Research Journal of Environmental and Earth Sciences 4(10): 866-877, 2012
ISSN: 2041-0492

Submitted: March 26, 2012 Accepted: June 15, 2012 Published: October 20, 2012

Analysis of the Processes behind Woodland Transition in Commercial Charcoal Producing Areas: A Case Study of Kintampo North District of Ghana

[1]Raymond Aabeyir, [2]William Oduro and [3]Jonathan Arthur Quaye-Ballard
[1]Department of Environment and Resource Studies, University for Development Studies, Wa Campus, Ghana
[2]Wildlife and Range Management,
[3]Depatrment of Geomatic Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Abstract: The study examined the processes behind woodlands transition in Dawadawa, a major charcoal producing community in the Kintampo North District (KND) of Ghana. It is argued that commercial charcoal production plays a significant role in woodland degradation because of the manner in which the trees are harvested. Such arguments are informed by simplistic analysis of land cover change because they focused on the change in quantity of the land cover excluding the processes behind the change in quantity in the analysis process. The study has demonstrated that focusing land cover analysis on solely the quantity of change is misleading since a large change in the quantity of a land cover type does not necessarily mean that the process initiating the change is systematic which has always been the assumption in conventional land cover change analysis. Image classification was applied to map land cover types in 2000 and 2007 and post-classification change detection technique was used to detect land cover change between the two timelines. The analysis of the processes of change was based on the changed matrix. The analysis of the processes of land covers change. This revealed that the transitions from riparian to woodland and bareland to shrubland have the largest ratio of 0.3; thus woodland and shrubland gained systematically from riparian and bareland respectively more than any of the other land cover types. Also, the transition of woodland to shrubland is random. The study concluded that the gap in systematic transition between woodland and shrubland is the cause of the worsening degradation of the woodland. It is recommended that woodland management should focus on shrubland to bridge the gap between the woodland and the shrubland in order to sustain the woodlands.

Keywords: Charcoal production, landcover transition, random process, systematic process, woodlands

INTRODUCTION

The woodland cover has been subjected to severe pressure by competing users such as commercial charcoal producers, farmers, Fulani herdsmen (Amanor, 2003).

Issues of sustainability of the woodlands are now matters of both economic and environmental concern in the sense that the future of the livelihoods of these people is gloomy. This is because as the woodland is being degraded, the effects of the degradation of the woodlands are also accumulating. Naughton-Treves *et al*. (2006), Ouedraogo (2006), Chambwera (2004), Arnold and Persson (2003) and Masoud (1990) argued that commercial charcoal production plays a significant role in woodland degradation because of the manner in which the trees are harvested. These arguments are informed by simplistic analysis of land cover change because they focused on the change in quantity of the land cover excluding the processes behind the change in quantity in the analysis process. It is important for decision makers to understand whether the process behind the transition of the woodland is random or systematic because policies on sustaining woodlands must first target reversing systematic processes. Besides, the nature of the transition is important for managers to understand whether regeneration or plantation activities are taking place in woodlands because these are the activities that sustain the woodlands.

The issue with general assertions based on change in quantity of land cover is the tendency to point accusing fingers in the wrong direction. Such assertions have the tendency of making governments craft policies banning rural livelihood activities such as charcoal production thereby creating conflicts between resource managers and rural poor (Kalame *et al*., 2008). This is because resource managers think that the rural poor

Corresponding Author: Raymond Aabeyir, Department of Environment and Resource Studies, University for Development Studies, Wa Campus, Ghana

who depend on such resources for their livelihoods go beyond the sustainable measures; while the rural poor think they must survive on the available resources. For instance District Assemblies (DAs) in some parts of Ghana and Burkina Faso have banned charcoal production in pursuance of the arguments raised by Naughton-Treves *et al.* (2006), Ouedraogo (2006), Chambwera (2004), Arnold and Persson (2003) and Masoud (1990) provoking conflicts and accusations among interest groups (Kalame *et al*., 2008).

Land cover changes are generally complex issues (O'Higgins, 2007; Pontius *et al*., 2004; Braimoh and Vlek, 2005) because of the competing multiple uses which go on at the same place in many cases especially in developing countries. It therefore requires critical analyses which include analysis of the processes behind the changes for informed policy crafting so as not to trigger needless tensions between land based-resource users and managers of such resources. Pontius *et al.* (2004) and Braimoh and Vlek (2005) explained that in studying the processes behind transformation of woodland cover, it is important to look at them from the perspectives of random and systematic processes (Braimoh, 2006). Random land cover transitions are triggered by the interplay of land use factors that act spontaneously such as loss of entitlement to natural resources, internal conflicts, spontaneous increase in migration and changes in macro-economic conditions (Braimoh, 2006; Braimoh, 2004).

Systematic land cover transitions are dictated by natural population growth, changes in institutions governing natural resources, increase in commercial activities, lack of public education on the environment and annual bushfires (Braimoh, 2006, 2004). A land cover transition is said to be purely a random process if the difference between the expected gains and the observed transition or the difference between the expected losses and the observed transitions is zero (Pontius *et al*., 2004; Braimoh and Vlek, 2005; Versace *et al*., 2008). The closer the difference is the more random is the transition and the further the difference is from zero, the more systematic is the transition (ibid).

Though land cover analyses are not new in the study area, such analyses (Pabi, 2007; Park *et al*., 2005) have focused on the quantity of change creating a gap in the analysis of change. Accurate and reliable assessment of woodland transition is still a major research challenge in terms of understanding land cover transition in the area. The aim of this study is to assess the processes behind the transition of woodland to other land cover types in the area. The main argument of this study is that land cover transition in the study area has been understood in a simplistic context which has informed decisions banning the cutting of green wood for fuel wood from the natural woodlands.

