LAND USE/LAND COVER MAPPING USING REMOTE SENSING FOR URBAN DEVELOPMENT-A CASE STUDY OF TARKWA AND ITS ENVIRONS

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ABSTRACT

Spatial information from remotely sensed data provides an effective solution to land use/land cover change detection. The study was carried out to detect land use/land cover change from 1990 to 2007 in the Tarkwa Municipality. Remote sensing technique was used for this change detection and to assess its implications for the management of future urban development. The data used for the assessment included temporal Landsat satellite images of a 20 km radius of Tarkwa for the years 1990, 2000 and 2007 as well as 162 ground reference points. The results revealed four dominant land use/land cover types with an accuracy of 86.67% and kappa statistic of 0.87. Over the period of study, vegetated areas (VA) lost 46 000 ha whereas non-vegetated areas (NVA) gained over 60 000 ha of land. If this situation is left unchecked, VA in the Tarkwa municipality will reduced by 455 768 ha whereas NVA will increase by 779 163 ha by 2030.

INTRODUCTION

Reliable information on land use/land cover changes is useful for monitoring progress towards sustainable urban management. The land use/land cover pattern of a region is an outcome of both natural and socio-economic factors, and their utilization by man in time and space. To better understand the socio-economic drivers and environmental consequences of urban growth, research continues to expand (Chin 2001; Leichenko 2001; Kozulj 2003). Land is becoming a scarce commodity due to immense mining, agricultural and demographic pressures. Hence, information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare within an urban development. Increasing human interventions and unfavorable bio-climatic environment has led to transformation of large tracts of land into waste/bare lands. Accurate and up-to-date data describing land use and land cover change support these studies in a number of ways. They can be used to; quantify the amount of rural to urban change, identify change trajectories, determine the changes taking place in vegetated and non-vegetated areas, help understand how change is occurring, and predict future changes. Remote sensing approach plays an important role in generating information about the latest land use/land cover pattern in an area and its temporal changes through times. Early uses of satellite imagery were to derive several land use and land cover classes using spectral information (Forster 1983). Researchers discovered quickly that the spectral complexity of the mixed urban environment made classification very challenging. Research themes evident today in urban remote sensing can be divided into (a) improving techniques for classifying images or (b) understanding the urban environment with interpreted scenes (Foster 1983; Barnsley 1997; Mesev 1997). Improvements to supervised/unsupervised techniques using the spectral signature are: combining images with ancillary data (Barnsley 1997; Mesev 1997), incorporating structural and textural information as part of the classifier (Gong 1990), and the use of expert systems (Stefanov 2001). These improved classifiers are now being used in a variety of ways to better understand the urban environment. Studies such as these include land use and land cover change (Al-Bakri 2001; Herold 2003), measuring the density of urban land use and measuring the percent of impervious area (Deguchi 1994).

Tarkwa is one of the areas in Ghana where rapid land use/land cover changes are taking place. Population as well as industries such as mining are expanding and hence increasing the need for up-to-date information on the present status of land use/land cover changes occurring within the municipality for proper urban development. These changes may, if nothing is done, lead to very serious consequences such as deterioration of the land, changing climate, potential agricultural failures on massive scale, environmental damage and other undesirable effects. Knowledge on the land use/land cover maps, magnitudes of human impacts on vegetation and urban status are lacking. It is therefore important that these changes be inventoried accurately so that the physical and human processes at work can be better understood. Thus, this paper seeks to use remotely sensed data to map land use/land cover types and also monitor the changes occurring within Tarkwa and its environs as a case study for the management of future urban development.

STUDY AREA

Tarkwa is one of the landlocked municipal capitals in the Western Region of Ghana. It is located between latitudes 4˚0'0"N and 5˚40'0"N and longitudes 1˚45'0"W and 2˚1'0"W. The environs of Tarkwa under consideration is a 20 km radius buffer (Figure 1). The Tarkwa-Nsueam Municipality which host Tarkwa shares boundaries with Wassa Amenfi District to the north, Ahanta West District to the south, the West by the Nzema East District and the East by Mpohor Wassa East District.

