# Spatio-temporal Change Detection of Land-use Land Cover of Hong Local Government Area, Adamawa State, Nigeria

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## Abstract

The concern of the study is spatio-temporal change detection of land use land cover. Data required for the study are area cover, population and land use land cover that were generated from relevant materials and the field. The lands at images were analyzed using various GIS and remote sensing techniques. The generated data on varied land-use land covers were analyzed by comparison. The study was restricted to Hong Local Government Area. The attributes of land cover investigated are vegetation cover, agricultural land, built-up area, bare land and water body. The time frame is from 1976 to 2009 with sample years as; 1976, 1989, 1998 and 2009. The result reveals increase in population, from 11,2845 in 1976 to 170,452 in 2009, led to drift in agricultural land, bare land, built-up area, vegetation cover and water body by 11.58%, 6.96%, 1.25%,19.79% and 0.00% accordingly. Results of correlation coefficient and 't' test at 0.05% degree of freedom reveal there is relationship between population trends and drifts in land use land cover. There should be adequate planning of land use to protect environmental resources such as vegetation cover and water body from diminishing in size and utility.

***Key words***: *Land cover, Change detection, Human activities, Time and space, Population increase.*

## Introduction

From the concepts of Environmental Possibilism and Environmental Quality man has changed the natural terrain configuration (Upton, 1997; Ballinger, 2011). As a result, the diverse landuse land cover patterns of a region are an outcome of natural and socio-economic utilisation by man in time and space (land reform, 2010). For that reason, the physical characteristics of the Earth's surface does not remain static, but changes do occur due to increase in population and expansion of socio-economic activities such as arable farming, construction of structures like road networks and settlements (Rawat and Kumar, 2016). More importantly, Harris *et al.* (1998) stated that land is a precious resource that is used for construction of houses and roads; provide minerals, water, soil for crop cultivation, and its vegetation sustain animals. However, with increase in human comforts such as modern road networks, farmlands and buildings have significantly altered the natural Earth's surface (Upton, 1997).

In many developing countries, little or no attention is given to planning for and carefully controlling the use of land and its associated resources such as soil fertility, vegetation cover and water (land reform, 2010). Therefore, changes do occur, mostly in relation to the expansion of settlements, road networks and material harvesting. It implies certain land cover decrease while others increase (pollution, 2010). Land cover is the observable features of the surface while change detection is the procedure of discovering and observing the difference in a body of features by visualisation at different times (Rawat and Kumar, 2016). Hence, information on land cover is essential in monitoring the changes in landuse resulting from regular, uncontrolled progress, and destruction of environmental quality by varied demand of the increasing population (Patidar and Sankhla, 2015).

A lot of research has been carried out on landuse land cover change detection using GIS and remote sensing techniques. For example, Rawat and Kumar (2016) monitored Landuse/cover Change of Hawalbagh Block, India; Suleiman *et al.* (2014) monitored Dynamics of Landuse Land Cover Change in Ilorin Metropolis, Kwara State, Nigeria; and Peter *et al.* (2015) monitored Landuse Land Cover Change detection of Mubi Metropolis, Adamawa State, Nigeria. Researchers like Rawat and Kumar (2016), Suleiman *et al.* (2014) and Peter *et al* (2015) adapted satellite imageries, ground trothing and topographical maps to generate data on land cover attributes such as agricultural land, built-up area, vegetation cover, barren land, settlement and water body. The data were processed using diverse GIS and remote sensing techniques while the results were analyzed by comparison using varied statistical techniques. The results indicate there were considerable changes in landuse land cover in the areas. The studies recommended that for sustainable resources development people should integrate development and conservation measures. The result of studies especially those of Rawat and Kumar (2016), Peter *et al.* (2015) and Suleiman *et al.* (2014) are important by identifying the prominent landuse land covers, materials and methods. However, the studies were not restricted to Hong Local Government Area of Adamawa State neither analysed the causes of changes in surface cover nor restricted to time frame of 33 years (1976 to 2009).