MATERIALS AND METHODS

Study area: The Kintampo North District (KND) of the Brong Ahafo Region is located between latitudes 8º45′N and 7º45′N and Longitudes 1º20′W and 2°1′W (Fig. 1). It shares boundaries with five other districts: Central Gonja to the North, Bole to the West, East Gonja to the North-East, Kintampo South to the South and Pru to the South-East. Some of these districts are also known for commercial charcoal production (MLRDE, 2006). The elevation of the terrain generally ranges between 60-150 m above mean sea level (Fig. 1) and slow down the activities of charcoal producers in the rainy season when the terrain gets flooded during heavy down pour. The major rivers are the Urukwan and Kunsu rivers. These rivers are barriers to charcoal production especially in the rainy season (Aabeyir *et al*., 2011) when they get flooded. The district falls under the interior wooded savannah and forms part of the transitional ecological zones of Ghana. It is believed that the transitional zone was once forested and that the savannah conditions currently prevailing have been as a result of man's activities such as agriculture, logging, bush fire (Pabi, 2007) and charcoal production.

KND is a major supplier of fuel wood to the urban centers such as Kumasi and Accra. The district is predominantly a farming community and a fast growing urban centre (Kintampo North District Assembly, 2006). Land based economic activities have increased leading to accelerated woodland conversion to farms and settlements (Amanor, 2003). KND has a heavy presence of migrant population most of whom engaged commercial charcoal production. The migrants do not have any ownership rights to woodlands due to the land tenure system in the district. Consequently, they rent woodlands from the chiefs and individual family heads. Since right of use of woodland can be taken from tenants at any time, they are neither motivated to protect existing trees nor plant trees on rented lands. Besides, planting of trees on rented land by tenant is generally considered as perpetuation of stay, which may in turn imply indirect ownership of land (Varmola, 2002; UN Energy, 2006).

Selection of study area: KND was selected on the basis that it is a major charcoal producing district in Ghana and Dawadawa was selected because it is a major charcoal producing community in KND. The

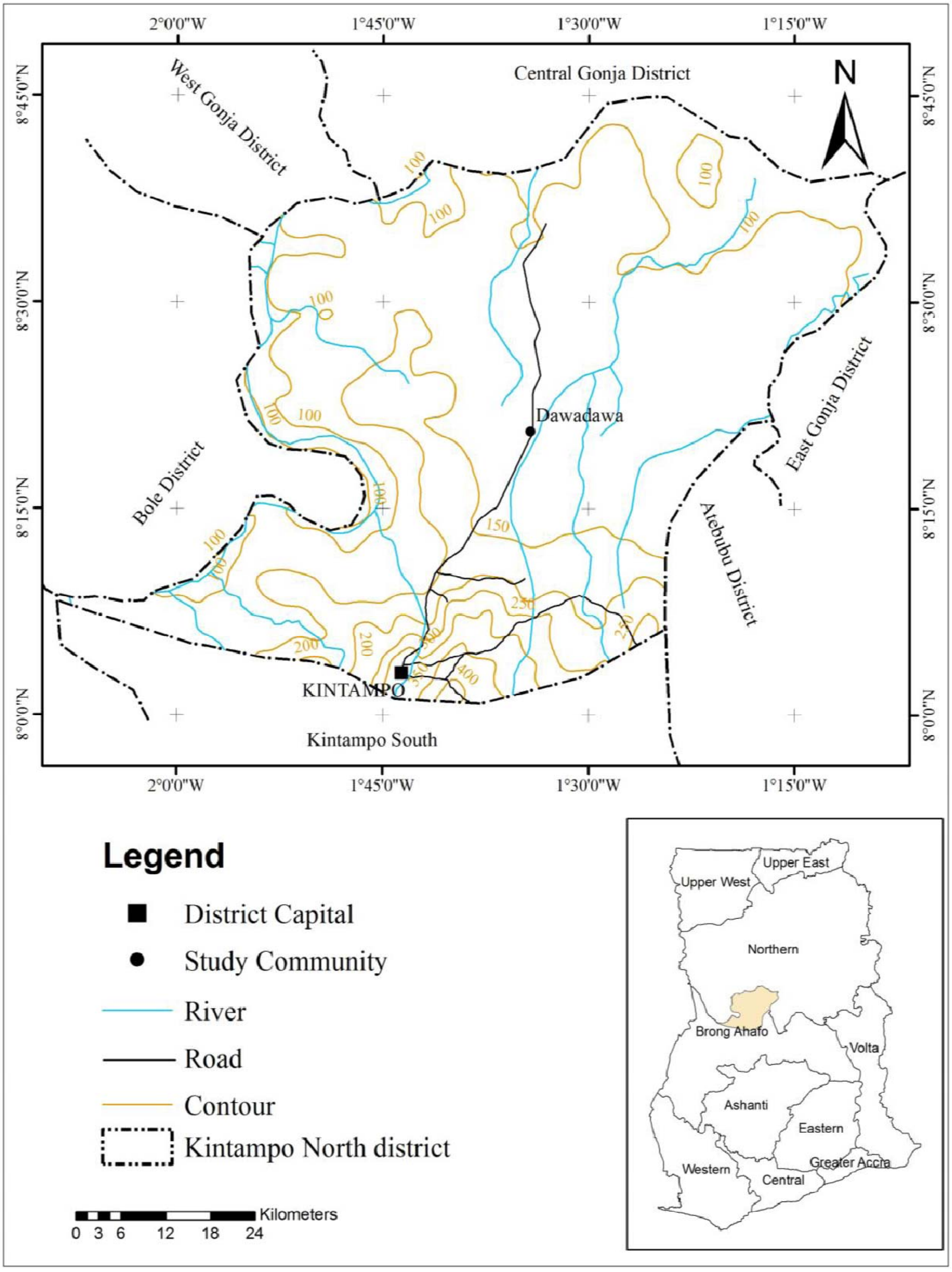

Fig. 1: Study area in the district and national context

number of communities was limited to one because of time constraint and cost. Finally, the selection of the community was also guided by availability of satellite images covering district, since remote sensing is a major component of the research method.