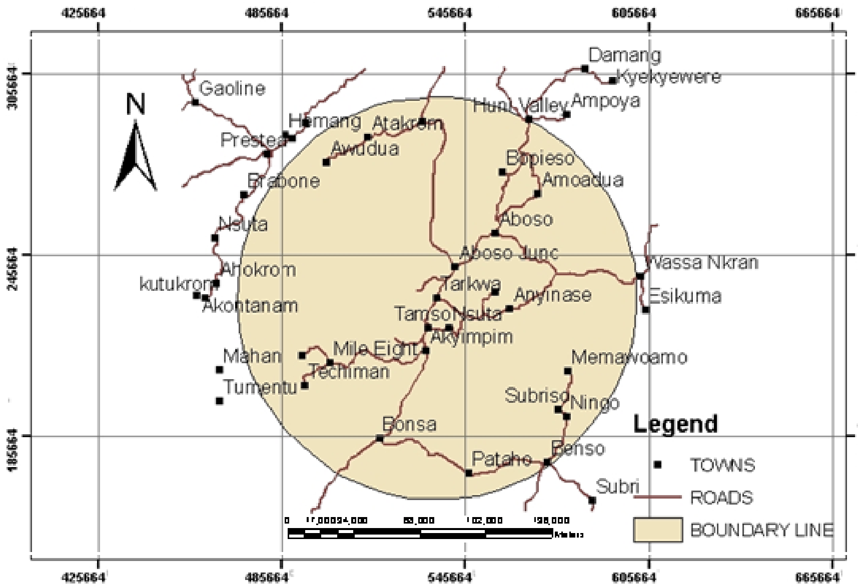

Figure 1. Study Area (Tarkwa and Its Environs).

The municipality is estimated to have a total land area of 2354 sq. km with Tarkwa having a population of 40,397 as of 2005 (Anon. 2008). Tarkwa and its environs lie within the South-Western Equatorial Zone. It therefore has fairly uniform temperature, ranging between 26˚C in August and 30˚C in March. Relative humidity is generally high throughout the year between 70-80 percent. It has a mean annual rainfall of 187.83 cm with a double maximum rainfall starting from March. Vegetation in Tarkwa falls within the rainfall belt with the height of trees ranging between 15-40 m high. They also have wide crowns. The forest is full of climbers and lianas, which are able to reach into the upper tree layer. Economic trees include mahogany, wawa, odum, sapele among others. In recent times, most part of the rich forest has been reduced to secondary forest through increased human activity. Human activities like, excessive open cast mining, farming activities and indiscriminate lumbering, have impacted negatively on the natural vegetation. The municipality however can still boast of large forest reserves like the Bonsa Reserves (209.79 km^2), Ekumfi Reserve (72.52 km^2) and Neung Reserve (157.84 Km^2) (Anon. 2008).

MATERIALS AND METHODS

Materials

In order to estimate the spatial distribution pattern of land use/ land cover in Tarkwa and its environs, Landsat TM images of a 20 km radius spanning three different years (1990, 2000 and 2007) were used together with ground observations (year 2007). Topographic map of the area obtained from the survey department of Ghana were also used. Digital Image Processing (DIP) was done using Erdas Imagine software to prepare land use/land cover maps. Land use/land cover data were interpreted and digitized from the digital images into ArcGIS shape files in the Ghana National Grid (GNG) coordinate system. Statistical analyses were done using R 2.4 software.

Methods

The methods employed in the land use/land cover mapping of Tarkwa and its environs included interpretation of the Landsat satellite images for the years 1990, 2000 and 2007; field data collection; classification; as well as accuracy assessment. The methodology applied in DIP is as shown in Figure 2.

Interpretation. A visual interpretation of the Landsat TM image of Tarkwa for the years 1990, 2000 and 2007 at a scale of 1: 30 000 were carried out. A preliminary legend was established in terms of the image characteristics, by identifying homogeneous areas in terms of the tone or colour, pattern, texture, shape, size and location or situation of the image. The visually interpreted image formed the basis for the field work design and observations.

Field data collection. The purpose of the field survey was to observe what the different image characteristics are in reality. A total of 162 field points were observed using a hand-held global position system in order to check the correctness of the mapping unit boundaries delineated on the interpreted image, to collect additional information on land use/land cover which could not be obtained from the image. In order to minimize the time spent on the field, the points were selected and mapped based on a stratified clustered representative sampling where an equal number of sample points were allocated to each preliminary legend unit (irrespective of the size of the unit and number of polygons that belong to the unit). The field data were then ordered to formulate the four field classes (multiple canopy, single canopy, shrub herbaceous, built-up/bare land). Theses classes were then correlated with the initial interpreted image to generate the land use/land cover map of Tarkwa and its environs (Figure 2).

