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Application of GIS to create social media awareness to the effects of illegal mining on natural resources in the Tano North District of Ghana

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Abstract
Decisions pertaining to the maintenance and sustainability of natural resources are vital in every national development agenda. Water resources and forests are essential for humanity's survival. Nevertheless, Ghana has recently seen a lot of destruction in these resources due to "Galamsey" activities. Most communities depending on these resources for survival have been deprived of their livelihood. It therefore becomes prudent to create management tools that can help regulate the exploitation of these resources. The aim of this study was to apply Remote Sensing and Geographical Information Systems to map the catchment area of River Tano in Ghana and disseminate the results via social media. Landsat ETM imagery of the study area for two different dates (2003 and 2013) was acquired and exported into ArcGIS and geo-referenced. Resource database of the study site was then generated to evaluate the changing pattern of the river and forest around it between the two dates. The study revealed that about 7% of forest vegetation has been lost between 2003 and 2013. The river course has been channeled onto portions of land around it creating pockets of waterlogged areas (about 6% increases in water areas) in the vicinity of the river. The extent of forest cover deterioration as calculated from NDVI values has also been mapped. A map showing the status of the land area around the river was displayed in a web map application as a social media to create awareness to the effects of illegal mining on vegetation.

Keywords
Social media, GIS, natural resource, Galamsey, Normalized Difference Vegetation Index.

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Contents

1. Introduction

Natural resources are the pride of every country, and hence governments and societies take peculiar interests in their protection in order to sustain such resources [1]. Water bodies and forests are natural sources of water and food for humanity. Most inhabitants in a community where these resources are located depend on them for their livelihood [2]. These resources provide numerous benefits ranging from food to foreign exchange earnings to the community and the nation at large. Protection of these resources is therefore vital to their sustainability and maintenance so that they could continue to provide the needed support to human livelihood [3]. The protection of natural resources is essential because they could be threatened by the community who benefit from these resources. In addition, the alteration of these natural resources could greatly influence the changing patterns of the climate [4]. Over-exploitation, pollution and improper maintenance of the natural resources within a country have been reported by a number of researchers [5-7]. Such activities threaten the sustainability of the resources to continue to provide the benefits that improve livelihoods of people [8], a situation that is gradually surfacing in Tanoso in the Tano North district of Ghana where one of the rivers in Ghana (River Tano) traverses. River Tano serves as a source of domestic water supply for most communities within its environs. The river basin traverses three administrative regions in Ghana: Ashanti, Brong-Ahafo and Western regions. The highest percentage of the total landmass is occupied by arable lands. Commercial farming of cocoa, plantain and other commercial and food crops are located close to the river. Only about 10% of the landmass is used for human settlement. The forest cover represents the second highest land use pattern in the basin and follows closely after agricultural lands, occupying about 50% of the total landmass of the basin. The remaining 40% of the landmass is covered by forests which are largely protected areas [9]. The Tano basin has its source within the forest in Pooyem, 4 Km from Techiman, and flows roughly north-south into the sea. The basin enters the sea outside Ghana, in Cote d'Ivoire. The main tributaries of the Tano River system are the Abu, Amama, Bo, Disue, Soro, Atronie, Sabom, Gaw, Kwasa, Sumre, and Totua. The Tano River System has a total catchment area of about 15,000 Km2 shared between Ghana and Cote D'Ivoire. About 93% of the drainage area is within Ghana whilst the remaining 7% is in the Cote D'Ivoire. The Tano River Basin constitutes a major source of domestic water supply from surface and groundwater. Other uses include industrial, mining and irrigation [9].

Irrespective of the uses of this water resource, it is being threatened, especially by the activities of illegal mining along the river basin [10]. And the situation along the Tano River in Tanoso of the Tano North District of the Brong Ahafo Region in Ghana is no different [11]. Illegal gold mining activities, popularly known as 'galamsey' has reportedly been on the increase in Ghana [12-14]. The youth living in communities close to these water resources resort to over-exploitation of underground and alluvial minerals as their source of livelihood [15]. They apply all sorts of mining techniques to extract the underground minerals disregarding its effects on the environment, especially on the natural resources particularly the river bodies and forests. Consequently, the rivers are left extremely polluted and the forests highly degraded [16]. The communities become affected and their sources of livelihood are threatened. These communities are faced with food insecurity and lack fresh water for domestic uses, which subsequently affect the health of the community. Although policymakers mandated to manage freshwater resources in Ghana have set up plans that coordinate activities and initiate interventions for the ecological health of the Basin [17], these 'galamseyers' continue to operate illegally and the basin continues to lose its fresh water whilst the forest continue to be depleted [10]. The aim of this study, therefore, was to apply Remote Sensing (RS) and Geographical Information Systems (GIS) technologies to evaluate the health of vegetation in the catchment area of River Tano in Tanoso, a farming community in Tano North district where illegal mining activities have taken over farming, causing that stretch of the river to dry up in early 2017 during the dry season affecting most communities who depended on the river for water.

