

Change Detection Analysis on the Impact of Illegal Mining (Galamsey) In Ghana; A Case Study Focusing On Land Cover Changes in Some Selected Districts within the Ashanti and Central Regions of Ghana.

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Key Words: Illegal Mining, Galamsey, Remote Sensing, Satellite Image

ABSTRACT

Illegal mining (Galamsey) has become a national pandemic over the past decade resulting in the destruction of natural resources (Land, Water, Forestry) mostly within the Ashanti, Western, Eastern, Central and Brong Ahafo Regions of Ghana. There have been several efforts by the government and some well-meaning personalities including traditional leaders, university lecturers, environmental professionals, social commentators, etc. to help halt these activities, remedy the effects and initiate the structuring of relevant policies and laws for proper mining activities by small and medium scale enterprises. This paper analyzes all the changes spanning from Galamsey activities in the selected districts to assist decision-making bodies in preparing the best strategies in restoring its effects. Four remotely sensed images were adopted for the analysis; LANDSAT Images dated January 1, 1991, April 2, 2001, December 31, 2015 and January 3, 2018. Radiometric, spatial and spectral enhancements where performed to enhance the quality of the images. Vegetation and Water Indices were generated for analysis. Maximum likelihood Supervised Classification was performed on the images. Finally, change detection analysis was performed by observing the Image Difference technique and the Post Classification Technique. The results clearly show that there have been drastic changes to our land cover over the past two decades with most of the changes occurring in the past few years. The Land being degraded as a result of Galamsey activities grow each year with the total area covering approximately one third of the total area observed as human settlements. To help monitor land cover changes that have already taken place, activities currently ongoing and activities of the future, we need to invest into remote sensing technologies and commission a division to provide decision makers with spatial analysis to assist our development as a nation.

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INTRODUCTION

Mining in Ghana is an ancient vocation that earned us our title as the Gold Coast. Before the days of our dependency and independence from the British (Colonial masters), our economy as a country stood and stands not only because of our agricultural riches but also our mineral resources, an identity that rightfully earned its place on our national flag. Amongst the numerous mineral resources being mined in Ghana today, gold maintains its place on top as the mineral with the biggest earning power. In Africa, Ghana is only second to South Africa in terms of discovered gold reserves and maintains its spot amongst the world's top ten gold producers. This very viable economic pillar has been a blessing to our finances but a plague on our environment. Our environment remains plagued by illegal mining activities (Galamsey); activities that have gained momentum in the past few years. The government of Ghana in the late 1980s incanted a provision to allow for indigenes with just the right tools, skills and experience to also mine on a small scale; activities that were captured as either being small or medium scale mining. Individuals and groups of people are allowed to obtain licenses for operating as such but over the years, a lot more individuals have also join in the act without the proper license. Those illegally operating such small scale or medium scale mines are termed as Galamseyers or Orpailleurs in neighboring francophone nations (*Wikipedia 2017*).

In the early 2000s, Galamsey became a very topical issue because it provided a livelihood for many in mining communities but this also resulted in the involvement of children who should have been in school. Back then, the national concern was youth involvement but in recent years that subject has lost its sympathy to our environmental health. The sudden involvement of foreigners not only from our neighboring African countries but individuals from mostly Asia and Europe have increased the rate of land degradation and water pollution. We have witnessed rivers like the offin, Tano and Birem turn muddy due to Galamsey. Most of our forest reserves are at a risk of depletion and that has spark a completely new commentary. We have to accurately define the depth of our problem in order to synthesize an appropriate solution. The objective of this study is to help answer the question “what is the depth of our problem?” with the assistance of remote sensing technologies and research methods. This paper concludes by defining the extent of damage incurred as a result of illegal mining in some selected districts of Ghana.

1. STUDY AREA

The study area covers selected districts from the Ashanti and Central Regions of Ghana. The districts selected are Adansi North, Adansi South, Amansie Central, Amansie East, Amansie West, Atwima Mponua, Atwima Kwanwoma, Bosomtwe and Obuasi districts in the Ashanti

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Region and Upper Denkyira in the Central Region. The total area covered by these districts is approximately 920000 hectares and is located between longitudes $2^{\circ}27'40.93''W$ and $1^{\circ}13'55.65''W$ and latitudes $6^{\circ}47'18.67''N$ and $5^{\circ}37'11.02''N$. The Study area is shown in figure 1 below.

