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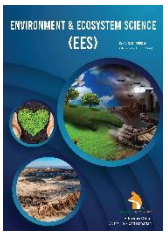

RESEARCH ARTICLE

ASSESSMENT OF AGRO-ECOLOGICAL CHANGES IN THE KASSENA-NANKANA DISTRICT(S) AS A RESULT OF THE CONSTRUCTION OF THE TONO RESERVOIR USING MULTI-TEMPORAL IMAGERY

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ABSTRACT

Land Use / Land Cover (LULC) changes has been progressive across the globe, causing the alteration and shifting of various land use/land cover features. These changes are caused by natural factors such as extreme environmental conditions, earthquakes, volcanic eruption, flooding and also human factors including agricultural expansion, urban and industrial development of infrastructure. The study combined spatial time series satellite data and field observations to observe the changes which have occurred in the land cover mapping between 1999 and 2007. Land cover features were categorized into Vegetation, Crop/farmland, Settlement, Bare land and Water body. Satellite imagery for the intervening period was used to assess the changes in LULC. LULC classes of Settlements and Bare land recorded an increase of 3.21%, and 33.1%, whereas Vegetation, Crop/farmland and Water decreased by 1.8%, 33% and 2.1% respectively. It was observed that the mean conversional change between 1999 and 2007 was 2148.55 hectares. A total land size of 9297.79 hectares did not undergo any change; conversion into Water body was 417.62 hectares, 7688.56 hectares was changed into Crop/farmland, 1137.76 hectares into Settlement, 337.17 hectares into Bare land, and 1161.65 hectares into Vegetation. It was also observed that the sharp increase in Settlement is as a result of rapid population growth and expansion of infrastructure.

KEYWORDS

Agro-ecology, Landuse/Landcover, remote sensing, Guinea savannah, Tono *Dam,*

1. INTRODUCTION

Water is both irreplaceable and unreplaceable. It is a universal solvent, which makes it a compound vector and transport medium, as well as a climate regulator, an energy carrier, and a cooling and heating agent (Bogardi et al., 2012). Water is an essential resource for human culture and ecosystems to survive (Gain et al., 2016). The construction of dams has inevitably contributed significantly to providing water for agricultural activities, industrial, and socio-economic development. A report by the World Commission on Dams indicated that dams irrigated over 30% of the 271 million hectares irrigated worldwide by the year 2000 (World Commission on Dams, 2000). These dams, however, displaced more than 40 million people, changed cropping patterns, and considerably worsened the salinization and waterlogging of agricultural land (Duflo and Pande, 2007).

Lack of access to water poses a significant threat to economic growth in most semi-arid and arid countries, including Ghana (Sayektiningsih and Hayati, 2021), as water projects such as irrigation, water supply, and hydropower serve as engines of economic growth (Kumar et al., 2008). According to the Sustainable Development Goal (SDG) 6, a country's economic strength is determined by the efficient use of natural resources such as water (United Nation (UN), 2016). Dam construction is a form of climate change adaptation that offers a potential answer for lessening its consequences. Dams provide a variety of benefits, including irrigation, flood control, water conservation, and fisheries, as well as hydroelectric power (Sayektiningsih and Hayati, 2021). Despite the various advantages of constructed dams, there are a number of negative effects on the environment and society. These include water resource imbalances between settlements, community dislocation and its inhabitants, landslides, and livestock reduction (Sayektiningsih and Hayati, 2021; Shuka et al., 2022).

Agro-ecological study examines how the major biophysical and socioeconomic components of farming systems interact (Altieri A., 2002). Land use is a term used to refer to how the land's biophysical attributes (land cover) are manipulated as well as the purpose for which the land is manipulated (Briassoulis, 2000). (Wulder et al., 2018) defines land cover as the physical or biophysical material on the surface of any piece of land which provides an insight into the environment and change drivers by informing the functional interaction between topography, climate, and soils. Land cover includes grass, trees, bare ground, and water, among others. According to (NOAA), 2021), land use and land cover are intertwined, in the sense that land cover gives additional information on human activity and specifies it in terms of commodity identification, timing, and other factors.