The initial surface cover such as vegetation, arable land, water and bare lands varies affectedly due to the influence of climate, soil, elevation, and human control on the environment (Makinwa, 2015). In Hong Local Government Area, it was observed that there is increase in farmlands, road networks and settlement sites while vegetation cover and water body decrease. Moreover, the wetlands of DolKwabuku at Shiwa, Ngilang at Pella and Kwatudaku at Wurro Bokki that were sustainable grazing lands during the dry season (March to May) have been converted into farmlands on crops such as sugar cane, maize and rice. To this end, it is important to carry out spatio-temporal change detection study of landuse land cover, and to highlight the reasons for the changes. The emphasis is on trends detection of the spatio-temporal changes in landuse land cover. The time frame is from 1976 to 2009 with sample years of 1976, 1989, 1998 and 2009. The attributes assessed include agricultural land (farmlands), bare surface, vegetation cover, built-up area and water body which are the basic components of rural environment.

## The Study Area

Hong Local Government Area lies between latitudes 09$^0$57'N to 10$^0$32'N and between longitudes 12$^0$38'E to 13$^0$16'E as shown on Figure I. It has an approximate area of about 2,486km$^2$. The wet season is from May to October while the dry season commences from November to April. Gandapa (2014) maintains that the mean annual rainfall is 1042.8mm while the monthly average is

86.9mm. Adebayo (1999) stated that temperature of Adamawa State in which the study area is located is generally high (about 27.8$^{0}$C) throughout the year varying from month to month. The seasonal rainfall and high temperature affects landuse land cover by making changes from water body to bare land surfaces and vice versa.