2. Materials and Methods

2.1 Study area description

Tanoso is one of the communities along the Tano River located in the Tano North district of the Brong Ahafo Region in Ghana. The town is geographically located on latitude 7^o 21' 27" N and longitude 2^o 58' 39" W. The extent of the study area covers purposely used in this study is about 19.6 hectares. The indigenes in the community are mostly farmers who farm along the banks of the river, as the river is used to irrigate their farmlands; and others are artisans who use clay materials in moulding earthenware. The youth in this community also engage in small-scale mining activities in search of alluvial gold as their livelihood. The main occupational activities in this community, which are farming and artisanship, are gradually shifting to small-scale mining, which the youth see as more lucrative. Fig. 1 shows the location of the study area whilst Fig. 2 shows the satellite imageries and boundaries of the extent of the study site.

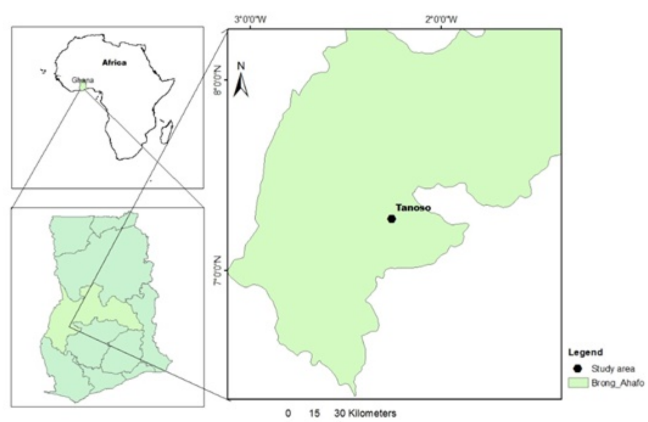

Figure 1. Map of the study area.

2.2 Satellite imagery acquisition and processing

The satellite imagery of the study area was acquired from Landsat google earth imagery. Two imageries of the location were acquired at different dates: one in the year 2003 and the other in the year 2013. These two images were selected to achieve the aim of the study which seeks to identify the vegetation change over a specified period; which is ten years for this study, and also due to the availability of clear image data. The study location was specified and the boundaries were well defined. Four coordinates were taken from the image (from the four corners of the image) and used for georeferencing the image in ArcGIS ArcMap 10.4.1 software based on the first order (affine) transformation. The image was then saved and imported into ArcMap where it was georeferenced in order to fit into the real world location after the geometric correction and registration. The root means square error, which should be well below one, was used to assess the accuracy of the registration and correction of the image [18].

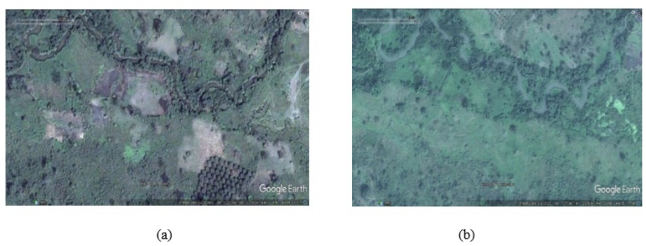

Figure 2. Landsat ETM satellite imagery of the study area for the years 2003 (a) and 2013 (b).

2.3 Preparation of the Land use map of the study area

Unsupervised classification based on iso cluster using spatial analyst in ArcGIS was used to group the classes according to their spectral reflectance. For the purpose of this study, four classes were specified and the features within the classes were grouped accordingly as per their spectral reflectance values and the verified features on the ground.

2.4 Determination of normalized difference vegetation index of the study area

The image analysis tool in ArcGIS was used to generate the normalized difference vegetation index (NDVI) for the two images acquired for the study. The NDVI is a standardized index that allows an image to be generated displaying relative biomass, thus greenness of an area [19]. This index makes use of the contrast of the characteristics of two bands from a multispectral raster dataset which is the red (R) and near infra-red (IR) bands and it is the most used vegetation index to assess vegetation of an area [4]. The NDVI was employed in the study to monitor the vegetation in the area because it helps to compensate for changing illumination conditions, the surface slope of the study area, aspect and other external factors. The equation used to generate the NDVI output as reported by and Mas [20] and Fung and Siu [19] is given as follows:

$$\text{NDVI} = \frac{IR-R}{IR+R}$$

The NDVI was calculated from the bands 7 (IR portion) and 5 (R portion) of the Landsat ETM imagery. The images were enhanced using the nearest neighbour enhancement and stretched based on the percent clip.