Materials and software: A geo-referenced Aster Jan 29, 2007 and Landsat TM February 17, 2000 images were obtained from International Institute for Geo-Information Science and Earth Observation (ITC) database. The Visible Near Infrared (VNIR) bands of the Aster and 432 band combination of Landsat Thematic Mapped images were used. Garmin 76S handheld Global Positioning System (GPS) receiver was used to pick the coordinates of the land cover samples and the fuel wood collection site samples for the validation of charcoal production sites. ERDAS Imagine 9.1 was used to process the image while ArcGIS was used for the spatial analysis and map processing.

Land cover type sample collection: The land cover samples were collected in October 2007. Purposively sampling was used since the objective of the field work was to collect land cover classes. The sampling method also ensured that all the land cover types were taken into account during data collection in the field (Wilkie and Finn, 1996). Coordinates of representative land cover sample areas were recorded with the Garmin 76S GPS and the corresponding land cover described. Curran (1985) recommended a minimum of 50 points per land cover class. This was not possible for riparian areas for reasons of inaccessibility in certain areas and limited time for the fieldwork. Thus a minimum of 25 points were picked for riparian area.

Participatory mapping: The mapping of the charcoal production sites was done on an enlarged geo-referenced Aster-2007 image which had the roads and study communities overlaid on it to improve the location of the harvesting and production sites (Corbett *et al*., 2006). The Aster image was used because it brought out minor rivers, roads and even some footpaths to farms that more clearly compared to the Landsat image. These features were useful in identifying production sites on the image.

The participants in the mapping exercise were eight experienced migrants and indigene commercial fuel wood collectors comprising 5 males and 3 females of different age groups. Participants identified areas on the image where trees were either harvested or were being harvested for charcoal production. Boundaries were sketched around these areas based on consensus. Participants made reference to the walking distance from the settlements, the Urukwan and Kunsu Rivers to the harvesting areas. They also located the areas relative to the Tamale-Techiman trunk road and Kintampo-Kunsu road. Participants in Dawadawa made reference to villages such as Attakura, Kawumpe and Jewu while those in Kunsu community utilized villages such as Meawani and Adomano.

Data processing: The GPS coordinates recorded in the field were in WGS84 coordinate system. The points and the images were transformed to the local coordinates system using the Transverse Mercator projection, Clarke 1880 Spheroid with legion datum to ensure compatibility of coordinates with the existing datasets such as roads, rivers and communities. The effect of haze was also reduced using ERDAS Imagine haze reduction module.

Since the two images were of different spatial resolutions, there was the need to resample one of the images to the resolution of the other. Lu *et al*. (2004) in their review of land cover change detection techniques, recommended that aside precise geo-referencing, if possible satellite images of the same spatial and spectral resolution should be used for land cover change detection to improve the accuracy of the changes. However, Mertens and Lambin (2000) re-sampled a SPOT image to the spatial resolution of a Landsat MSS image in order to use the two images to detect land cover change in southern Cameroon. In this case the ASTER image (15 m) was re-sampled to the spatial resolution of the Landsat image (30 m) using the nearest-neighbor technique so that the two images were comparable in terms of spatial resolution and the change detection could be done.

Since the images were already geo-referenced, there was the need to validate the accuracy of the geo-referenced images using Ground Control Points (GCP) (Chang, 2004). Eight well distributed GCP were picked at identifiable roads or rivers intersections using a hand-held Garmin GPS. The reliability of the average Root Mean Square Error (RMSE) is also dependent on the distribution of the GCP (Kerle *et al*., 2004). The RMSE was quantified using the Eq. (1) (Chang, 2004):

$$\text{Average RMSE} = \sqrt{\frac{[\sum_{i=1}^{n}(Y-y)^2 + \sum_{i=1}^{n}(X-x)^2]}{n}} \tag{1}$$

where,

n : The number of control points
(X, Y): The ground control point
(x, y) : The corresponding point on the image

The validation of the images achieved average Root Mean Square Errors (RMSE) of 0.434435 and

Table 1: Description of main land cover types in the study area

Land cover type	Description
Woodlands	These were areas of typical semi-deciduous pioneer tree species interspersed with herbaceous vegetation and grass dominated by *Anogeissus leiocrcarpus*, *Albizia coriaria*, *Pterocarpus erinaceus*, *Taminalia macroptera*, etc. Tree species tend to be smaller and drought-resistant. The tree height exceeds 2 m.
Bareland	This cover type comprises farms, buildings and open spaces. Buildings were mostly thatch roofed.
Shrubland	Lands with herbaceous and young trees. The foliage can either be evergreen or deciduous. Tree height is less than 2 m. Dominant grasses include *Pennisetum pedicellatum*, *Andropogen gayanus*.
Riparian areas	These were areas of typical semi-deciduous pioneer tree species interspersed with herbaceous vegetation and grass around water bodies. Vegetation comprises *Anogeissus schimperi*, *Celtis integrifolia*, *Cola laurifolia*, *Cynometra vogelii*, etc.