Changes in land use/land cover can be so widespread that they have a profound impact on the environment. They have an impact on biotic diversity, as well as contribute to local and regional climate change and

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global warming (Oliver and Morecroft, 2014; Santos et al., 2021). Changes in LULC largely lead to soil deterioration and have an impact on biological systems' ability to serve human needs. As a result of these changes, areas and individuals are more vulnerable to climatic, economic, and socio-political disruptions (Lambin et al., 2001). In this study, we used remotely sensed data and ground truth data collected by spatial and field observations to examine land use/land cover changes that occurred during an eight-year period, from 1999 to 2007. To produce and assess maps of land use/land cover changes occurring after the construction of the Tono dam, we combined commonly used computer-based methods of land use/land cover classification (the process of defining land use classes on the basis of selected diagnostic criteria) with multi-temporal image analysis, both of which are sets of tools and techniques incorporated into Geographic Information System (GIS) and remote sensing.

2. Materials and Methods

2.1 Study Area

The Kassena-Nankana district(s) lies within the Guinea Savannah woodlands. The district(s) is located between latitude 11°10' and 10°3' North and longitude 10°1' West. It covers roughly 1,674 square kilometers and stretches 55 kilometers north-south and 53 kilometers east to west. The Kassena Nankana (municipal and West) is part of the 260 Metropolitan, Municipal and District Assemblies (MMDAs) in Ghana, and forms part of the fifteen (15) Municipalities and Districts in the Upper East Region. It shares boundaries to the North with Burkina Faso, to the East with Bongo and Bolgatanga Districts, West with the Builsa District and Sissala District (in the Upper West Region) and South with West Mamprusi District (in the Northern Region) (Figure 1) (Ghana Statistical Service, 2014a, 2014b).

The drainage systems of the district(s) are centered on the Sissili River's tributaries Asibelika, Afumbeli, Bukpegi, and Beeyi. The Tono River, a tributary of the Asibelika River, has been dammed to provide irrigation facilities, which are vital to the district's economy. A few dugouts and ponds are used for cattle, agriculture, and domestic purposes (Ghana Commercial Agriculture Project (GCAP)/Ministry of Food and Agriculture (MoFA), 2018).

The district's vegetation is dominated by Sahel and Sudan-Savannah plant types, which include wide savannah with fire-swept grassland and deciduous trees (Figure 2). Along river basins and forest reserves, some of the district's most heavily vegetated areas can be found. The Sissili and Asibelika basins, as well as the Kologo and Naga forest reserves, are examples. During the dry season, the majority of these trees in forest areas shed their leaves. However, human activities have had an impact on the initial (virgin) vegetation cover over time. Dawadawa, baobab, sheanut, and mango trees are common in the research region (United Nations Programme, 2011).