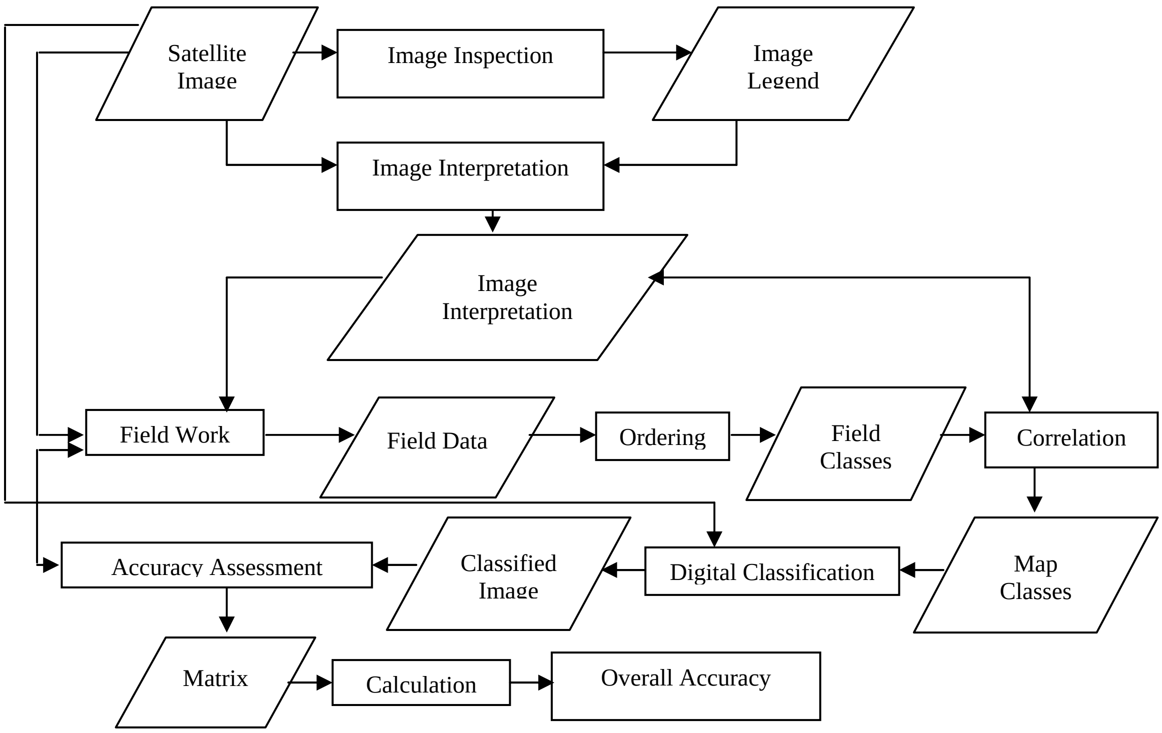

Figure 2. Flowchart of Methods.

Classification. Land use/land cover classifications for Tarkwa and its environs were derived from Landsat TM data using an expert system (or knowledge-based) method for 1990, 2000 and 2007 (Stefanov 2001). Two adjacent scenes were necessary to provide coverage of the entire area. The visible to shortwave infrared bands of the TM data were geo-referenced to the GNG coordinate system using nearest-neighbour re-sampling to estimated 0.3-0.6 pixel location accuracy. The two scenes histograms were then matched and mosaic to form a single contiguous dataset using Erdas Imagine image-processing software package. The study area was then subset out of the mosaic and atmospherically corrected. The six TM visible to shortwave infrared bands (bands 1-5 and 7) were used as the initial base data for land use/land cover classification. A soil-adjusted vegetation index (Jensen 1994) was calculated from the visible and near infrared bands and used in place of TM band 6 (the 120m/pixel mid-infrared band) to minimize shadow effects in subsequent classification. An initial maximum likelihood supervised classification (Jensen 1994) was performed on the TM subset using the four classes: multiple canopy, single canopy, shrub/herbaceous, built-up/bare land. Spatial variance texture was also calculated using the visible wavelength bands and a 3 x 3 pixel moving window. This operation highlights large changes in brightness value (or reflectance) between adjacent pixels and has been shown to correlate well with urban versus non-urban land cover types due to the small spatial scale and regularity of brightness changes typical of urban surfaces (Irons 1981; Gong 1990; Stuckens 2000).

Qualitative assessment of the maximum likelihood classification results indicated that significant misclassification was present both within and between the various shrub/herbaceous, multiple canopy, and built-up classes. A knowledge-based or expert classification system was constructed to perform post-classification recoding of the maximum likelihood classification result. An expert classification system applies a sequence of decision rules to a set of georeferenced datasets using Boolean logic (Stuckens 2000). This approach allows for the introduction of a priori knowledge into the classification data space and can significantly reduce errors of omission and commission.