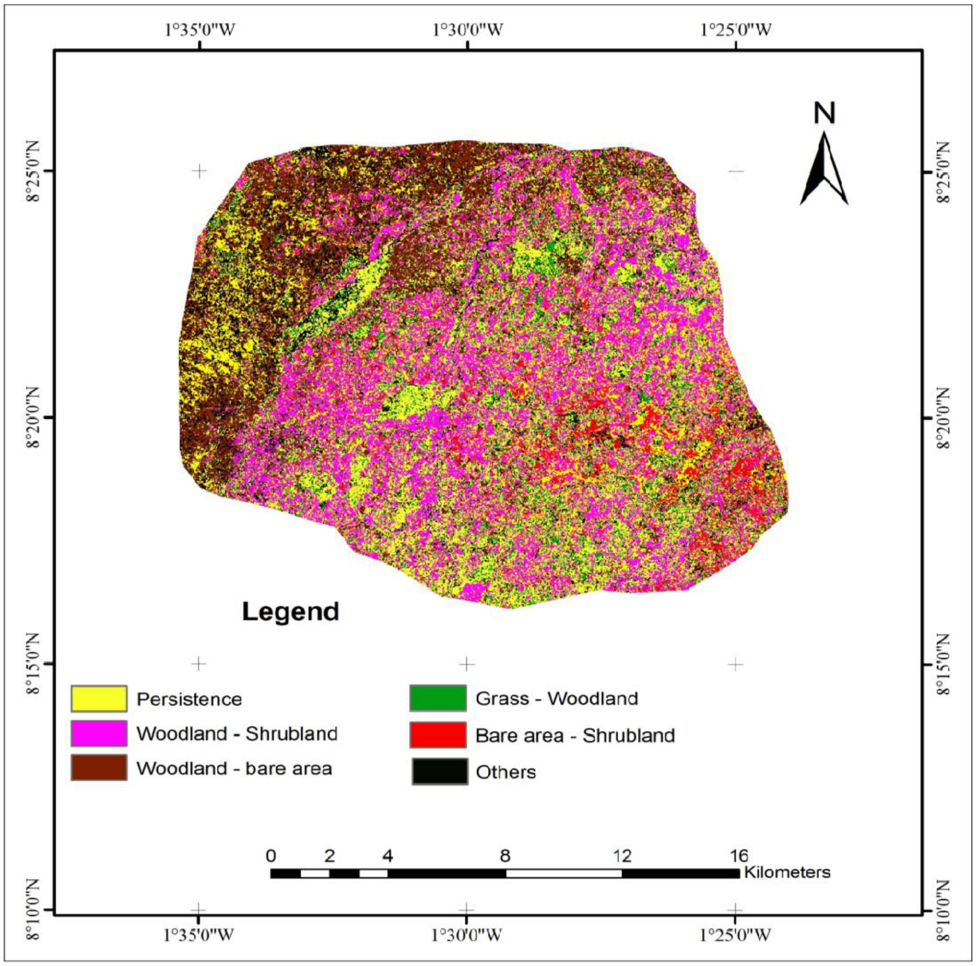

Fig. 2: Land cover change map

0.52568 pixel for the Aster image and Land sat, respectively.

Image classification: A supervised classification was performed using Gaussian Maximum Likelihood Classifier (MLC) in Erdas Imagine. Though other classification methods are available, the choice of the Gaussian MLC was based on its advantages expressed in literature (Lillesand and Kiefer, 1994; Shrestha and Zinck, 2001). In terms of application in conventional classification of multispectral data, the MLC is considered to provide the best results since it takes into account the shape, size and orientation of a cluster (Shrestha and Zinck, 2001). The MLC quantitatively evaluates both the variance and correlation of a category of spectral response patterns when classifying an unknown pixel (Lillesand and Kiefer, 1994). However, the Gaussian MLC requires that the distribution of training samples is Gaussian (normal) but normality assumption is an ideal situation and difficult to achieve in practice. The land cover sample points were divided into two sets; training data and validation data.

Four main separable land cover types were identified for the purpose of this research; woodland, shrubland land, riparian area and bareland (Table 1, Fig. 2).

Accuracy assessment: The accuracy of the classified images was assessed using 150 points for Aster 2007 and 140 points for Landsat 2000. The accuracy of the Landsat 2000 image was assessed by using points picked in areas that did not change between 2000 and October 2007, as ascertained by some charcoal producers during the field validation to the production sites. These people were involved in charcoal production at least since 2000 and were familiar with the changes in the landscape of the study area (Braimoh, 2005; Mertens and Lambin, 2000). Some old farmers were also involved particularly those the field validation team met in the field.

Change detection: Post-classification technique was used in the change detection because of its ability to generate a change matrix and the fact that it reduces external impact from atmospheric and environmental differences between multi-temporal images. Hence the classified images 2000 and 2007 were input into the ERDAS imagine to generate change map and matrix. The changed matrix was the basis for the analysis of the processes of transition. The changed map was reclassified to combine the unchanged classes into one class. The change matrix was then exported to MS Excel for further analysis to generate the following: gain and loss in each cover type, swap, net change in each land cover type, expected gains and losses, inter-category gain, inter-category loss (Versace *et al*., 2008; Braimoh, 2005; Pontius *et al*., 2004).

Gain in a land cover i between timeline 1 and 2 refers to an increase in extent of a land cover type i within the period. It is computed using Eq. (2) (ibid):

$$\text{Gain, } g = P_{+j} - P_{jj} \tag{2}$$

where,

P_{+j} = The column total of cover type j

P_{jj} = The persistence of cover type j of the transition matrix

Loss (l) in a land cover i between timeline 1 and 2 is a decrease in extent of a land cover type I within the period. It is computed using Eq. (3):

$$l = P_{i+} - P_{ii} \tag{3}$$

where,

P_{i+} : The row total of cover type i

P_{ii} : The persistence of cover type i of the transition matrix

Swap is defined as the change in location of a land cover type between timeline 1 and timeline 2 (Versace *et al*., 2008; Braimoh, 2005; Pontius *et al*., 2004) and in this case between year 2000 and year 2007. The swap gives more meaning to the interpretation of a situation where the net change in a land cover type is zero and avoids the tendency of interpreting the situation to mean no change. Net change is the difference in area of a land cover between timeline 1 and timeline 2. It accounts for change in quantity but does not account for change in location, which the swap does. The swap shows a simultaneous gain (g) and loss (l) of a land cover type on the landscape and the amount of swap (S_j) is computed using Eq. (4):

$$S_j = 2{*}\text{MIN}(P_{j+} - P_{jj}, P_{+j} - P_{jj}) \text{ or } 2{*}\text{MIN}(l, g) \tag{4}$$

Random and systematic transitions are analyzed on the basis of gains and losses with the expected gains and expected losses Eq. (5) and (6) as significant variables in determining systematic and random transitions. In terms of gains, the difference between the expected gains and the observed transitions indicates whether a land cover type is gaining more or less. If the difference (observed-expected) is positive, the land cover type in the base year is said to have lost more to the cover type in the current year than expected under a random process of gain in the cover type of the current year. If the difference is negative, the land cover type in the base year is said to have lost less to the cover type in the current year than expected under a random process of gain in the cover type of the current year (Versace *et al*., 2008; Braimoh, 2005; Pontius *et al*., 2004). The observed transitions are the values in the transition matrix.