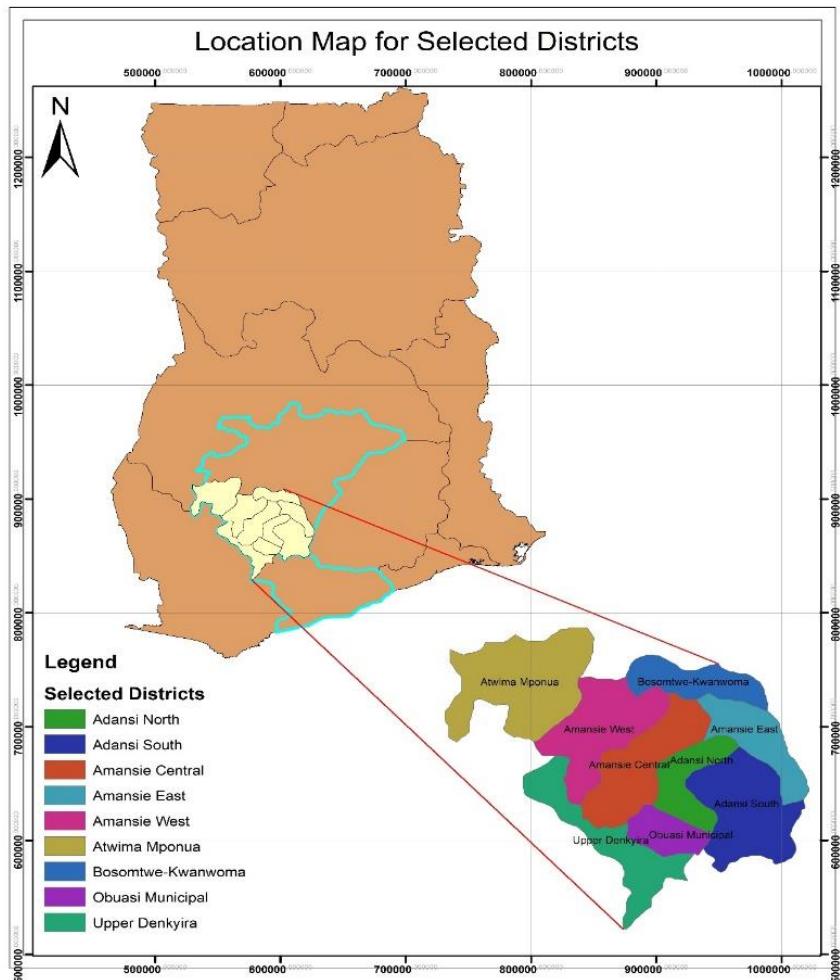


Figure 1. Location Map for Selected Districts

2. DATA

The data obtained for the purpose of this analysis is classified into two groups. The first group consist of data obtain through remotely sensed satellite images. This consist of four images dated 1st January 1991 (LANDSAT 4), 2nd April 2001 (LANDSAT 7), 31st December 2015 (LANDSAT 8) and 3rd January 2018 (LANDSAT 8).

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The second data group consist of GIS information including topographic maps, classified satellite images and statistical data.

3. METHODS USED

3.1. Creation of Base Layers

To perform analysis on the selected districts which include Adansi North, Adansi South, Amansie Central, Amansie East, Amansie West, Atwima Mponua, Atwima Kwanwoma, Bosomtwe and Obuasi districts in the Ashanti Region and Upper Denkyira in the Central Region, a base layer was generated from the existing base map for Districts in Ghana.

3.2. Extraction of Bands

The Images used in the analysis are LANDSAT Images that consists of 7 bands for LANDSAT 4, 8 bands for LANDSAT 7 and 11 bands for LANDSAT 8. The various bands consisting of the red, green, blue, near infrared (NIR), shortwave infrared (SWIR) bands were extracted for the purpose of the analysis.

3.3. Cropping and Mosaicking of Data Corresponding to The Study Area

The LANDSAT Images are captured in swaths with different rows and columns. This allows for easy access to data for a specific study area. For our study area, the different images that were mosaicked together and later cropped fell between WRS PATH = 194 & WRS ROW = 56, WRS PATH = 194 & WRS ROW = 55 and WRS PATH = 195 & WRS ROW = 55.

3.4. Image enhancement

Enhancements (Radiometric, Spectral and Spatial) were performed on the values in a remotely sensed image to improve its visual qualities for a specific purpose. The brightness values at individual pixels were changed to achieve improved brightness, contrast, color balance and other qualities.

3.5. Computation and analysis of various vegetation indices

The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not.

The NDVI is calculated from these individual measurements as follows:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

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The normalized Difference Water Index (NDWI) refers to one of at least two remote sensing-derived indexes related to liquid water.

The NDWI is calculated from these individual measurements as follows:

$$NDWI = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$

Figure 3 and 3 belows displays the results for the said analysis.