2.5 Creating a Web Map application and sharing map application on social media

The ArcGIS web application builder was used to create a web map application of the four classes of land use identified. The application is an online map viewer that was customized by adding digitized layers of the various classes of land use as point features and overlaying them on the base map of the study area.

3. Results and Discussion

3.1 Classified Land use map of the study area

Features of land use classes identified around the Tano River in the georeferenced imagery of the study area (RMSE = 1.86 e-0.005) after geometric corrections have been applied to the image were the evergreen forest, transitional zones which were forest lands that have been converted gradually to agricultural lands close to the river, wetlands and water bodies which comprise of the river and other pockets of water in the study area (Fig. 4). The dominating land use change of the study area was the transition of forest lands into agricultural land uses, followed by wetlands (Fig. 3), which possibly could have resulted from the activities of illegal mining. The bare soils have reduced massively in size and transformed into other land use form (wetland or transition). It is therefore inferred from the land use classes obtained that agricultural activities along the banks of the river have been intensified within the years transitioning part of the forest lands. The expansion of the wetlands and bare soils are likely due to the activities of extensive mining as observed from the satellite imageries which has reduced the vegetation cover of the area [18] and the river course rechanneled onto the land areas illegally for the mining activities thereby polluting the river [9].

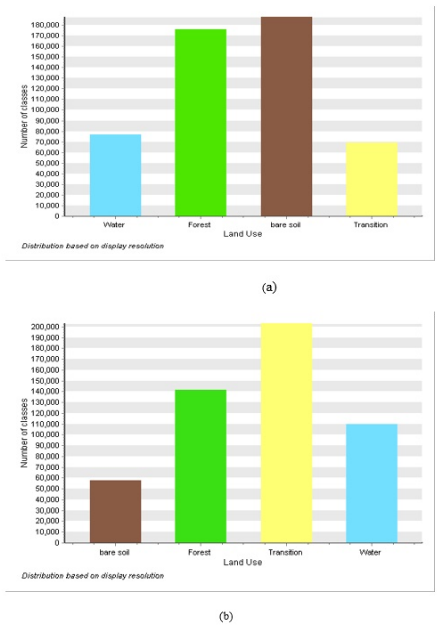

Figure 3. Classes of land use pattern in the study area for the year 2003 (a) and 2013 (b)

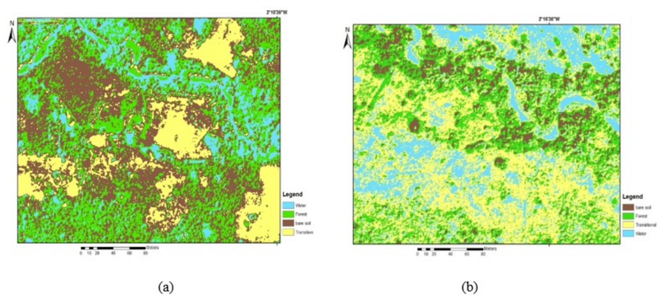

Figure 4. Map showing the spatial pattern distribution of land use classes in the study area for the year 2003 (a) and 2013 (b).

3.2 Normalized Difference Vegetation index maps of the study area

The maps showing changes in vegetation cover of the 19.6 ha land around River Tano in Tanoso, Brong Ahafo region between 2003 and 2013 have been presented in Fig. 5. The index outputs values between -1 and 1. Negative values of NDVI represent water and values close to zero represent bare soil (depleted vegetation). Moderate values (0.2 to 0.3) indicate shrubs or grassland while NDVI values close to 1 (high values) represent temperate and tropical rainforest areas of the study location [21].

The lowest NDVI values generated for the 2003 imagery were -0.11 to -0.24 and that of 2013 imagery was -0.17 to -0.29. The NDVI map of the 2003 imagery displayed large portions of vegetation cover, as compared to the NDVI map of the 2013 satellite imagery. The total number of classes representing the four identified land use patterns in the study area, according to the generated histograms, show 522 000 classes in 2003 and 528 000 classes in 2013. Forest cover shows about 175 000 classes, covering 33% of the land area in 2003 and 140 000 classes, also covering 26% of the land area in 2013 based on the spectral display resolution (Fig. 5). Results obtained from the number of classes in the spectral display of features indicate that about 7% (1.4 ha) of the forest cover in the study area has been lost to other uses. The results also revealed that water area (including wetlands and muddy areas) had increased from 15% to 21% within the 10 year period in the study area. Even though climatic changes over time periods could cause changes in vegetation cover, human intervention rapidly deteriorates the destruction of natural resources, and knowledge about the relationship between human and natural processes better enhance decisions pertaining to their management [22]. Human interaction with the natural resource in the area such as the activities of illegal mining during the period of 2003 and 2013 might have been intensified and as a result destroyed the vegetation cover of the study area leaving pockets of water that were channeled from the river for galamsey activities in the year 2013 resulting in the increase of water area by 6%.