In terms of losses, if the difference between the expected losses and the observed transitions (observed-expected) is positive, the land cover type in the current year is said to have gained more from the cover type in the bases year than expected under a random process of loss in the cover type of the base year and if the difference is negative, the cover type in the current year is said to have gained less from the corresponding cover type in the base year than expected under a random process of loss in the cover type of the base year Versace *et al*. (2008), Braimoh (2005) and Pontius *et al*. (2004).

The expected gain (G_{ij}) of land cover type j from another type i represent a gain under a random process and is computed using Eq. (5):

$$G_{ij} = (P_{+j} - P_{jj})\left(\frac{P_{i+}}{100 - P_{j+}}\right), \forall\ i \neq j \quad (5)$$

The expected loss of a land cover type i to another type j (L_{ij}) represent a loss under a random process and is computed using Eq. (6) (Versace *et al*., 2008; Braimoh, 2005; Pontius *et al*., 2004):

$$L_{ij} = (P_{i+} - P_{jj})\left(\frac{P_{+j}}{100 - P_{+i}}\right), \forall\ i \neq j) \quad (6)$$

RESULTS

Land cover transition map: The major land cover transitions are woodland to shrubland and woodland to bare area (Fig. 2). The spatial distribution of these major transitions shows that much of the woodland in the middle and south-eastern part was converted to shrubland while the transition from woodland to bare area dominated the northern and north-western parts of the study area. Subtle changes (riparian to woodland, grass and bare area; bare to woodland and riparian area; shrubland to riparian area and woodland to riparian) also occurred over the entire landscape of the study area and are put together as other changes.

The transition matrix (Table 2) shows the observed transitions on the landscape. Woodland was the dominant land cover in the year 2000 constituting 65.3% of the landscape followed by shrub land which constituted about 16.8% of the landscape. In the year 2007, woodland and shrub land maintained their dominance on the landscape but with a reduction in size, from 65.3 to 45.2% and an increase in size of the shrub land from 16.8 to 32.4%, respectively. All the land cover types gained and lost in quantity differently with the woodland losing more (32.4%) than the others while shrub land gained more (25.6) than the rest.

Generally, 55.4% of the landscape underwent transition from 2000 to 2007 while 44.6% (sum of leading diagonal values in Table 2) persisted for the same period. The significant transitions were woodland to shrub land which is 20% of the landscape and woodland to bare land which is 11% of the landscape.

Summary of land cover transitions: The general landscape dynamics is looked at in terms of the gain, loss, total change, swap and net change with emphasis on the last three. The total change on the landscape was 55.4% of the entire landscape. It is half the sum of the change in each land cover type because a change in one pixel counts as a loss in one land cover and a gain in another. The same explanation applies to the total swap and the total net change on the landscape. The swap values indicate intra-land cover dynamics (simultaneous gain and lost in a land cover type). The significant total land cover transitions occur in the woodland and shrub land which constitute 44.6 and 35.7% of the landscape respectively (Table 3). For the woodland, swap constitutes 24.6% of the total change while 20.1% constitutes pure lost. In the case of the shrub land, 20.1% of the total change is swap and 15.6% is pure gain. The general landscape dynamics are both a swap and net change i.e., 33% Swap and 22.4% net change. The gain and loss values indicate that while woodland is losing significantly, shrub land is gaining significantly but it cannot be concluded that shrub land is gaining from woodland because woodland is losing.

Analysis of the processes of transition in terms of gains: The processes of transitions were analyzed in terms of gains and losses on the basis that when one land cover type gained, it means another lost.

Processes of transition in terms of gains: Table 4a shows the expected gains of the various land cover types on the landscape. These values represent gains under a random process of transition since the land cover that gains replaces other cover types in proportion to their sizes on the landscape in the base year (2000). The observed transitions are the values in the transition matrix (Table 2).

Table 4b shows the differences between the observed transitions (Table 2) and the expected gains (Table 4a). The leading diagonal values of Table 4b are zeros as expected and indicate a purely random process of transition because they are the persistent proportions of the various land cover types under study. Table 4b shows that except the transition from shrubland to woodland, the rest of the transitions are systematic since the values are none zeros. However, the important systematic transitions are: riparian to woodland, woodland to riparian, bareland to shrubland and shrubland to bareland since these transitions have positive values indicating that the land cover types in the year 2007 gained more than expected under a random process of loss in these land covers in the year 2000. The negative values show that the land cover type in 2007 gained less than expected under a random process of loss. However, there is the need to test the strength of these systematic transitions since it is not clear from Table 4b.