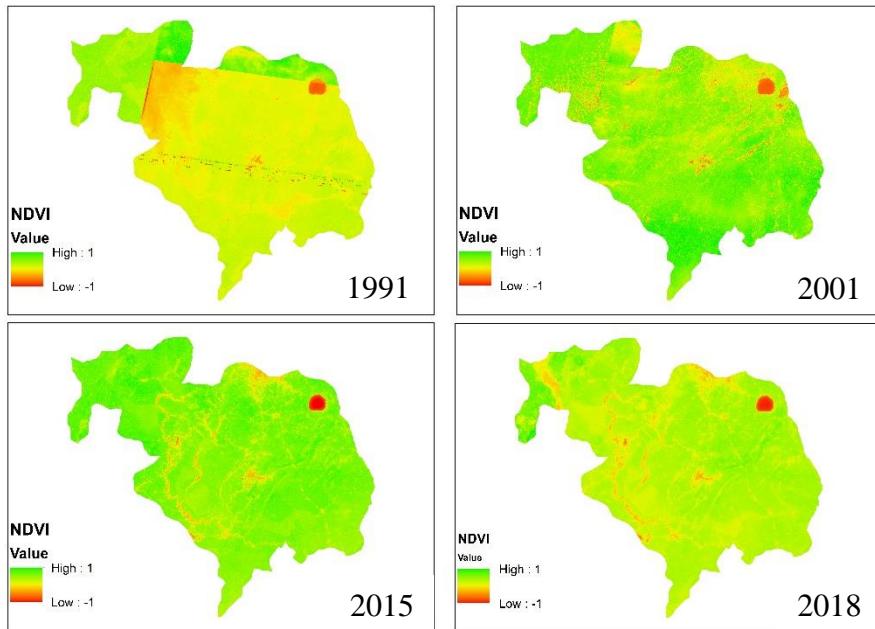


Figure 2. NDVI Analysis on the Images from Selected Time Periods

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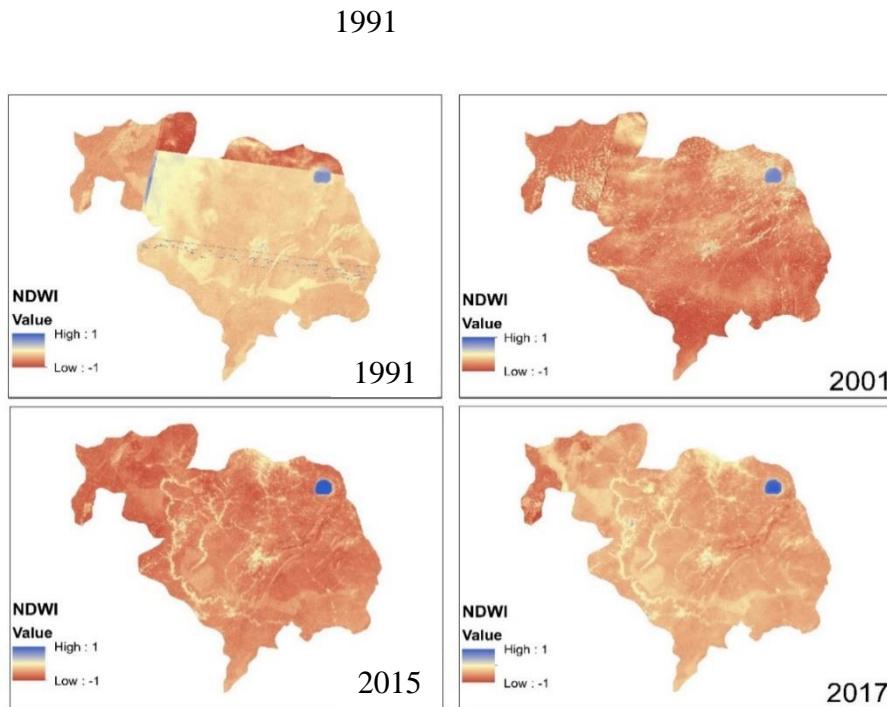


Figure 3. NDWI Analysis on the Images from Selected Time Periods

3.6. False color composite

The images obtained for the years 1991 and 2001 were heavily affected by cloud and haze cover making it extremely difficult to consider for post classification change detection analysis. The false color combination was performed to visualize the changes in Galamsey activities over the period, from 1991 to 2018. False color combination is basically switching the Red Band slot to a Near Infrared Band, the Green Band Slot to a Red band and the Blue Band slot to a green band. This process afford analyst the opportunity to mainly analysis vegetation in an area. Below in Figure 4 is the results of the false composite for the various time periods.

2018
1991

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When the false color composite was performed, one thing that clearly stood out was the indication of Galamsey activities in the years 2015 and 2018, something that was not seen in the 1991 and 2001 images. This indication is also witnessed in the NDVI and NDWI analysis results.