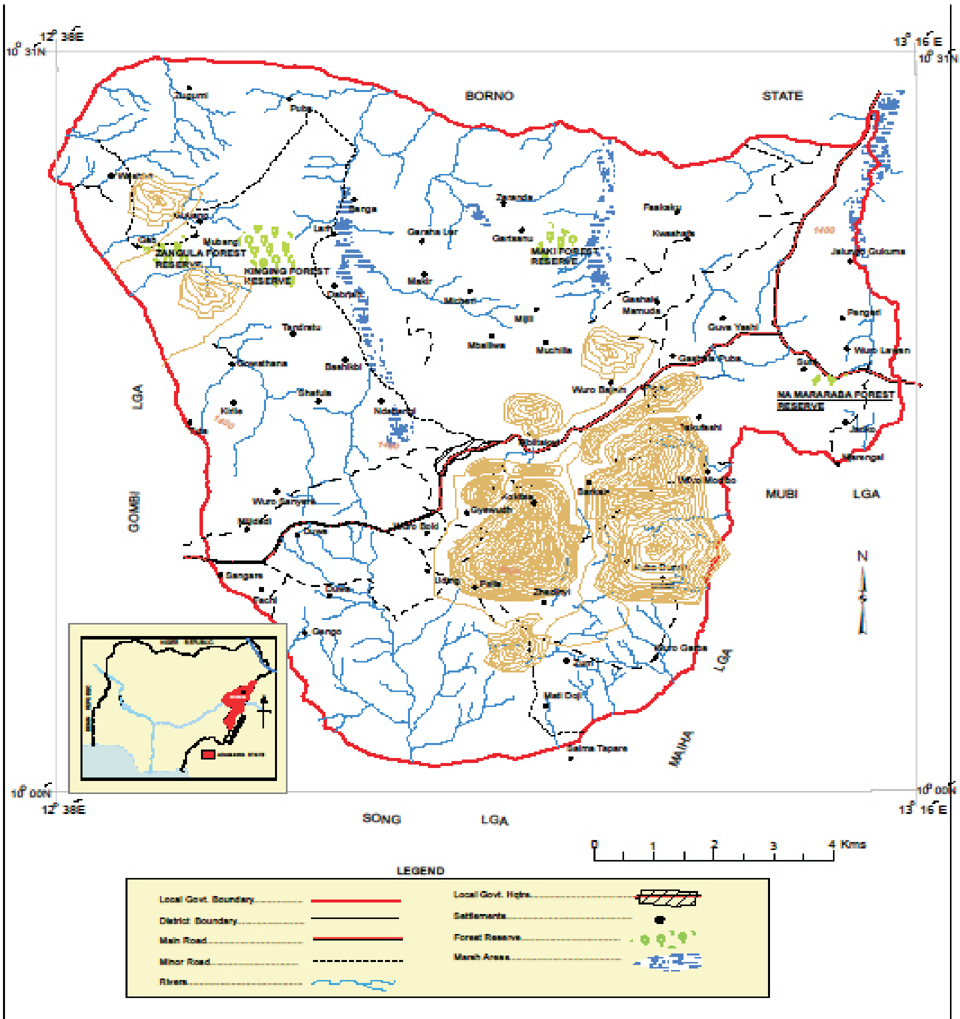


Fig. 3.1 : THE STUDY AREA
SOURCE: Fieldwork, 2010, Garkida Sheet 155

The major terrain configuration consists of bare rock surfaces, water body, farmlands, vegetation cover, settlement sites and road networks. The relief and landforms are generally hilly with highlands ranging from about 426 to 1158m above mean sea level (Garkida, Nigeria, Sheet 155). These hills exhibit significant bare surfaces in addition to influencing fluvial process that lead to the development of large gullies. The soils favour arable farming of crops such as groundnuts, guinea corn, maize, and beans. Rivers such as Fa'a, Bubulum, Ngilang and Dogwabaare seasonal.

The vegetation of the area lies within the Sudan zone (Aregheore, 2002). It is characterised by short woody plants of about less than 2m to 14m high; have scattered woody plants of about 1 to 30 stands per $100m^2$; and the girth varies from 0.18m to 2.15m while grasses form the dominant plant cover (Gandapa, 2014). The Sudan region has the greatest human influence on vegetation because of the joint effects of human activities such as bush burning, tree felling, arable farming and pastoralism that lead to varied land cover (Mohammed-Saleem, 2009). The population has increased from 112,845 in 1976 to 170,452 in 2009 (National Population Commission, 2010). Consequently, density increased from 45 persons per $km^2$ in 1976 to 69 in 2009 while the land per capita decreased from 2.2 to 1.9 hectares. The predominant economic activity is arable farming on rotational bush fallow and crop rotation.

## Materials and Methods

Data required for this study are landuse land cover, landmass, population, and causes of land cover changes. The data were generated from the field, published relevant materials and lands at images. Landsat imageries were analysed using GIS and remote sensing techniques (Patidar and Sankhla, 2015). Using ArcGIS (version 9.3) the following resolutions were adopted: 1976 MSS 50m (resample), 1987 TM 30m, 1998 TM 30m and 2009 ETM 15m (ERDAS Imagine, 1997). Likewise, to determine changes in landuse land covers signature files were developed using five colour groups (silver, dark green, light green, light brown and blue) to represent built-up area, vegetation cover, agricultural (farmland) land, bare surface and water body that were extracted from the images. These were run on a supervised classification model that generates statistics for the five signature files created (ERDAS Imagine 1997).

The five colours were compared to determine the relative amount of areas covered by the landuse land cover types. The emphasis is to isolate and determine the area coverage of the classes. Relationship between population trends and drifts in landuse land cover was determined using Pearson's product-moment correlation coefficient and 't' test at 0.05% degree of freedom to decide on the region of acceptance or rejection of the two means. The results were analysed by comparison to determine the magnitude of the changes in landuse land cover and the causes

## Results on Detected Trends in Landuse Land Cover Changes from 1976 to 2009

Figure II present the landsat images of 1976, 1987, 1998 and 2009 from which varied landuse land cover statistics were generated.