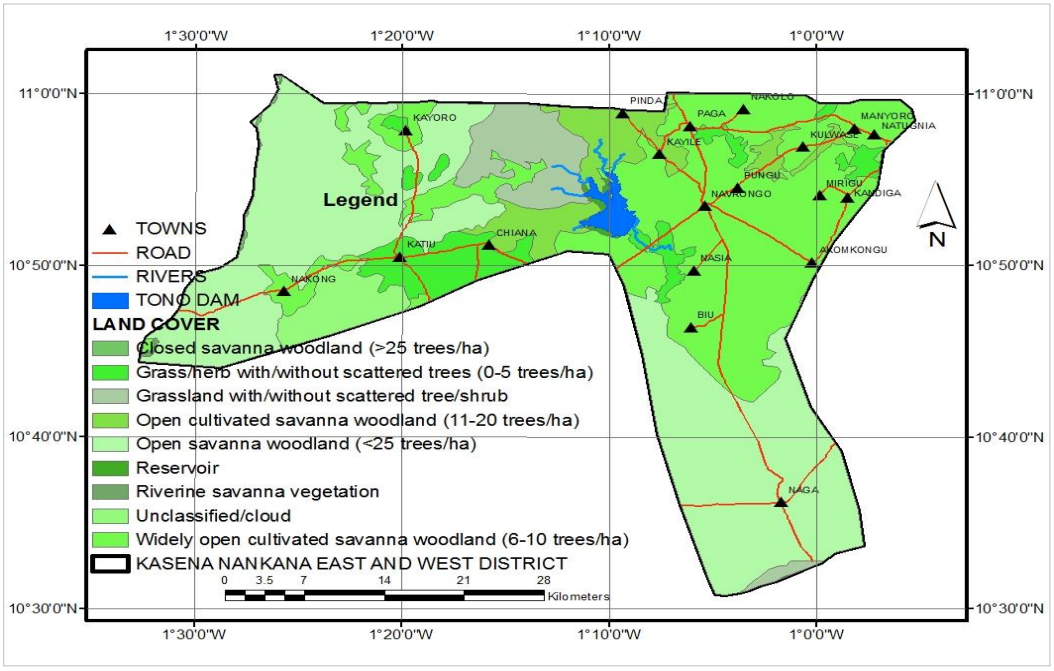

Figure 1: A Map Showing the Location of The Kassena Nankana District (s)

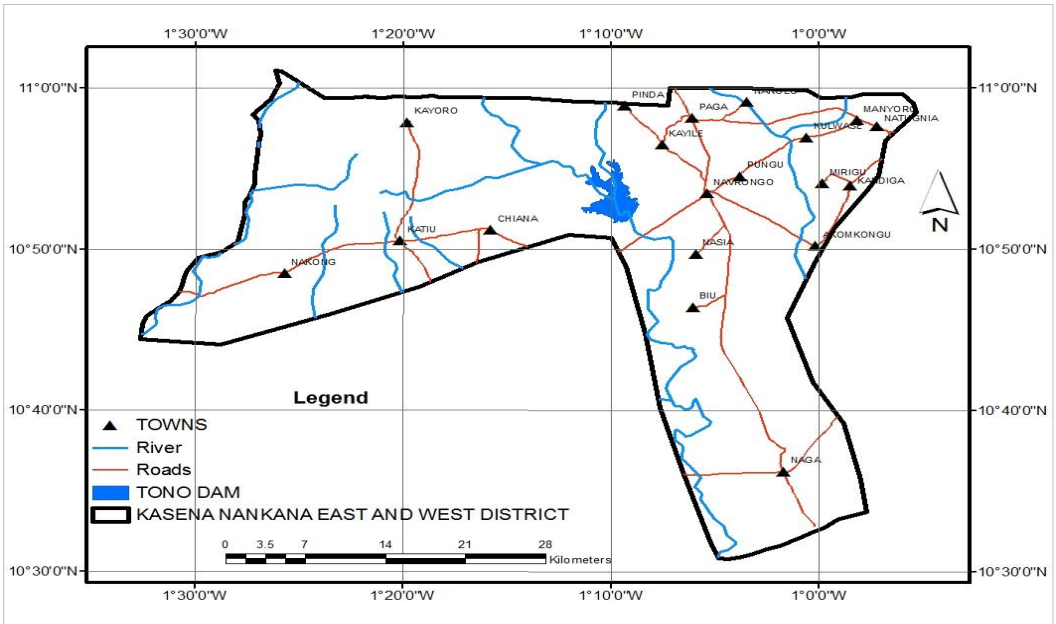

Figure 2: Map of Vegetation Cover Types in The District (s)

Table 1: Crop Output Wet Season (2002-2012). Source: ICOUR, 2014

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Maize	1.3	1.2	1.3	1.3	1.3	-	-	-	1.3	1.3	1.3
Sorghum	1.2	0	-	1.4	0	-	-	-	-	-	-
Cowpea	0.5	0.5	0.5	0.5	0.5	-	0.5	-	-	-	-
Millet	0	0.7/0.7	0.7/0.7			-	-	0.7	-	-	-
Soybean (grain)	1.3	0.8	0.9	1.3	1	-	-	0.5	-	-	-
Soybean (seed)	1.2	1.3	-	1.2	0.9	-	-	1.5	0.9	0.6	0.6