3.7. Classification of Remote Sensing Data

Image classification is the process of sorting pixels into a finite number of individual classes, or

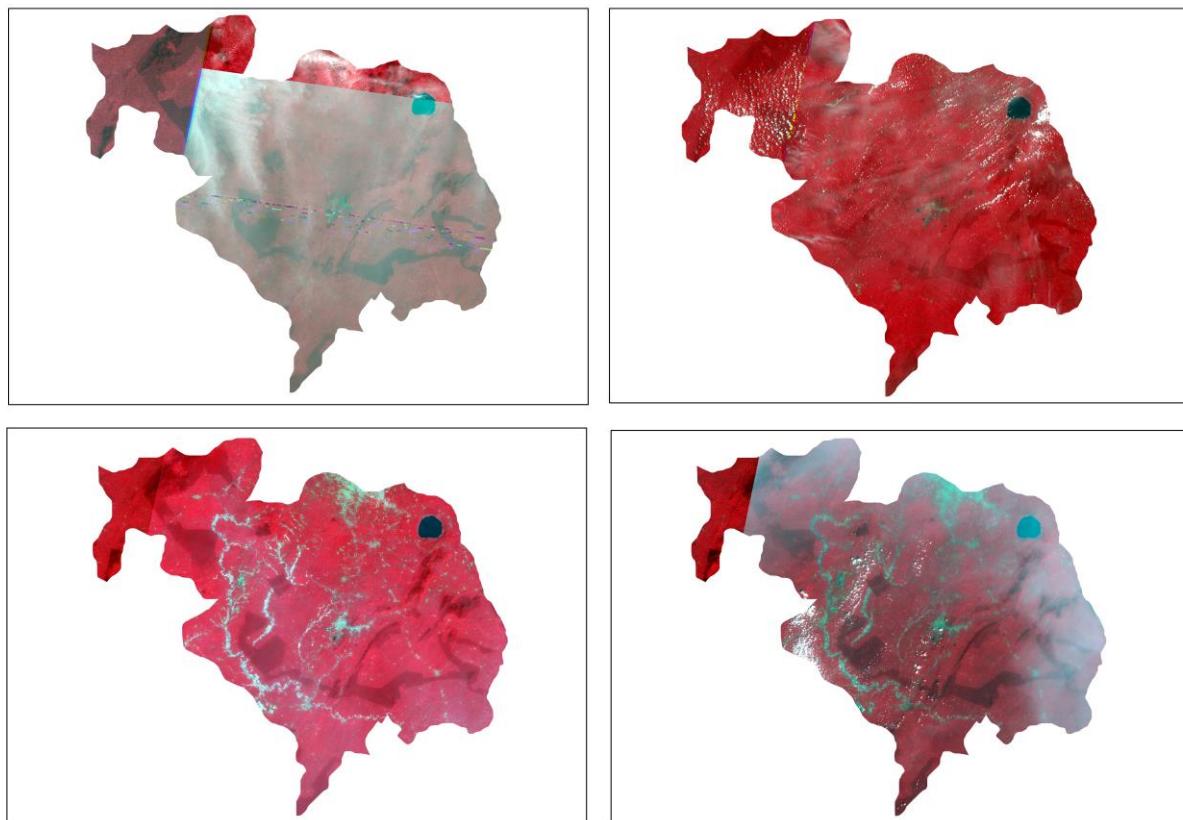


Figure 4. False Color composite of images from the various time periods

categories, of data based on their pixel values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion. There are two methods for classifying images which are namely Unsupervised and Supervised Classification. For our

analysis we limited ourselves to the supervised Classification for only the 2015 and 2018 images which were mildly affected by cloud and haze cover.