Accuracy Assessment. Image classification results in a raster file in which the individual raster elements are classes labeled. As image classification is based on samples of the classes, the actual quality should be checked and quantified afterwards. This is usually done by sampling approach in which a number of raster elements are selected and both classification result and the true world class are compared. Comparison is done by creating an error matrix from which different accuracy measures can be calculated. The true world class is preferably derived from field observations. In this paper, the accuracy assessment was carried out using 162 points obtained from the four land use/land cover types of the study area. These points were determined using selective sampling method to ensure an adequate representation of the different land use/land cover types within the study area. Mining and waterlogged areas were not used for the accuracy assessment due to lack of accessibility. In order to increase the accuracy of the land use/land cover mapping of the three images, Ancillary data from visual image interpretation were integrated into the initial image classification results. A visual interpretation of the images was done using on-screen digitizing. The resulting polygons of the cover types were rasterised and incorporated into the classified land use/land cover spectral classes (Table 3).

RESULTS AND DISCUSSIONS

Results

Land Use/Land Cover Types between 1990 and 2007. The classification yielded three land use/land cover maps from the Landsat satellite images of 1990, 2000 and 2007 of the study area. The classified land use/land cover maps of Tarkwa and its environs for the years 1990, 2000 and 2007 are shown in figures 3, 4 and 5 respectively. The classification categorized the area into four (4) main land use/land cover types as detailed in Table 1. According to the 1990 land use/land cover thematic map (Figure 3), multiple canopy are predominantly found in the north-eastern and southern portions of the study area where human activities are relatively less intense whilst single canopy occurs as patches across the landscape.

Table 1. Description of main land use/land cover types in the study area

COVER TYPE	DESCRIPTION
Multiple Canopy	Rain-forest with three layers of multiple species obstructing sunlight from reaching the floor.
Single Canopy	No-shade, secondary re-growth, other trees with no overhead canopy, crop farm with mixture of crops, fallow re-growth.
Shrubs/herbaceous	Grass cover and fallow vegetation which dry up in the dry season exposing partly the soil cover, freshly cleared/planted areas of fallowed and access road corridors.
Built up/bare lands	Bare soils (mining surfaces) and built up surfaces of settlements.

Shrubs/Herbaceous is common in the central and northern part and around towns and frequently associated with built up/bare areas (Figure 3).

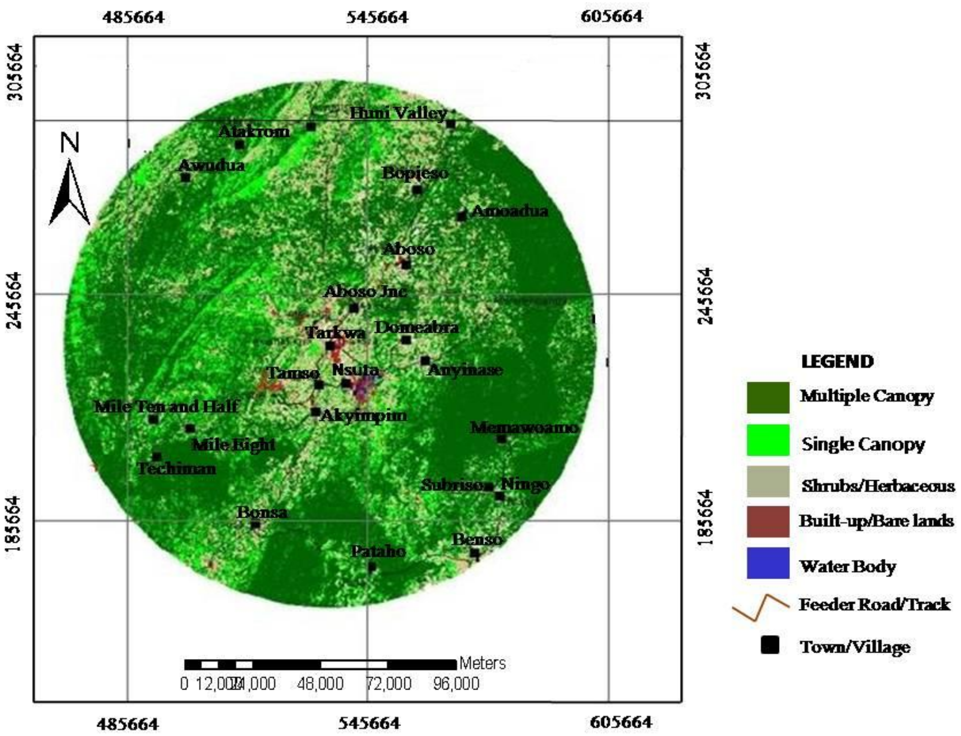

Figure 3. Land use/land cover map of the study area in 1990.