Table 2: Crop Output Dry Season (2002-2012). Source: ICOUR, 2014

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Tomato	-	-	-	-	-	-	-	-	-	-	-
Onion	7.6	0	10	-	3	-	10.5	-	-	-	-
Pepper	0.3	0.3	0.3	-	-	-	-	-	-	-	-
Cowpea	0.5	-	-	-	-	-	-	-	-	-	-
Soybean	-	-	-	-	-	-	-	-	-	-	-

2.2 Farm Activities Around the Dam

The Tono dam is one of two irrigation projects under the management of the Irrigation Company of Upper Regions (ICOUR), constructed by the Ghana Irrigation Development Authority in Ghana (Nath et al., 2020). Rice, soya bean, and tomato are common cash crops planted under the scheme. Cashew could also be one of the future cash crops (ICOUR, 1995). Pepper, spring onions, spinach, and other leafy vegetables grown locally are among the other crops. Tables 1 and 2 above show the seasonal agricultural output statistics from 2002 to 2012.

3. Methodology

Landsat images with the same sensor and pixel resolution (30m) were downloaded from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/) for the years December 1999 (ETM) and January 2007 (TM) during the dry season. Further field data was collected using a Global Positioning System (GPS) (Etrex HCx). ESRI ArcGIS 10.1®, ERDAS imagine 9.1®, DNR Garmin (map source), and Microsoft Office 2010® are the software utilized.

The GPS coordinates (field data) were transferred to ArcGIS 10.1 using the DNR Garmin software, which was then utilized to map both the validation and classification points selected from the study field. To plot the imported GPS coordinates and build all other map layers required in the research, as well as to mask the satellite picture downloaded for the study, ESRI ArcGIS 10.1® was employed. The ERDAS imagine 9.1® software was also utilized for LANDSAT image preparation and processing, field data classification and validation, accuracy assessment, and the study area change matrix. Microsoft Excel was used to create the output data and analyze it. The method used in the study is graphically represented in figure 3.