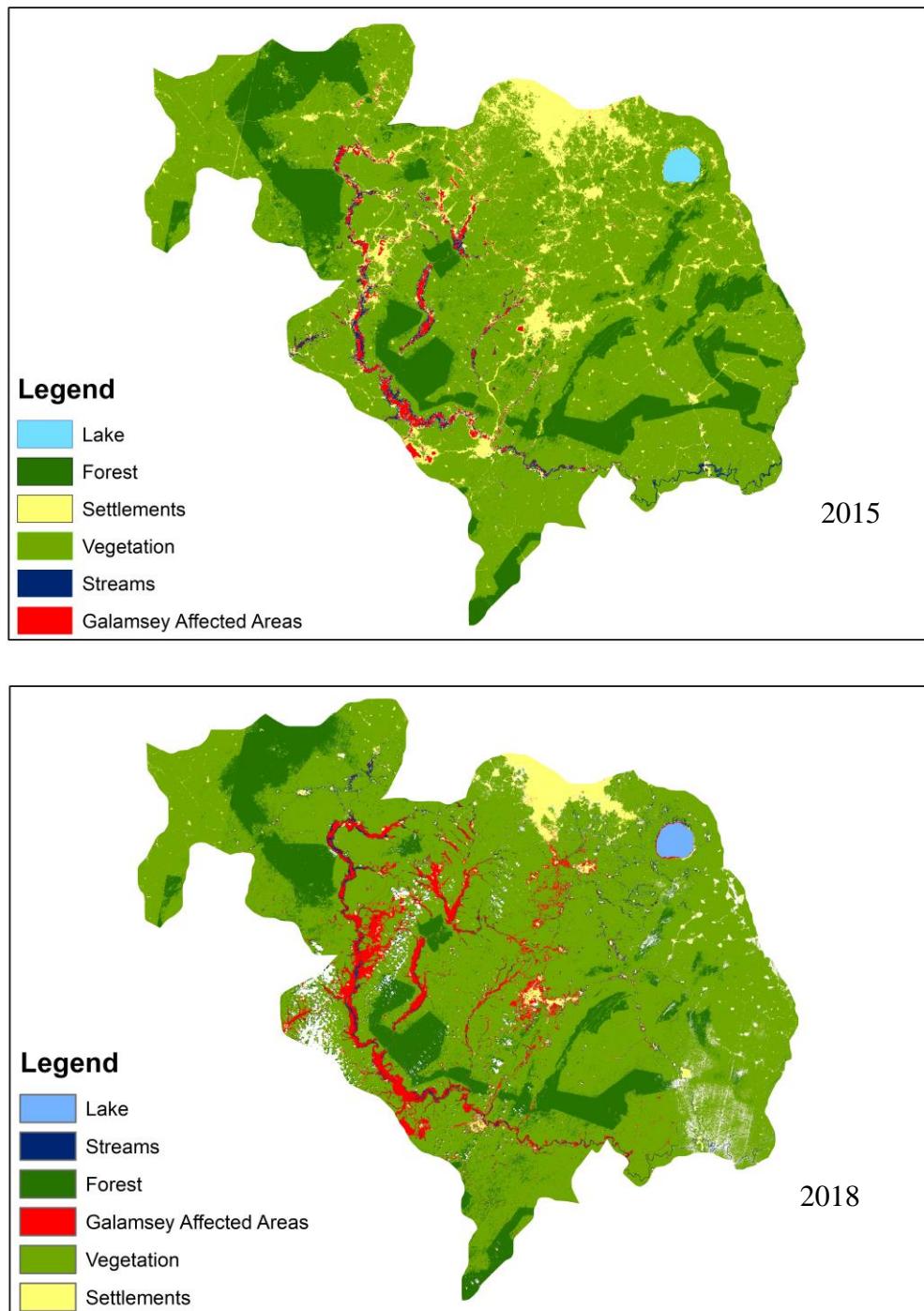


Figure 5. Maximum Likelihood Supervised Classification of LANDSAT Images from 2015 and 2018

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3.8. Change Detection

To help understand the changes that occurred over the different time periods, Image differencing post classification differencing techniques were employed. Differences in atmospheric condition, differences in sensor calibration, moisture condition, and illumination condition also affect the radiance of the pixels. Figure 6 below shows the scale of change over the period of 27 years, that is from 1991 to 2018 obtained from the Image Differencing Technique. There is a lot of change in the areas affected by Galamsey and Urbanization through population growth. Due to cloud cover and haze limitations, some parts of the images were omitted for this analysis.