The 2000 land use/land cover map showed multiple canopy mainly in the south-eastern portions of the study area where as single canopy spreads across the entire landscape as patches except the middle and south-western portions that have been taken over by shrubs/herbaceous. A built up/bare area has increased predominantly in the central part of the study area as patches (Figure 4).

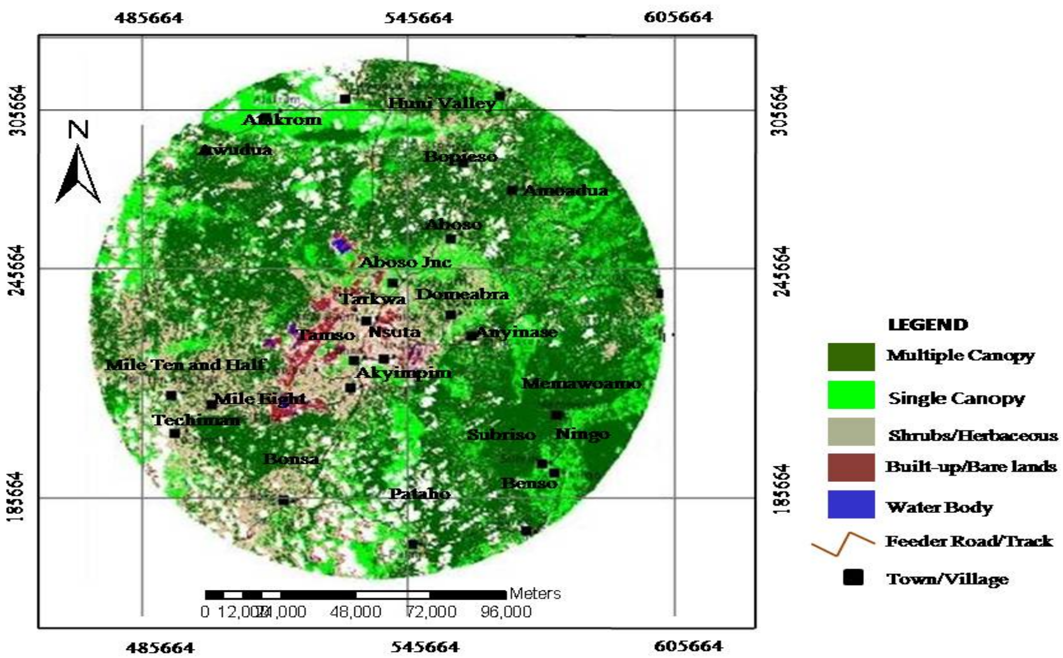

Figure 4. Land use/land cover map of the study area in 2000.

A careful perusal of the 2007 classification depicts multiple canopy as a large homogenous patch in the south and east of the study area.

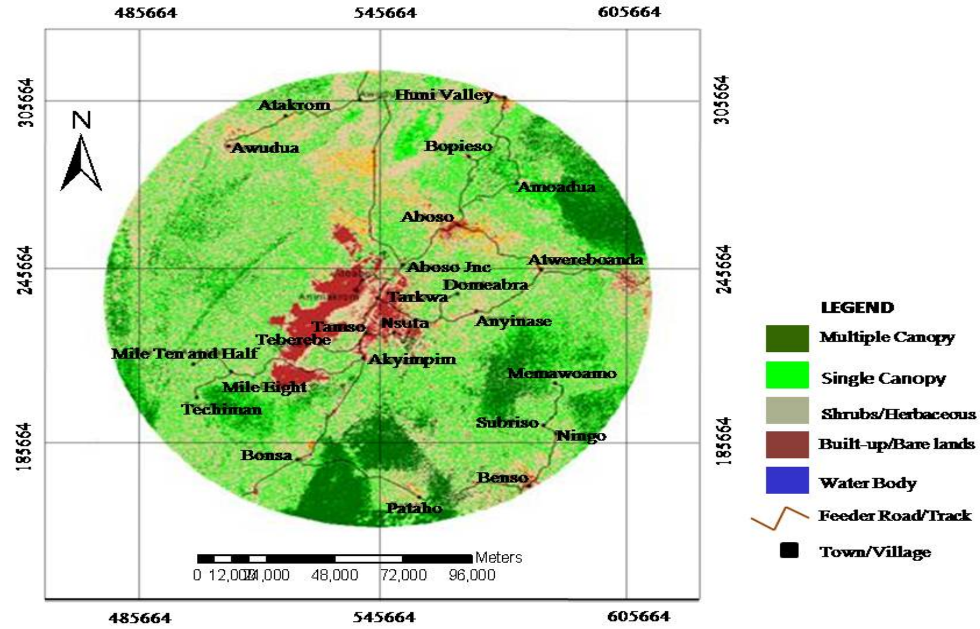

Figure 5. Land use/land cover map of the study area in 2007.