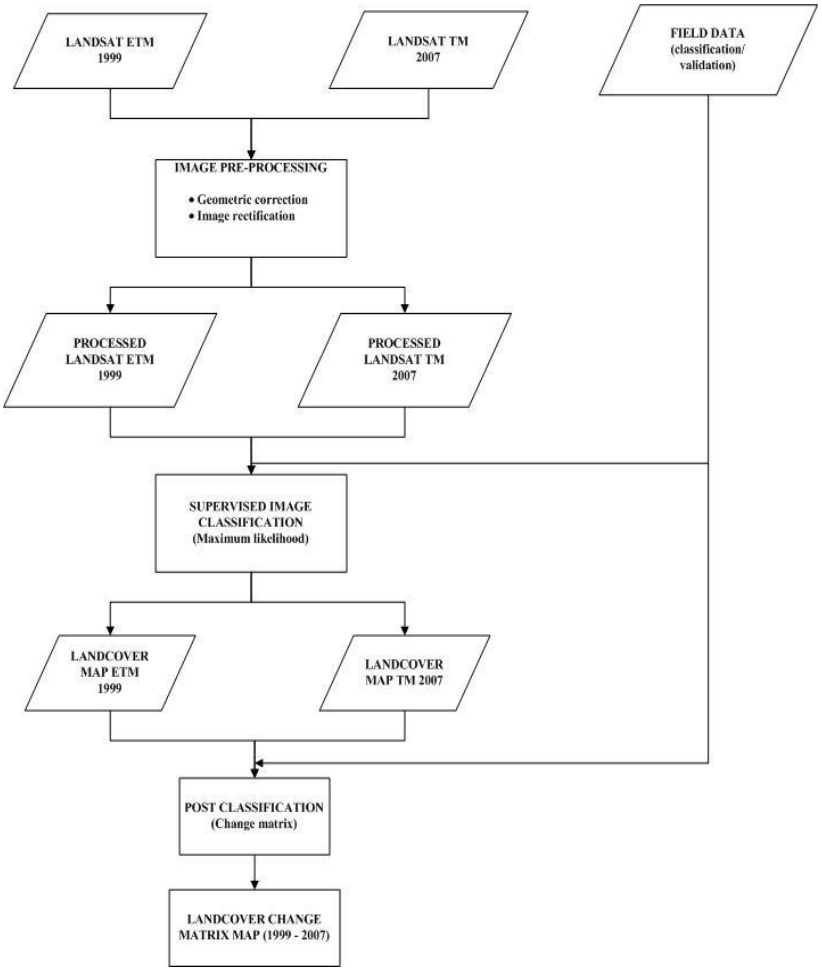

Figure 3: A flow Chart of the Research Method Used in the Study

4. Results

4.1 Classification Scheme

To enable successful spectrum selection of the numerous land use/land cover features in the Landsat images, a classification scheme was devised. This was accomplished by rigorous spatial analysis, fieldwork, and other sources such as topographic maps and Google maps. Table 3 shows the classification scheme adopted in the study.

4.2 Accuracy Assessment

A total of 78 validation points were collected from the field to validate the robustness of the maps produced for land use/land cover in 1999 and 2007. The overall accuracy assessment for the 1999 land cover map was 53.85 percent, whereas it was 67.95 percent in 2007. The accuracy evaluation report for the 1999 and 2007 land use/land covers (LULC) is shown in Tables 4 and 5 respectively.

4.3 Land Use/Land Cover Proportion

For both 1999 and 2007 classified maps, the land use/land cover proportion (area) in hectares (ha) was calculated after the satellite images were classified. Crop/farmland was the most common cover type detected in the 1999 cover map, accounting for 52.12% of total cover. This was followed by 22.79% for settlement, 9.7% for bare land, 8.2% for water, and 7.18% for vegetation (Table 6). The 2007 land cover map showed percentages of 42.75%, 26.00%, 19.17%, 6.3% and 6.0% for bare land, settlement, crop/farmland, water body and vegetation respectively (Table 6).

Table 3: Classification Scheme for the Study

Land Cover	Land Use Descriptions
Vegetation	• Forest (dense/open) • Grassland • Shrubs • Herbaceous
Farm/Croplands	• Cereals • Vegetables
Built Areas	• Residential • Institutions
Bare Lands	• Gravels • Exposed Rocks • Soil
Water Bodies	• Lakes • Streams • Rivers • Dams