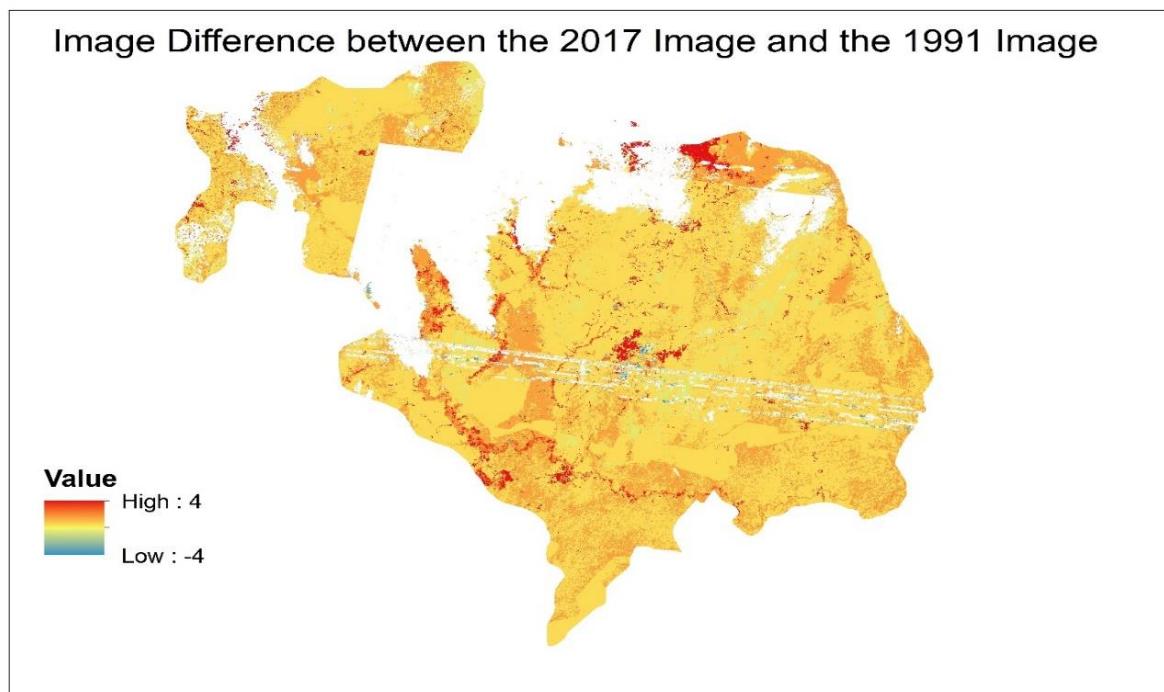


Figure 6. Image Difference between 2017 and 1991 LANDSAT Images

3.9. Accuracy Assessment of Classified LANDSAT Image

Assessing the accuracy of our classified image can be done in two different ways. Random observations can be made on ground and its corresponding feature on the final map can be checked against the ground observation for validation. Another very popular method employed today for mostly large areas is the use of google earth. Google earth provides its users with very high resolution satellite images for observing features at virtual close range. Google earth has recently been upgraded to even provide its users with three dimensional (3D) imagery over some parts of the world. This method of validation is highly cost effective since one can

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maximize his or her sample size without the cost component that comes with observing directly from the ground.

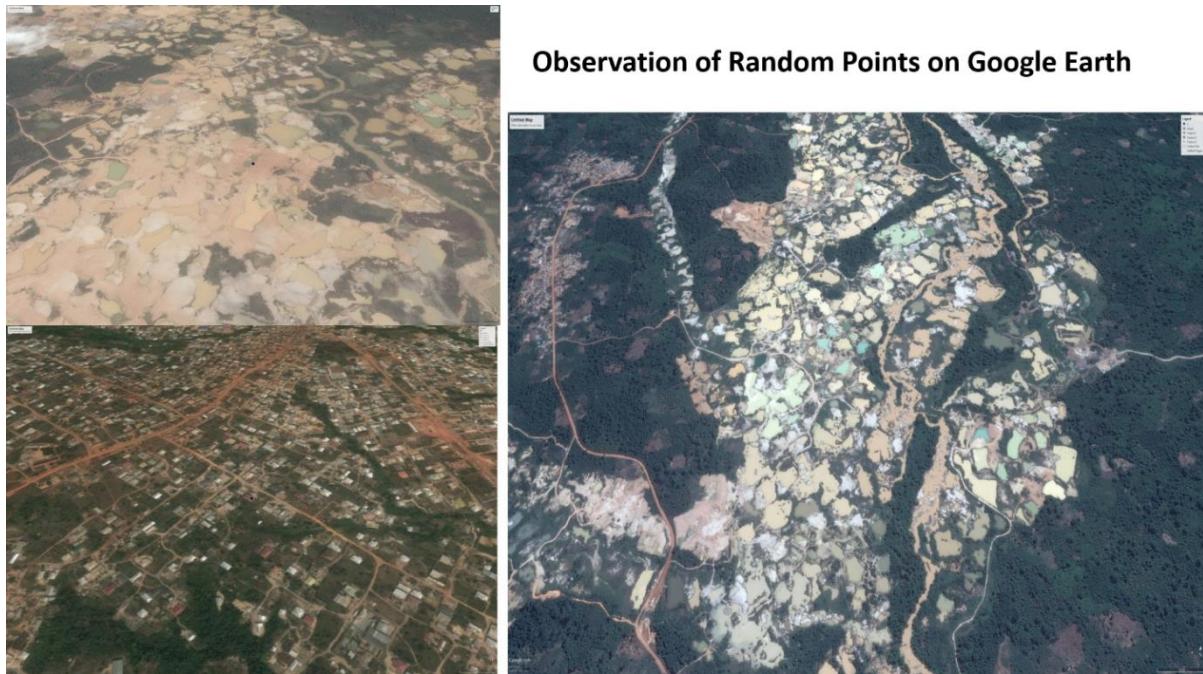


Figure 7. Observation of Random Points in Google Earth

One hundred (100) randomly sampled points were generated over our selected districts for validation. The corresponding features of the random points on the classified image was recorded for validation. The same random points were exported into the google earth platform and their corresponding features were also noted.