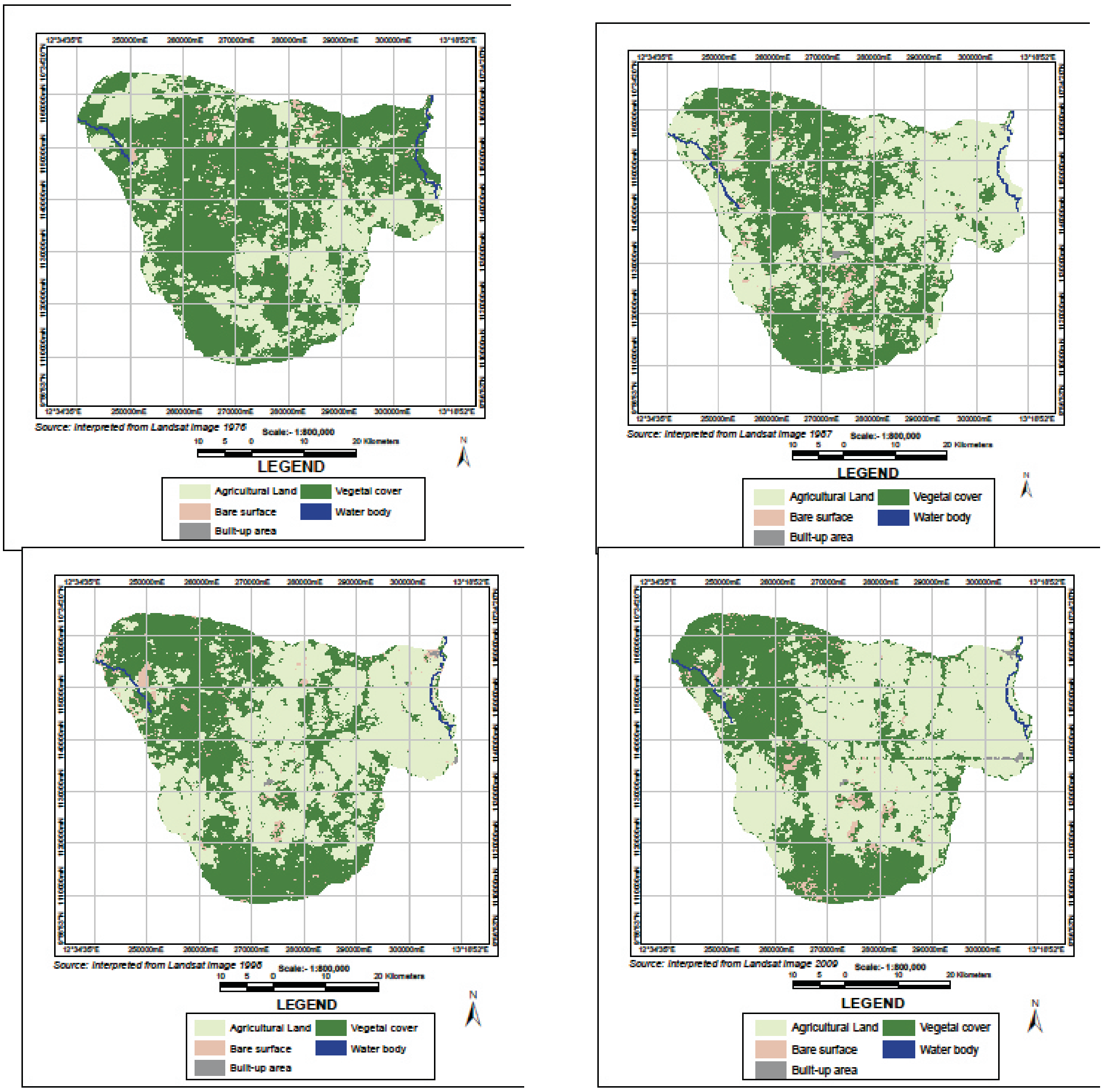


Figure II: Landuse Land Cover of Hong Local Government Area
Source: Landsat Images of 1976, 1987, 1998 and 2009

Table 1 shows the magnitude of statistics on detected trends in agricultural land, bare surface, built-up areas, vegetation cover and water body for 1976, 1987, 1998 and 2009 that were

41.23%, bare surface enlarged from 3.10% to 10.06% and built-up areas boosted from 29.65% to 0.89% while vegetation cover has decreased from 66.85% to 47.06%. Water body indicates no variation with the exception of 0.8% increase in 1987.