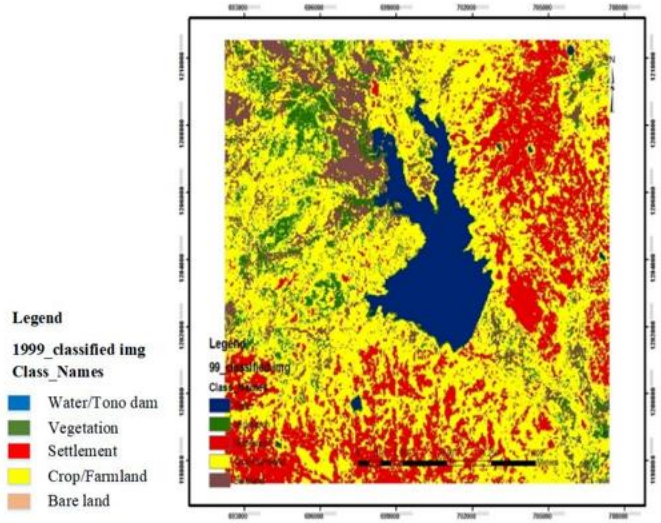

Figure 4: A Map of the Study Area's Land Use/ Land Cover in 1999

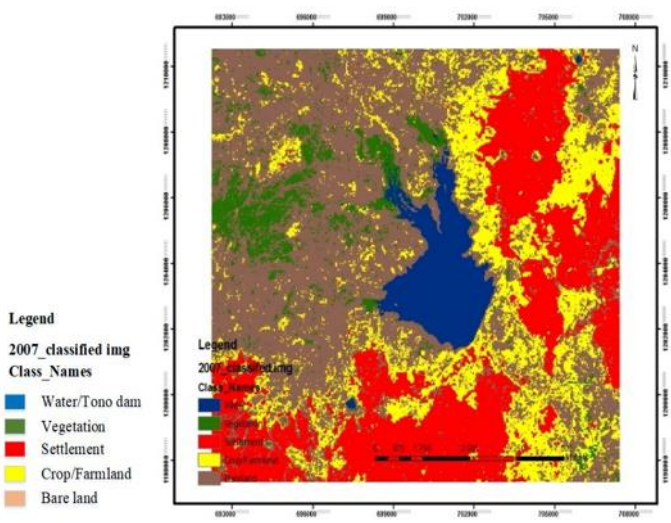

Figure 5: A Map of the Study Area's Land Use/ Land Cover in 2007

Table 4: Accuracy Assessment for 1999 Land Use/Land Cover

Class Name	Reference Total	Classified Total	Number Correct	Producer Accuracy	User Accuracy
Settlement	14	20	9	64.29%	45%
Bare land	17	9	5	38.46%	55.56%
Water	3	3	3	100%	100%
Vegetation	13	11	7	41.18%	63.64%
Cropland	31	22	18	58.06%	81.82%
Totals	78	65	42		
Overall Classification Accuracy = 53.85%					

Table 5: Accuracy Assessment for 2007 Land Use/Land Cover

Class Name	Reference Total	Classified Total	Number Correct	Producer Accuracy	User Accuracy
Settlement	14	13	9	64.29%	69.23%
Bare land	17	15	10	58.82%	66.67%
Water	3	3	3	100%	100%
Vegetation	13	12	10	76.74%	83.33%
Cropland	31	30	21	67.74%	70%
Totals	78	73	53		
Overall Classification Accuracy=67.95%					

Table 6: Percentage and Area Cover of Land Use/Land Cover Types of 1999 / 2007						
Class Name	**Area (Hectare)**				**Change (1999-2007)**	
	1999	% Cover	2007	% Cover	Area (Ha)	%
Vegetation	1440.81	7.18	1206	6.00	-234.81	-1.18
Settlement	4572.09	22.79	5210.73	26.00	638.64	3.21
Crop/farmland	10455.1	52.12	3850.02	19.17	-6605.08	-33
Bare land	1945.44	9.7	8586	42.75	6639.04	33.1
Water	1646.93	8.21	1230.39	6.13	-416.54	-2.1
Total	**20060.37**	**100**	**20083.14**	**100**	**22.77**	

4.4 Land Use / Land Cover Conversions

The tables below (table 7-12) show the results of a change matrix that was used to determine the land use/land cover conversion between the various classifications and to identify regions that had not changed between 1999 and 2007.

Table 7: Change to Settlement		
Class Name	**Area (Ha)**	**%Change**
Vegetation to Settlement	3.1725	0.28
Water to Settlement	0	0
Bare Land to Settlement	344.003	30.24
Cropland to Settlement	790.582	69.49
Totals	**1137.76**	**100**

Table 8: Change to Water		
Class Name	**Area (Ha)**	**%Change**
Vegetation to Water	207.675	50
Settlement to Water	0	0
Bare Land to Water	204.93	49.07
Cropland to Water	5.018	1.2
Totals	**417.623**	**100**

Table 9: Change to Bare Land		
Class Name	**Area (Ha)**	**%Change**
Vegetation to Bare Land	167.063	50
Settlement to Bare Land	5.1975	1.54
Water to Bare Land	0.188	0.06
Cropland to Bare Land	164.723	48.85
Totals	**337.1715**	**100**

Table 10: Change to Cropland		
Class Name	**Area (Ha)**	**%Change**
Vegetation to Crop Land	546.548	7.12
Settlement to Crop Land	1764.11	22.94
Water to Crop Land	0.5625	0.007
Bare Land to Cropland	5377.34	69.94
Totals	**7688.5605**	**100**

Table 11: Change to Vegetation		
Class Name	**Area (Ha)**	**%Change**
Crop Land to Vegetation	127.552	10.98
Settlement to Vegetation	5.625	0.48
Water to Vegetation	0.3375	0.03
Bare Land to Vegetation	1028.14	88.51
Totals	**1161.65**	**100**

