze cover. Also the temporal and spatial resolution can be problematic. In the present study, the images selected were of the dry season and had no clouds.

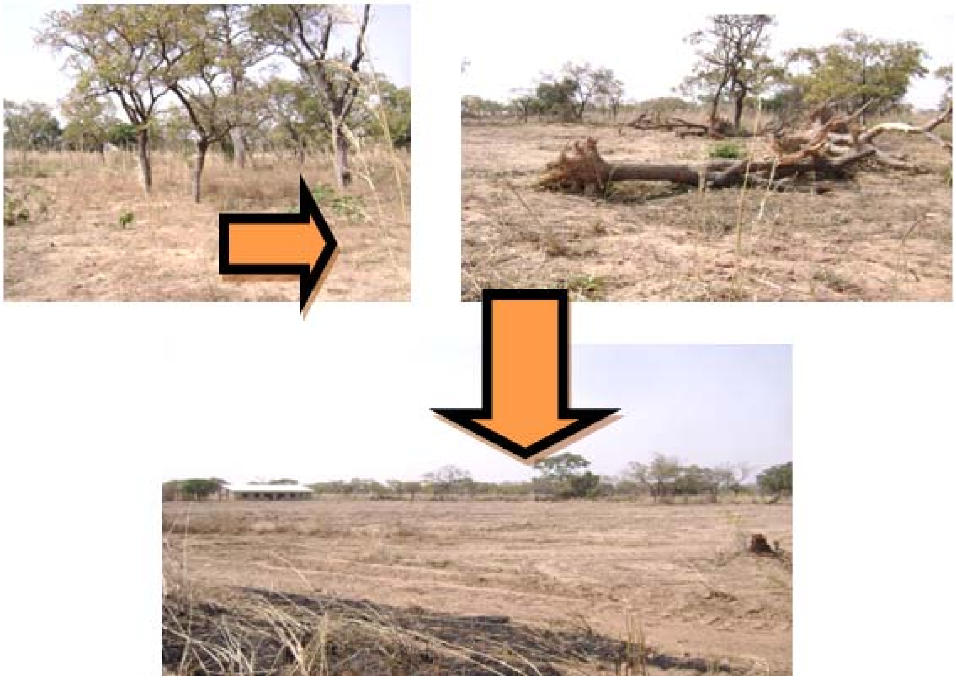

Fig. 4: Photographs showing land cover changes in wa

CONCLUSION

Satellite remote sensing and GIS technology has been used to quantify the land use/land cover dynamics in Wa between 1986 and 2011 successfully. The overall accuracy of land cover mapping was 68%. However, accuracy of the mapping with respect to the land cover classes of interested (vegetation and built-up) was not below 70%. Furthermore, the study has showed that the developed land area of Wa has increased considerably in the past 25 years. Unfortunately, the size of bare lands has nearly doubled while a tenth of originally vegetated areas have been lost. Therefore, considering the rate at which the land is degrading, if measures are not implemented to protect the environment, the biodiversity of Wa and its surrounding areas would be lost in the not too distant future. Also the degradation can intensify the effects of possible climate change such as floods and droughts.

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