Table 4c presents the differences between the observed and expected transitions relative to the sizes of their respective land covers in 2000. The relative differences indicate the strength of the systematic transitions. The most systematic transition is riparian to

Table 2: Land cover transition matrix (%)

		2007					
2000	Landcover	Riparian area	Woodland	Shrubland	Bareland	Total 2000	Loss
	Riparian	0.8	2.50	1.00	0.70	5.10	4.20
	Woodland	1.6	33.0	19.9	10.8	65.4	32.4
	Shrubland	0.1	5.90	6.80	4.00	16.8	10.1
	Bareland	0.2	3.80	4.70	4.00	12.7	8.70
	Total 2007	2.8	45.3	32.4	19.5	100.0	55.4
	Gain	2.0	12.3	25.7	15.5	55.4	

Table 3: Summary of landscape dynamics (%)

Landcover	Total 2000	Total 2007	Persistence	Gain	Loss	Total change	SWAP	Net change
Riparian	5.10	2.80	0.80	2.00	4.20	6.20	3.90	2.30
Woodland	65.4	45.3	33.0	12.3	32.4	44.7	24.6	20.1
Shrubland	16.8	32.4	6.80	25.7	10.1	35.7	20.1	15.6
Bareland	12.7	19.5	4.00	15.5	8.70	24.2	17.4	6.80
Total	100.0	100.0	44.6	55.4	55.4	55.4	33.0	22.4

Table 4: Inter land cover gains (%)

2007					
Land cover	Riparian	Woodland	Shrubland	Bareland	Total 2000
(a) Expected gains in the land cover types					
Riparian	0.8	1.80	1.60	0.90	5.10
Woodland	1.3	33.0	20.2	11.6	66.1
Shrubland	0.3	6.00	6.80	3.00	16.1
Bareland	0.3	4.50	3.90	4.00	12.7
Total 2007	2.8	45.3	32.4	19.5	100.0
(b) Observed transition minus expected gains (difference) in the land cover types					
Riparian	0.0	0.7	-0.6	-0.2	
Woodland	0.3	0.0	-0.2	-0.8	
Shrubland	-0.2	0.0	0.0	1.0	
Bareland	-0.1	-0.7	0.8	0.0	
(c) Relative difference (relative to the observed)					
Riparian	0.0	0.4	-0.4	-0.2	
Woodland	0.2	0.0	0.0	-0.1	
Shrubland	-0.6	0.0	0.0	0.3	
Bareland	-0.2	-0.2	0.2	0.0	

Table 5: Inter land cover class losses (%)

		2007				
2000	Landcover	Riparian	Woodland	Shrubland	Bareland	Total 2000
(a) Expected losses (Inter-category losses)						
	Riparian	0.8	2.00	1.40	0.90	5.10
	woodland	1.6	33.0	19.2	11.5	65.4
	Shrubland	0.4	6.70	6.80	2.90	16.8
	Bareland	0.3	4.90	3.50	4.00	12.7
	Total 2007	3.2	46.6	30.9	19.3	100.0
(b) Observed land cover transitions minus expected losses (difference)						
	Riparian	0.0	0.6	-0.4	-0.2	0.0
	Woodland	0.0	0.0	0.8	-0.7	0.0
	Shrubland	-0.3	-0.8	0.0	1.1	0.0
	Bareland	-0.1	-1.1	1.2	0.0	0.0
(c) Relative difference (relative to the observed)						
	Riparian	0.0	0.3	-0.3	-0.2	
	Woodland	0.0	0.0	0.0	-0.1	
	Shrubland	-0.7	-0.1	0.0	0.4	
	Bareland	-0.3	-0.2	0.3	0.0	

woodland with a relative difference of 0.4 followed by shrubland to bareland with a relative difference of 0.3 and the transition from woodland to riparian and bareland to shrubland, both have relative difference of 0.2.

Processes of transitions in terms of losses: Table 5a shows the expected losses in the various land cover types between 2000 and 2007. These expected losses represent the losses under random process of transition. Table 5b presents the difference between the observed and the expected losses. With the exception of the transition from woodland to riparian, the rest of the transitions have none zero values and indicate systematic transitions but the important ones are: riparian to woodland, woodland to shrubland, shrubland to bareland and bareland to shrubland. These are the transitions in which the land cover types in the year 2000 loss more than expected under a random process of gain in the corresponding land cover types in the year 2007.

Table 5c shows the difference relative to the size of the land cover 2000 and indicates the strength of the systematic transition. The larger the value the more systematic the gain in the land cover in the 2007. On this basis, the significant systematic transitions are riparian to woodland, bareland to shrubland which both have a relative difference of 0.3; and shrubland to bareland which has a relative difference of 0.4. The transition from woodland to shrubland is not significantly systematic since it relative difference is zero (0).

DISCUSSION

Analysis of the transition matrix: Examination of the transition matrix (Table 2) reveals that it can mislead one to assume that the transition in the woodland is systematic based on its large magnitude and conclude that the transition within woodland is the most serious issue. It will indeed be simplistic because the magnitude alone is insufficient to determine whether transition is random or systematic one. From the quantities of the land cover type at 2000, woodland is the most populated land cover type on the landscape and for that matter; such large transition could occur in the woodland under random process of transition and further analysis is needed to be sure of the process behind the transition (Pontius *et al.*, 2004). This makes the analysis in Table 4 and 5 relevant as it fills in this gap.

The net change explains change in quantity while the swap explains change in location. The swap and net change values are non-zeros and indicate that each cover type experienced a change in quantity and in location. The net change shows that woodland and riparian area lost more than they gained while shrubland and the bareland gained more than they lost. However it is not clear the source of the gain or destination of the loss based on the net change and goes on to buttress the insufficiency of the net change in conventional land cover analysis. It will therefore be naïve to conclude that woodland is losing to shrubland because woodland lost more than the rest and shrubland gained more than the rest.

Interpretation of the processes of transition in terms of gain: The analysis of the processes of transition has revealed that the transition from woodland to shrubland and vice versa is purely random as their relative differences are zeros and that woodland does not replace bareland when it gains. The random process behind the transition is attributable to factors such as seasonal in-migration and intermittent crop failure (Lambin *et al.*, 2001; Braimoh, 2004; Pontius *et al.*, 2004; Braimoh, 2006). The area is a major destination for farm labor from the Northern, Upper East and Upper West Regions (Blay *et al.*, 2007). These laborers go there for contract farming during the dry season and to return home during the rainy season. In the event that few or no contract farming exists, they resort to charcoal production in order to gain some income to enable them return home because charcoal production has ready market as a result of the trunk road linking the area to major urban centers. It is worth noting that though charcoal production has ready market, it is tedious compared to farming and requires special skills to produce it; otherwise ones effort can be wasted.