Table 12: No Change		
Class Name	**Area (Ha)**	**%Change**
Crop land	2755.62	29.64
Settlement	3430.71	36.9
Water	1229.31	13.22
Bare land	1603.53	17.25
Vegetation	278.618	2.99
Totals	**9297.788**	**100**

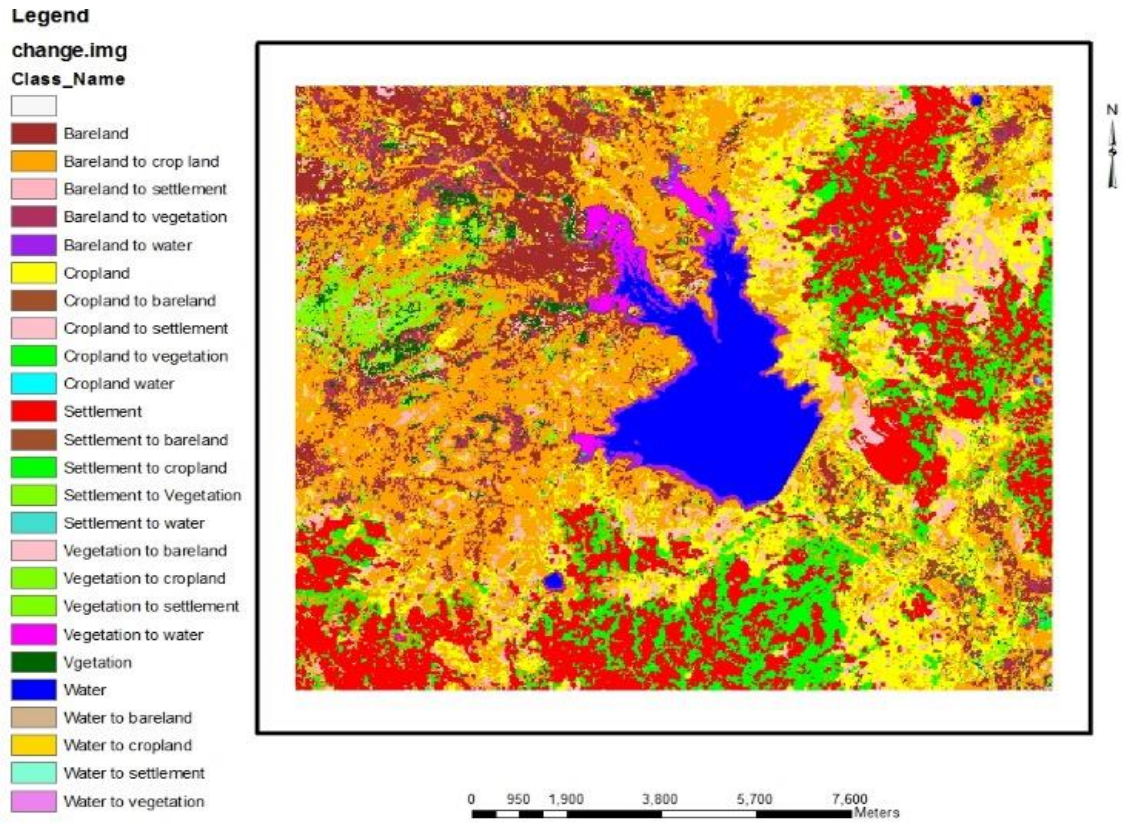

Figure 6: Change Matrix Map of 1999 and 2007

5. Discussion

The overall accuracy of the land use/land cover (LULC) of 1999 and 2007 was calculated using multiple accuracy evaluating factors as detailed in (Patel and Kaushal, 2010; Rwanga and Ndambuki, 2017). User's accuracy ranged from 45% to 100% while producer's accuracy ranged from 38.46% to 100% for the 1999 LULC, whereas user's and producer's accuracy for 2007 LULC ranged from 66.67% to 100% and 58.82% to 100% respectively (Tables 4 and 5).