Single canopy spreads across the entire study area and has thus, taken over areas previously occupied by multiple canopies in 1990 and 2000 classification. Built up/bare land has increased as large strips in the central as well as the fringes of the study area. Shrubs/Herbaceous is scattered across the landscape but not so much in the west as shown in Figure 5.

Table 2. Land use/land cover areas for the period under study

Cover Class	Areas Covered					
	1990		2000		2007	
	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Multiple Canopy	78204.69	75.07	59041.28	57.17	15568.74	12.44
Single Canopy	23582.70	22.64	23309.01	22.57	39618.54	31.64
Shrubs/Herbaceous	320.04	0.31	17941.77	17.37	64615.34	51.61
Built-up/Bare lands	2073.78	1.99	2987.64	2.89	5397.71	4.31
Total Area	104181.21	100.00	103279.70	100.00	125200.33	100.00

Table 2 shows that multiple and single canopies forms the major land use/land cover representing 75.07% and 22.64% of the study area respectively in 1990. It is followed by built up/bare land (1.99%) and shrubs/herbaceous (less than 1%). In 2000 the area experienced some amount of change in land used/land cover as shown in Table 2. Again multiple and single canopies formed the major land use/land cover occupying 57.17% and 22.57% of the study area respectively. Shrubs/herbaceous accounted for 17.37% whilst built up/bare land gave 2.89% of the area. The classification for 2007 revealed a considerable amount of change in the cover types. Multiple canopy reduced to 12.44% with single canopy increasing to 31.64% of the area. Shrubs/herbaceous obtained the major cover representing 51.61% and built up/bare land gaining 4.31% of the area under consideration.

Accuracy Assessment. The accuracy of the classified Landsat 2007 image was assessed using 162 reference points to obtain error matrix and kappa statistics of 77.5% and 0.75 respectively. The integration of the classified image with ancillary GIS data (visual interpretation data) increased the accuracy of the classification to 86.67% and a kappa of 0.87 (Table 3). However, the accuracy of the 1990 and 2000 could not be statistically assessed but was ascertained with the use of local knowledge and validated with information on "no change area" in the 1990 and 2007 images.

Table 3. Accuracy assessment.

Class Name	Reference Total	Classified Totals	Number Correct	Producers Accuracy (%)	User Accuracy (%)	Kappa
Multiple Canopy	21	21	19	90.48	90.48	0.91
Single Canopy	22	24	18	81.82	75.00	0.79
Shrub/Herbaceous	20	16	16	80.00	100.00	0.81
Built-up/Bare-land	12	14	12	100.00	85.71	0.95
Total	75	75	65			
Over all Accuracy	**86.67**					
Over all Kappa	**0.87**					

Land Use/Land Cover Change (1990 – 2007). A comparison of 1990, 2000 and 2007 land use/land cover maps (Figures 3, 4 and 5) shows different levels of change in the cover types due to the conversions between land use/land cover types. Figure 6 and Table 4 indicates the extent of changes in size from 1990 to 2007.

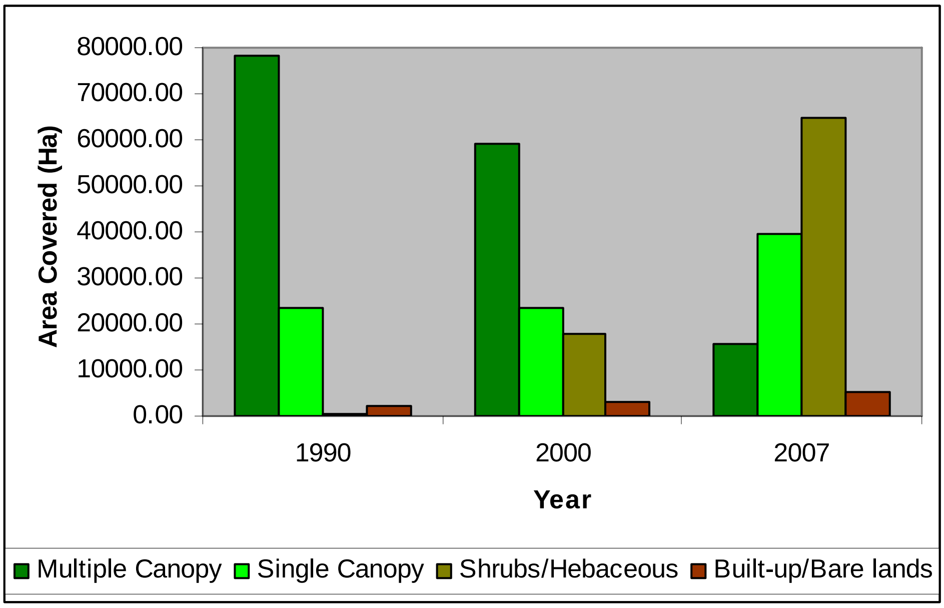

Figure 6. Changes in land use/land cover types in 1990 and 2007.