Table 1: Trends in detected landuse land cover change statistics from 1976 to 2009.

| Years | 1976 | | 1987 | | 1998 | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| Attributes | Area ($km^2$) | Percentage | Area ($km^2$) | Percentage | Area ($km^2$) | Percentage | Area ($km^2$) | Percentage | Percentage of variations |
| Agric. Land | 737 | 29.65 | 939 | 37.77 | 886 | 35.64 | 1025 | 41.23 | 11.58 |
| Bare land | 77 | 3.10 | 196 | 7.89 | 295 | 11.87 | 250 | 10.06 | 6.96 |
| Built-up area | 9 | 0.36 | 18 | 0.72 | 22 | 0.88 | 40 | 1.61 | 1.25 |
| Veg. cover | 1662 | 66.85 | 1331 | 53.54 | 1282 | 51.57 | 1170 | 47.06 | 19.79 |
| Water body | 1 | 0.04 | 2 | 0.08 | 1 | 0.04 | 1 | 0.04 | 0.00 |
| Total | 2486 | 100.00 | 2486 | 100.00 | 2486 | 100.00 | 2486 | 100.00 | 100.00 |

Source: Landsat Images: 1976, 1987, 1998 and 2009.

**Discussions of Results on Detected Trends in Landuse Land Cover Changes**

Results of the landsat images analyses are very similar considering the factors that have affected the landuse land cover of the study area in terms of drifts in sizes. For emphasis the factors are revisited below.

**Detected Trends in Agricultural Land**

From Table 1, farmland has increased by 11.58% from 1976 to 2009 due to increase in population from 112,845 in 1976 to 170,452. About 60% of the people practice arable farming (Gandapa, 2014). Therefore, farmland increased because there is need to produce more food to feed family members. Nonetheless, the increase in farmland is due to intensive uses of agricultural inputs such as herbicides to control weeds, and engine-driven saw to clear woody plants that facilitate the cultivation of very large farmland sizes. For example, there is massive removal of dense vegetation cover on the wetlands at DolKwabuku at Shiwa, and Ngilang at Pella for crop cultivation. In between the two ends, agricultural land decreased by 2.13% from 1987 to 1998. This is attributed to the increase in built-up area by 0.16% and bare surface (3.98%) which took over part of the agricultural land.

The result of correlation between the increasing population and agricultural land reveal high correlation and percentage of determination of r = 0.76 and 58% accordingly. Other factors such as the use of agricultural input (engine-driven saw and herbicides) that accelerate increase in agricultural land with insignificant human labour requirement accounted for 42% influence.

When the result of the two mean (population and agricultural land) were subjected to the students' 't' test, the calculated 't' value (1.66) while the critical 't' value (2.92) at 0.05% degree of freedom which confines to the region of acceptance since the difference is minor. Therefore, the null hypothesis that there is no statistical relationship between increasing population and farmland size is rejected. Hence, the alternative that there is statistical relationship is accepted.

Population per se is not in any way responsible for drifts in farmland sizes, but the increase in population of household that are predominantly farmers.

**Detected Trends in Bare Land**

The term bare land applies to those parts of the landscape that is identified on the images as spots without vegetation cover. Such places include rock outcrops, pits, gullies and access roads. Significant portion of the bare land in the base year are the exposed hard granitic rocks such as Zhegumi, Tholbang, Motuchi, Krama Hong, Kwagu and Mijili. However, Table 1 shows an increase of 6.96% from 1976 to 2009.

The increase in bare land is attributed to increase in laterite mining, roads and settlements expansion. For example, significant areas covered by vegetation in 1976 have been converted into pits, settlement site and road networks. Examples of the sample mining pits at Vami Kala'a (latitude $13^0$00'.740"N and longitude $10^0$14'.565"E) cover34,465$m^2$, and Motuku Uding (latitude $12^0$54'.879"N and longitude $10^0$09'.776"E) is 212,500$m^2$. Also, there are numerous dry river channels that do not support vegetation regeneration, neither used for arable farming nor for settlement construction. Hence, they remain bare.