When woodland gains, it systematically replaces riparian and when riparian gains, it does so systematically from woodland. Increase in commercialization of charcoal production has accounted for it. In either way, the aim is to go to areas that are concentrated with large preferred tree species for charcoal production. There is high demand for charcoal in the urban areas which makes commercial charcoal production a brisk business in the area. It has become a mainstream income generation for some community members (Energy Commission of Ghana, 2006; Aabeyir *et al.*, 2011)

In terms of strength, there is higher affinity for woodland to gain from riparian than the other way round because the fact that more and bigger preferred tree species for charcoal production are found in the riparian areas than in the woodland. Commercial charcoal producers who use chainsaws prefer to go to the riparian areas for economic reasons. The transition of riparian area to woodland should therefore be understood in terms of the density of the vegetation and not a change in the positions of the rivers and their banks which looks ridiculous.

When shrubland gains, it systematically replaces bare land and when bare land gains, it systematically targets shrub land. Though the shrub land losses to and gains from the bare land, the affinity (0.3) for the shrub land to systematically lose to bare land is higher than that (0.2) of bare land to lose to shrub land. This has negative implication for the sustainability of the woodland in the area. These could be due to annual bushfires and expansion of farms and settlements as triggered by population growth (Lambin *et al.*, 2003; Braimoh, 2006; Pontius *et al.*, 2004). The ritual annual bushfires that occur at the beginning of every dry season in the area (Apusigah, 2006) is likely to make it difficult for shrub land to gain from the bare land through regeneration. The high affinity for the transition from shrub land to bare land could be due to expansion of settlements and farms in the shrub land. Establishment of tree plantation is not a culture of the inhabitants of the study area due to factors such as land tenure and the annual bush fires (Aabeyir *et al.*, 2011). It is this gap which actually negates the natural resilience of the woodlands to transition and attests to the fact that sustainability of woodlands in the study area is indeed an issue. It is also not clear that it is the immediate activities of commercial charcoal producers that cause the degradation of the woodland. It is rather remote factors such as the bushfires, effects of climate change which either compel farmers to expand their farms or engage in shifting cultivation for sufficient harvest. Discussions during field visit to collection sites with Commercial charcoal producers have argued that the areas they currently harvest wood are not primary woodlands but secondary ones. Some of these areas were once harvested for the same purpose but today they have become dense again and for that matter commercial charcoal producers should not bare the greater part of the blame for the transition of the woodlands.

Interpretation of the processes of transition in terms of loss: The analysis of the losses shows that when riparian loses, woodland replaces it but not shrub land in a systematic manner. It is also clear that woodland does not replace shrub land or bare land in a systematic manner. This shows that there are no efforts to sustain the woodlands through plantation establishment; fallow period for the shrub land to gain the status of woodland through natural regeneration is short due to pressure exerted by domestic fuel wood collectors, farmers and annual bushfires. This could be due to increase in the number of firewood collection activities or the fact that domestic firewood collectors are not motivated to walk long distances to compete with commercial fuel wood collectors. Coomes and Burt (2001) noticed that when fuel wood collectors are constrained by access to new woodlands, they are compelled to compromise sustainable practices. In this case fuel wood collectors are constrained by longer distances to new areas as longer distance to collection sites is a major factor affecting fuel wood collectors in the area Aabeyir *et al.* (2011).

The gap between the woodland and shrub land in terms of systematic transition from shrub land to wood is due to the manner in which fuel wood is harvested in the area. Three categories of commercial fuel wood harvesters were found in the study area: chainsaw users, axe users and cutlass users. The chainsaw users target larger preferred tree species because of the ability of the chainsaw to cut such trees. The axe users go into the same area fell the sizeable young trees that are considered immature and uneconomical to cut with a chainsaw. The cutlass users, who are mostly elderly women, find harvestable species that were left by the axe user because the cutlass can easily cut these small trees. This makes it difficult for natural regeneration to take place in the shrub land to systematically sustain the woodland.

CONCLUSION AND RECOMMENDATIONS

The study has demonstrated that assessment of the processes leading to the transition of land cover brings out significant details behind the quantities of change. Thought the dominant transition in terms of quantities is woodland to bare land, the analysis of the processes shows that the transition is a random process which is contrary to the views of resource managers in the district. This supports the claim of this study that the banning of the charcoal production in the study was a misinformed decision based on the extent of the woodland cleared in the area.

The transition from shrub land to bare land is a systematic process just as the transition from riparian to woodland and vice versa, however, the riparian area has a high affinity to lose to the woodland. There is a systematic transitional gap from shrub land to woodland and bare land to woodland. The bare land is more inclined to gaining from the shrub land than losing to it.

REFERENCES

Aabeyir, R., J.A. Quaye-Ballard, L.M. Leeuwen and W. Oduro, 2011. Analysis of factors affecting sustainable commercial fuelwood collection in dawadawa and kunsu in kintampo north district of Ghana. IIOABJ-2, 2: 44-54.

Amanor, K.S., 2003. Natural and cultural assets and participatory forest management in West Africa. International Conference on Natural Assets, Paper 8, Philippines.

Apusigah, A.A., 2006. Promoting sustainable wildfire management in Northern Ghana: Learning from history. Eur. J. Soc. Sci., 2: 109-123.

Arnold, M. and R. Persson, 2003. Reassessing fuelwood situation in developing countries. Int. For. Rev., 5: 379-383.