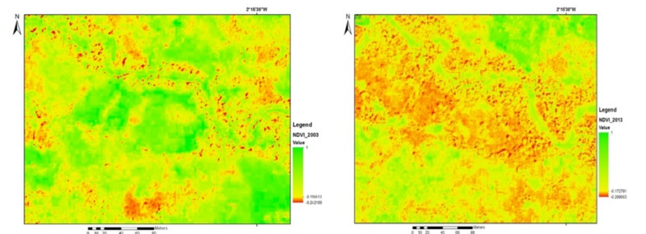

Figure 5. Generated normalized vegetation index maps (the year 2003 (a) and year 2013 (b)) of the study area depicting the extent of vegetation cover change

3.3 Web Map Application and social media integration

The built web map application has been displayed in Fig. 6. The Fig. shows the interface of the built application and the URL through which it could be assessed in the public information map.

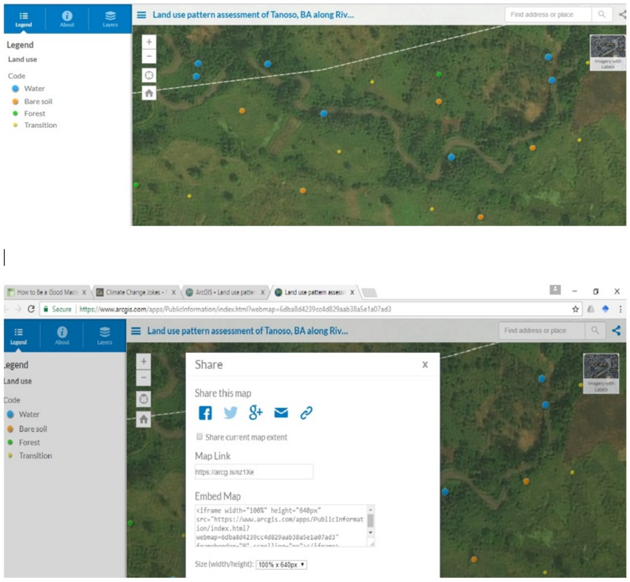

Figure 6. Web map application of the results of effects of illegal mining on vegetation and water in Tano north district of Ghana

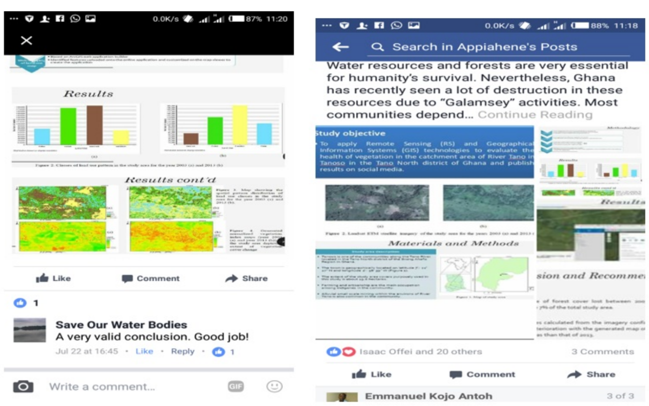

Figure 7. Results of web map application shared on Facebook (social media) to create awareness to the effects of illegal mining on vegetation in Tano North District of Ghana

4. Conclusion and Recommendations

The study demonstrated the application of GIS in the fight against illegal mining through the mapping of the land use changes over a 10 year period. The percentage of forest cover lost between 2003 and 2013 was estimated to be 7% (1.4 ha) of the total study area. The extent of forest cover deterioration as calculated from NDVI values of the imagery confirm the extent of forest cover deterioration with the generated map of 2003 displaying more green areas than that of the map of 2013. A generated map showing the status of the land use pattern changes and the vegetation changes has been uploaded in a web mapping application which was shared via social media to create awareness about the dangers of illegal mining on the forest and water resources in communities where these water bodies traverse.

The study recommended that future review of the work should concentrate on the volume of water lost from the river in that period through channeling the course of the river onto the land areas for other uses. Also, the pollutants in the river can be identified so that remediation can be effected accordingly. Future works should also look at mining the opinions and analysis of people's sentiments (is the computational study of public's feelings, assessments, approaches, and reactions concerning things, persons, topics, happenings, subjects and their characteristics[23] within a period for instance 6-12 months on the study results after it was shared on the various social media platforms such as Facebook and Twitter by the general public as done by [24]. This would enable us to know the impact of the study results on the general public and how it is affected their attitude towards galamsey and other human activities that affect our natural resources.

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