Still, migration of people from homestead settlements with population less than 50 people to more populated settlements with more than 5000 people increased bare lands. For example, settlements such as Jalingo (latitude $10^0$06'N and longitude $20^0$57'E) have moved to Mbulnyi (latitude $10^0$05'N and longitude $12^0$57'E); Daku (latitude $10^0$21'N and longitude $12^0$58'E) relocated to Gartsanu (latitude $10^0$24'N and longitude $12^0$58'E); and Kwaguhimba (latitude $10^0$17'N and longitude $12^0$51'E) repositioned to Hong (latitude $10^0$13'N and longitude $12^0$55'E).

The abandoned sites became bare surface devoid of significant vegetation cover while on the destination built-up area increased. In between the two ends, the bare surface decreased from 11.87% in 1998 to 10.06% in 2009. For the reasons some bare surfaces (pits) at Kala'a have been taken over by stagnant water. Furthermore, some of the abandoned settlement sites like Jalingo (latitude $10^0$06'N and longitude $20^0$57'E) were taken over by farmlands. The result implies with increase in human activities such as mining, road networks and settlement expansions lead to increase in bare land surfaces at the detriment of vegetation and surface water covers.

Result of correlation between population trends and bare land reveal r = 0.59 and percentage of determination is 35%. Other factors responsible for increase in bare land like erosion apart from activities of the increasing population accounted for 65% influence. Comparing the critical 't' value (2.92) at 0.05% to computed 't' value (1.04) the result is within the region of acceptance because the difference is negligible. Hence, the null hypothesis that there is no statistical relationship between population increase and bare land is rejected; however, the alternative that there is statistical relationship between increasing population and bare land is accepted.

Based on this result, the increase in bare land is insignificantly (35%) caused by activities of the increasing population, but significantly (65%) by natural factors such drought; erosion, siltation and flooding especially at the datum of the hills and on floodplains of the rivers.

**Detected Trends in Built-up Area**

From the results built-up area increased from 0.36% in 1976 to 1.61% in2009. The reasons for the increase are due to increase in population from 112,845 in 1976 to 170,452 in 2009 manifested by increase in settlements sizes. There were few clustered settlements like Gaya, Gashala, Hong, Pella, Uding, Bangshika, and Zhedinyi on the pediments in 1976, but by 2009 have expanded; and other settlements such as Fa'aShibi have emerged. Another reason is the improvement in infrastructures and amenities. From the result of field study, the local government has 149 primary schools, 60 health centres and 72 post primary schools. These establishments considerably increased built-up area at the detriment of farmland and vegetation covers.

Result of correlation coefficient between increasing population and built-up area reveal r = 0.97 and percentage of determination is 94%. Other factors responsible for increase in built-up area apart from increasing population accounted for 6% influence. Comparing the critical 't' value (2.92) at 0.05% to computed 't' value (5.60) the result is in the region of acceptance because the dissimilarity is irrelevant. The null hypothesis that there is no statistical relationship between increasing population and built-up area is rejected. Hence, the alternative hypothesis that there is statistical relationship between population and built-up area is accepted.

**Detected Trends in Vegetation Cover**

From Table 1, 1976 had the highest vegetation cover amounting to 66.85%, but decreased to 47.06% in 2009. The reasons for the occurrence of high vegetation cover in 1976 was due to low population (112,845) and farmland ($737km^2$) sizes, and there were few road networks predominantly footpaths, linking the few scattered settlements. However, the decrease in vegetation cover by 19.79% is due to increase in population from 112,845 in 1976 to 170,452 in 2009.

The increase in population (57,607) caused increase in farmlands, built-up areas and bare lands by 11.58%, 1.25% and 6.9% accordingly from 1976 to 2009. Subjecting the result of the two means (population and vegetation cover sizes) to correlation analysis reveal r = - 0.75 and percentage of determination is 58%. Other factors like erosion and flooding of the floodplains that have crowded vegetation cover accounted for 42% influence. Comparing the computed 't' value (- 1.66) to critical 't' value (2.92) at 0.05% confidence limit occurs within the acceptance region for the variance is unimportant. The Null is no significant relationship between population trend and vegetation cover is rejected. Hence, the alternative hypothesis that there is a relationship is accepted.