Table 4 shows that multiple and single canopies decreased in size (24.5% and 1.16% respectively) where as shrubs/herbaceous and built up/bare land increased between the periods 1990 and 2000 culminating in 5506.10% and 44.00% respectively. Between 2000 and 2007 multiple and shrubs/herbaceous experienced the most negative (73.63%) and positive (260.14%) changes respectively. Built up/bare land and single canopy increased in size during the same period by 80.67% and 69.97% respectively. A careful perusal of Table 4 reveals a considerable amount of changes occurring between 1990 and 2007. While multiple canopy lost a substantial area of 62 635.95 ha, which is about 80.09% of the previous extent of multiple canopy, shrubs/herbaceous increased by gaining 64 295.30 ha, representing 20089.77% of the existing shrubs/herbaceous in 1990. A total of 3 323.93 ha of built up/bare land were gained accounting for 160.28% and single canopy increased by gaining 16 035.84 ha representing 68.00% of the entire area over the 17 years under consideration.

Table 4. Land use/land cover change matrix

Cover Class	Changes between:					
	1990 & 2000		1990 & 2007		2000 & 2007	
	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Multiple Canopy	-19163.41	24.50	-62635.95	80.09	-43472.54	73.63
Single Canopy	-273.69	1.16	16035.84	68.00	16309.53	69.97
Shrubs/Herbaceous	17621.73	5506.10	64295.30	20089.77	46673.57	260.14
Built-up/Bare lands	913.86	44.07	3323.93	160.28	2410.07	80.67

Discussions

Land Use/Land Cover Classification and Accuracy Assessment. The over all land use/land cover classification accuracy of the 2007 landsat image was 86.67% and kappa statistic of 87%. These results generally suggest a good conformity between the classification and the actual land use/land cover categories with few misclassifications of pixels occurring across nearly all the cover types. The accuracy level is within the 85% and 90% classification accuracy standards predicted by Campbell (2002). The accuracy is also consistent with the results obtained by Kiage (2007), and with respect to the standards of Campbell (2002).

The high levels in classification accuracy and kappa statistic could be attributed to the incorporation of geographic information systems (GIS) ancillary data into the initial spectral clustering of the 2007 landsat image. Another reason could be the large number and the evenly distributed nature of the 162 field validation points. The third reason could be due to the fact that the reference points were collected in the same year as the 2007 satellite image was obtained. Even though, the classification accuracies in 1990 and 2000 images could not be statistically assessed, due to the unavailability of reference data. However, views gathered from the local people on the historical land use/land cover of the study area coupled with information derived from "unchanged" areas in the 1990 and 2007 landsat images assisted in the assessment of the classification accuracy.

Land Use/Land Cover Change. Over the 17 years (1990 – 2007) study period, Tarkwa and its environs experienced land use/land cover conversions of multifaceted nature, mainly attributable to urban expansion prevailed more prominently in areas associated with existing settlements/towns and roads, whereas significantly, mining expansion activities featured more in influencing conversion in areas distant from the communities. Two distinct land use/land cover conversion pathways with several direct and proximate causes were observed in the area. The first land use/land cover conversion pathway starts with gradual modification and eventual conversion of multiple canopy to single canopy and depending on the intensity and type of human activities involved, single canopy areas are either allowed to be converted to built up/bare land as a result of surface and/or mining and subsequently regenerated to shrubs/herbaceous. This trail of land use/land cover conversion is commonly found in the central and northern portions of the study area where physical expansion is relatively minimal compared to settlement expansion. This underlying mechanism of land use/land cover change reflected in the loss of multiple canopy by 80.09% and the resultant increase in shrubs/herbaceous (20089.77%) and built up/bare land (160.28%) as shown in Table 4 and Figure 5. In view of this, shrubs/herbaceous and built up/bare land areas serves as the intermediary land use/land cover that derive the conversion loop depending on the factors at play.