The overall accuracy of the 1999 LULC assessment was 53.85% (Table 4). This low accuracy level for 1999 LULC was likely due to the year discrepancy between the year the ground truth data was taken (2014) and the year of satellite image used (1999). There had been changes in some of the LULC features between these two dates, implying that the point used to validate the map, for the most part, did not fall within the exact location of the current features, reducing the number of correct points and affecting both the producer accuracy (the classification assigned) and user accuracy (how actually classified map is real on the ground).

Water had the highest user accuracy, with three reference totals, three classed totals, and three numbers correctly entered. Water highly reflects light, therefore, despite the difficulties in getting to the water bodies on the ground due to the lack of canoes, they were easily seen on the satellite image. Cropland had the second highest user accuracy, with 18 numbers correct and 22 of the 31 reference totals (validation points) categorized correctly. It had the second best user accuracy percentage (81.82%), as well as the most classified totals and correct numbers. This implies that agriculture's spatial placement in the district had changed. Figure 4 showed that cropland was densely populated over the study area, while figure 5 showed that most of the cropland had been converted to bare land, as corroborated by the change matrix map of 1999 and 2007 (Figure 6). However, it is also possible that this change is due to the satellite images being from the dry season. Vegetation came in third, with a user accuracy of 64.29%. This is due to the fact that there were only a few rainfalls before the validation ground truth data was collected. Due to the extreme weather conditions that left most of the plants without leaves, and reflection from the soils, the vegetation class consisting of forest (opened and densed), grassland, shrubs, and herbaceous plants had this number correct. This is followed by bare land, which had a user accuracy of 55.56%. This was owing to the fact that numerous locations were exposed to the severe weather during this period, resulting in the high proportion. It is, nevertheless, easily recognizable on the field, despite the fact that it occasionally conflicts with agricultural fields. Settlement, with the lowest user accuracy had 14 reference totals, 20 classified totals, and 9 accurate numbers, resulting in a user accuracy of 45%. These changes mean most of cropland, bare land, and vegetation-covered land has been converted to settlement areas.

The 2007 LULC map had a total accuracy of 67.95%, which was attributed to the fact that the 2007 year was only 6 years different from 2014, the year ground control points were selected, as opposed to the 1999 LULC image, which differed by 15 years. With a reference total of 14, 13 classed totals, and 9 numbers correct, settlement had a low user accuracy of 69.23%. Despite its user accuracy, the difference between the correct numbers was not significant. This is due to the fact that temperature had no effect on constructed areas, especially in locations where there is almost no greenery amongst settlement. Another aspect could be the difficulty of changing a settlement in a short period of time. User accuracies for vegetation, cropland, bare land, and water were 83.33%, 70%, 66.67%, and 100%, respectively.

The low level of accuracy is generally due to inaccurate spectral response on diverse cover/feature types.

Impact of the Tono Dam on LULC

Contrary to what was observed in the 2007 LULC map (Figure 5), cropland was densely populated around the Tono dam and even beyond it in the 1999 LULC map (Figure 4). These variations in cropland confirm the crop output data from the dry and wet seasons, as reported in tables 1 and 2 by the Irrigation Company of Upper Regions (ICOUR). Tables 1 and 2 also show that crop output has decreased dramatically over the years. The decrease in crop output was due to a reduction in the amount of land that was cultivated.

6. Conclusion

The study assessed the agro-ecological changes occurring in the Kassena Nankana district (s), particularly as a result of the construction of the Tono dam in 1985. Land use/Land cover (LULC) maps for the years 1999 and 2007 were assessed and compared to ground control/truth points of LULC collected in 2014, to determine the changes which have occurred.

The overall accuracy of the two maps of 1999 and 2007, based on the 2014 control points were 53.85% and 67.95% respectively. The study showed that these low accuracy values could be attributed to the year differences between the years of the satellite images assessed and the year the ground control points were taken. It was revealed that, this was an indication that the amount of LULC which had actively changed since the construction of the Tono dam.

With user accuracies of 45% and 69.23% for settlement, and 55.56% and 66.67% for bare land for the 1999 and 2007 LULC maps respectively, the study further showed that settlement and bare land were the two land uses which highly changed, likely due to increase in built up areas and structures, as well as population, as a result of the constructed Tono dam.

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