**Detected Trends in Water Body**

From Table 1, the area covered by water body is insignificant which varied from 0.04%, 0.08%, 0.04% and 0.04% for the period under review. This is attributed to high elevation of the terrain which ranges from 426 to 1158m above mean sea level (Garkida, Nigeria, Sheet 155). Such steep slopes have fairly straight, deep and narrow stream channels that do not encourage formation of larger surface water form, but accelerate surface flow down slope.

In between the two ends, there was an increase in water body from 0.04% in 1976 to 0.08% in 1987. The reason for the increase (0.04%) is due to the numerous mining pits that retain water in addition to the sources in 1976. The pits were created by road construction companies such Diestraccavalsecia (DTV) in 1976, Armey Roadstone Company (ARC) in 1982 and Directorate of Food, Roads and Rural Infrastructure (DFFRI) in 1987. For example, at Jannumba, a pit located on latitude $10^0 18'$.635"N and longitude $13^0 07'$.905"E is 4628$m^2$ and TsakuwaKala'a on latitude $10^0 14'$.741"N and longitude $13^0 01'$.328"E is 5,031$m^2$ retain stagnant water.

However, there is decrease from 0.08% in 1987 to 0.04% in 1998 and 2009. This is due to draining of wetlands such as Ngilang for sugar cane cultivation. Furthermore, in 2004 there was rainfall of 1310mm per annum which had two implications on surface water (Gandapa, 2003). First, there was massive erosion at some catchment regions like Zhegumi and Daku which eroded the bedrock of streams like Kwadaku which led to its inability to retain water. Secondly, siltation of streams like Mulashika and DolYaduma caused reduction in water body.

The result of correlation coefficient between increasing population and water body reveal r = -0.42 and percentage of determination is 18%. The low percent is attributed to draining of surface water for sugar cane cultivation. Other factors such as hilly region that encourage high surface run-off accounted for 82% influence. When the result of the two means were subjected to 't' test, the computed 't' value (- 0.66) while the critical 't' value (2.92) at 0.05% degree of freedom, the result falls within the region of acceptance because the difference is insignificant. The null hypothesis that there is no statistical correlation between population and surface water is rejected. Hence, the alternative that there is statistical relationship is accepted.

Based on the result of this study, if the rates of landuse land cover changes continuous there will be significant degradation of vegetation cover and other environmental resources such as surface water. To this end, the result of the study is in line with those of Rawat and Kumar (2016), Patidar and Sankhla (2015) and Peter *et al* (2015). Increase in population is the predominant factor causing changes in landuse land cover categories due toincrease in farmland and built-up areas at the detriment of vegetation cover.

## Conclusion

The results of the trends detection in landuse land cover changes from 1976 to 2009 indicate there are significant changes. **V**egetation cover decreased while farmland, built-up area and bare land increased. Water body indicates insignificant fluctuation. The reasons for the increase in agricultural land, bare surface and built-up area is due to increase in population from 112,845 in 1976 to 170,542 in 2009, manifested by rise in diverse human activities such as arable farming; construction of road networks and shelters at the detriment of vegetation cover that decreased by 19.79%.

The result implies that, with increase in population there is decrease in vegetation cover. Population per se is not in any way responsible for drifts in landuse land cover, but the socio-economic activities of the people concerned. Any control plan against drift in landuse land cover should be targeted at human socio-economic activities that have direct influence on surface cover change.

## Recommendations

Based on the results of this study, the following recommendations are proffered: There should be proper management strategy against the unsustainable resources harvesting that affects surface covers such as vegetation and water. More importantly, agro-vegetation on woody plants that are important to the community should be intensified on the bare surfaces with broader perspective to increase vegetation cover. Devegetaion, especially on the catchment areas such as Zhegumi, Motuchi and Kwagu should be minimised to reduce siltation of streams.The result suggests intensive management of farmlands by application of farmyard manure, adoption of mixed cropping and crop rotation that ensures a longer period of cultivation with gainful crop yield, and broader advantage on conservation of vegetation cover. Likewise, meaningful study should be embarked upon to identify the various valuable resources of the area that are affected adversely by changes in landuse land cover for meaningful management.

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