The second pathway involves a complete and permanent transformation of natural vegetation (multiple and single canopies in particular) to non-vegetated built up/bare areas with shrubs/herbaceous usually at the start-up end. This is generally observed close to existing settlements/towns especially at the northern portions of the study area (Figure 4). This observation confirmed the land use/land cover conversion patterns recognised by Duncan et al (2008) and Lambin et al (2003).

Implications for Urban Development. Over the 17 years study period, vegetated areas (VA) in Tarkwa and its environs lost over 46 000 ha where as non-vegetated areas (settlements and bare lands) gained over 60 000 ha of land. The results show a strong negative correlation (r = 0.98) between the VA and the period under study (Figure 7) culminating in the following model:

VA = -2 685.6 (Year) + 5 000 000 ----------------Eqn. 1

During this same period under study, the non-vegetated areas (NVA) showed a strong positive correlation (r = 0.94) with the years considered for the study (Figure 7) giving the following model:

NVA = 3 832.1 (Year) – 7 000 000 --------------- Eqn. 2

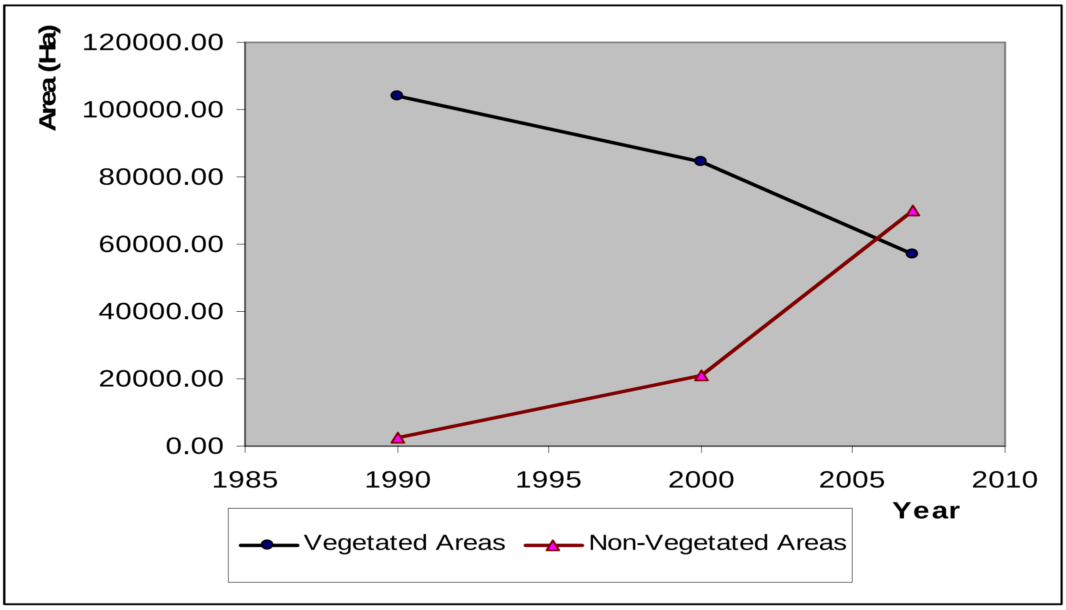

Figure 7. Trend of vegetated and non-vegetated areas in Tarkwa (1990 - 2007).

This raises concern about the ill-controlled growth in the NVA against the VA. If the current trend is not monitored and a comprehensive plan put in place for a sustainable development, by the year 2030, VA in Tarkwa and its environs would have lost 455 768 ha according to the model (Eqn. 1). The NVA would have also increased by 779 163 ha during the same year (Eqn. 2). The main deriving forces accounting for this trend in the municipality could be attributed to the large surface and small scale mining activities where large tract of both multiple and single canopies are cleared to pave way for mining as well the increasing number of communities springing up without proper planning. If the authorities in the municipality allow the situation to persist, there could be a massive ecosystem failure in Tarkwa and its environs.

CONCLUSIONS

- Four (4) dominant land use/land cover types (multiple and single canopies, shrubs/herbaceous and built up/bare land) exist in Tarkwa and its environs.
- Multiple canopy decreased in size whereas shrubs/herbaceous experienced the most negative and positive land use/land cover changes respectively.
- 62 635.95 ha of multiple canopy was lost in 2007 which is equivalent to 80.09% of the previous extent of multiple canopy (1990).
- Over the 17 years under study, VA lost over 46 000 ha whereas NVA gained over 60 000 ha.
- Finally, if the current development continuous, a total of 455 768 ha of VA will be lost whereas NVA would have been increased by 779 163 ha and this could change the balance in the ecosystem.

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