4. ERROR MATRIX

NB: Forest = 1, Vegetation Lands = 2, Galamsey = 3, Water = 4 and Urban = 5.

	Forest (1)	Vegetation Lands (2)	Galamsey (3)	Water (4)	Urban (5)	
Forest (1)	26 (i)	0 (ii)	0 (iii)	0 (iv)	0 (v)	26 (vi)
Vegetation Lands (2)	2 (vii)	40 (viii)	0 (ix)	0 (x)	0 (xi)	42 (xii)
Galamsey (3)	0 (xiii)	0 (xiv)	10 (xv)	0 (xvi)	0 (xvii)	10 (xviii)

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Water (4)	0 (xix)	0 (xx)	1 (xxi)	4 (xxii)	0 (xxiii)	5 (xxiv)
Urban (5)	0 (xxv)	1 (xxvi)	1 (xxvii)	0 (xxviii)	15 (xxix)	17 (xxx)
	28 (xxxi)	41 (xxxii)	12 (xxxiii)	4 (xxxiv)	15 (xxxv)	95 (xxxvi)

4.1. Overall Accuracy

This is calculated as percentage of random points that are the same in both cases.

$$Overall\ Accuracy = \frac{95}{100}$$

$$Overall\ Accuracy = 95\%$$

4.2. Calculation of Cohen's Kappa

Kappa provides us with insight into our classification scheme and whether or not we achieved results better than we would have achieved strictly by chance. The formula for kappa is:

$$\frac{Observed - Expected}{1 - Expected}$$

	Forest (1)	Vegetation Lands (2)	Galamsey (3)	Water (4)	Urban (5)	
Forest (1)	26	0	0	0	0	26
Vegetation Lands (2)	2	40	0	0	0	42
Galamsey (3)	0	0	10	0	0	10
Water (4)	0	0	1	4	0	5
Urban (5)	0	1	1	0	15	17
	28	41	12	4	15	95

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Observed is equal to Overall Accuracy.

Expected is calculated from the rows and columns in the Error Matrix and it is as follows.

	Forest (1)	Vegetation Lands (2)	Galamsey (3)	Water (4)	Urban (5)
Forest (1)	$28 \times 26 = 728$	$41 \times 26 = 1066$	$12 \times 26 = 312$	$4 \times 26 = 104$	$15 \times 26 = 390$
Vegetation Lands (2)	$28 \times 42 = 1176$	$41 \times 42 = 1722$	$12 \times 42 = 504$	$4 \times 42 = 168$	$15 \times 42 = 630$
Galamsey (3)	$28 \times 10 = 280$	$41 \times 10 = 410$	$12 \times 10 = 120$	$4 \times 10 = 40$	$15 \times 10 = 150$
Water (4)	$28 \times 5 = 140$	$41 \times 5 = 205$	$12 \times 5 = 60$	$4 \times 5 = 20$	$15 \times 5 = 75$
Urban (5)	$28 \times 17 = 476$	$41 \times 17 = 697$	$12 \times 17 = 204$	$4 \times 17 = 68$	$15 \times 17 = 255$

Used to Calculate Product Matrix

$$Expected = \frac{Product\ Matrix}{Cumulative\ Sum\ of\ Product\ Matrix}$$

Product Matrix (Sum of the diagonals) = $728 + 1722 + 120 + 20 + 255 = 2845$

The Cumulative Sum = $628 + 1066 + 312 + 104 + 390 + 1176 + 1722 + 504 + 168 + 630 + 280 + 410 + 120 + 40 + 150 + 140 + 205 + 60 + 20 + 75 + 476 + 697 + 204 + 68 + 255 = 10000$

$$Expected = \frac{2845}{10000} = 0.285 = 28.5\%$$

$$Cohen's\ Kappa = \frac{0.95 - 0.285}{1 - 0.285} = 0.93$$

This clearly shows that there is a perfect agreement between the observed and the obtained.