Blay, D., L. Damnyag, K. Twum-Ampofo and F. Dwomoh, 2007. Charcoal production as sustainable source of livelihood in afram plains and kintampo North Districts in Ghana. Afr. For. Res. Network, 19: 199-204.

Braimoh, A.K., 2004. Seasonal migration and land-use change in Ghana. Land Degradat. Dev., 15: 37-47.

Braimoh, A.K. and P.L.G. Vlek, 2005. Land cover change trajectories in Northern Ghana. Env. Manage., 36(3): 356-373.

Braimoh, A.K., 2006. Random and systematic land-cover transitions in northern Ghana. Agric. Ecosyst. Env., 113(1-4): 254-263.

Chambwera, M., 2004. Economic analysis of urban fuel wood demand: The case of Zimbabwe. Ph.D. Thesis, Wageningen University, Netherlands.

Chang, K., 2004. Introduction to Geographic Information Systems. 2nd Edn., McGraw Hill, New York.

Coomes, O.T. and G.J. Burt, 2001. Peasant charcoal production in the Peruvian Amazon: Rainforest use and economic reliance. For. Ecol. Manage., 140: 39-50.

Corbett, J, G. Rambaldi, P. Kyem, D. Weiner, R. Olson, J. Muchemi, M. McCall and R. Chambers, 2006. Overview: Mapping for change-the emergence of a new practice. Participat. Learn. Act., 54: 13-19.

Curran, P.J., 1985. Principles of Remote Sensing. John Wiley and Sons, New York.

Energy Commission of Ghana, 2006. Strategic National Energy Plan 2006-2020, Annex IV. Energy Supply to the Economy, Ghana, pp: 1-51.

Kalame, F.B., M. Idinoba, M. Brockhaus and J. Nkem, 2008. Forest Policy, Climatic Change, Non-Timber Forest Products, Minor Forest Products, Non-Wood Forest Products, Climate Change? Center for International Forestry Research (CIFOR), Bogor, Indonesia, pp: 8.

Kerle, N., L.L.F. Janssen and G.C. Huurneman, 2004. Principles of Remote Sensing: An Introductory Textbook. ITC, Netherlands.

Kintampo North District Assembly, 2006. Kintampo North District Profile.

Lambin, E.F., B.L. Turner, H.J. Geist, S.B. Agbola, A. Angelsen, J.W. Bruce, O.T. Coomes, R. Dirzo, G. Fischer, C. Folke, P.S. George, K. Homewood, J. Imbernon, R. Leemans, X. Li, E.F. Moran, M. Mortimore, P.S. Ramakrishnan, J.F. Richards, H. Skanes, W. Steffen, G.D. Stone, U. Svedin, T.A. Veldkamp, C. Vogel and J. Xu, 2001. The causes of land-use and land-cover change: Moving beyond the myths. Global Env. Change, 11: 261-269.

Lambin, E.F., H.J. Geist and E. Lepers, 2003. Dynamics of land-use and land-cover change in tropical regions. Annu. Rev. Env. Res., 28: 205-41.

Lillesand, T.M. and R.W. Kiefer, 1994. Remote Sensing and Image Interpretation. John Wiley and Sons Inc., New York,

Lu, D., P. Mausel, E. Brondi´zio and E. Moran, 2004. Change detection techniques. Int. J. Rem. S., 25(12): 2365-2407.

Masoud, R.S., 1990. Fuelwood demand in zanzibar town and the implications for forestry policy. M.Sc. Thesis, Agric. Univ. of Norway, AS.

Mertens, B. and E.F. Lambin, 2000. Land-cover-change trajectories in southern Cameroon. Ann. Assoc. Am. Geograph., 90(3): 467-494.

MLRDE, 2006. Ministry of Local Govt., Rural Development and Environment (MLRDE), Maks Publications and Media. Retrieved from: http://www.ghanadistricts.com/districts/?news&r =10&-=37.

Naughton-Treves, L., D.M. Kammen and C. Chapman, 2006. Burning biodiversity: Woody biomass use by commercial and subsistence groups in western Uganda's forests. Biol. Conserv., 134: 232-241.

O'Higgins, R.C., 2007. Savannah Woodland Degradation Assessments in Ghana: Integrating ecological indicators with local perceptions. Earth Env., 3: 246-281.

Ouedraogo, B., 2006. Household energy preferences for cooking in urban Ouagadougou, Burkina Faso. Energ. Poli., 34: 3787-3795.

Pabi, O., 2007. Understanding land use/cover change process for land and environmental resources use management policy in Ghana. Geo J., 68: 369-383.

Park, S.J., N. Giesen and P.L. Vlek, 2005. Optimal spatial scale for use change modeling: A case Study in the Savanna Landscape in Northern Ghana. J. Korean Geogr. Soc., 40(2): 221-241.

Pontius Jr, G.R., E. Shusas and E. McEachern, 2004. Detecting important categorical land changes while accounting for persistence. Agric. Ecosyst. Env., 101: 251-268.

Shrestha, D.P. and A. Zinck, 2001. Land use classification in mountainous areas: Integration of image processing, digital elevation data and field Knowledge (application to Nepal). Int. J. Appl. Earth Observat. Geoinformat., 3(1): 78-85.

UN Energy, 2006. Assessing Policy Options for Increasing the use of Renewable Energy for Sustainable Development: Modelling Energy Scenarios for Ghana. United Nations, New York, USA.

Varmola, M., 2002. Hardwood Plantations in Ghana. Forest Resources Development Service Working Paper FP/24, Forest Resources Division, FAO, Rome, Italy.

Versace, V.L., D. Ierodiaconou, F. Stagnitti and A.J. Hamilton, 2008. Appraisal of random and systematic land cover transitions for regional water balance and revegetation strategies. Agric. Ecosyst. Env., 123: 328-336.

Wilkie, D.S. and J.T. Finn, 1996. Remote Sensing Imagery for Natural Resources Monitoring: A Guide for First-Time Users. Columbia University Press, New York.