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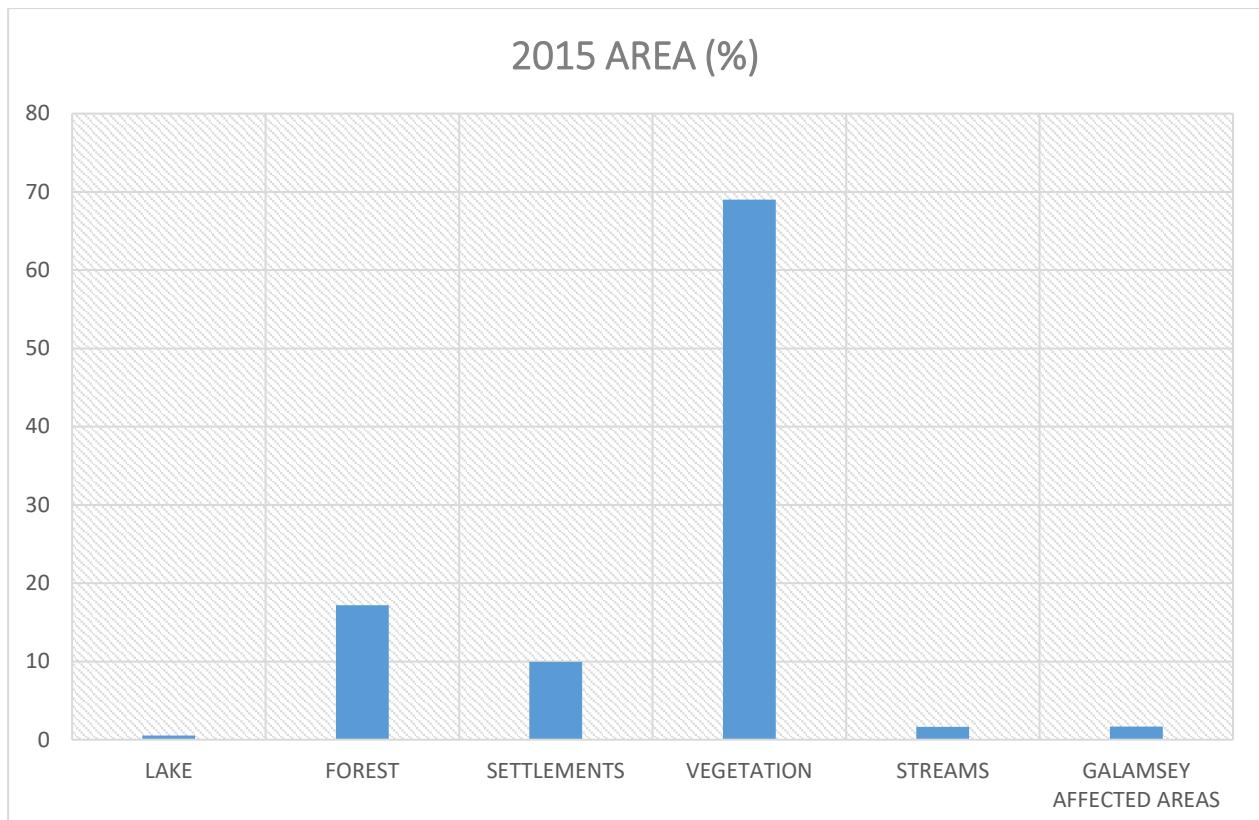
5. RESULTS AND DISCUSSION

2015		
VALUE	AREA (HECTARES)	AREA (%)
LAKE	4746.87	0.52
FOREST	156829.86	17.19
SETTLEMENTS	90793.80	9.95
VEGETATION	629416.50	69.01
STREAMS	15071.58	1.65
GALAMSEY AFFECT AREAS	15227.01	1.67

The 2015 image analysis shows massive signs of Galamsey Activities. The total area of land degraded by Galamsey activities amounts to 15227.01 Hectares and occupies 1.67% of the total Land Cover. These activities cover an area slightly bigger than the area covered by streams. The growth of land degradation has been attributed to the sudden involvement of foreign nationals in Galamsey, individuals who have introduced heavy machinery in the act. These activities are heavily observed in the mining towns, *ie.* Obuasi and Manso. Another observation is that the culprits are also mining heavily along the Tano and Offin Rivers.

This can also be attributed to the gold rich Birimian Sediments in the area and easy access to water for washing of the gold ore. The 2015 Image is ideal for analysis due to lack of cloud cover and the presence of very little haze. The haze obstructed the proper visualization and analysis of the Tano Offin River Forest and the Anwiaso Forest.

The Water body that was prominent during visualization and analysis was the Bosomtwe Lake. The 2015 image also showed a major increase in human settlement all over the selected districts. Below is a Bar chart showing the distribution of land cover within the selected districts in percentages.



2018		
VALUE	AREA (HECTARES)	AREA (%)
LAKE	4755.42	0.54
FOREST	127669.41	14.49
SETTLEMENTS	32313.87	3.67
VEGETATION	651156.38	73.90
STREAMS	21956.76	2.49
GALAMSEY AFFECTED AREAS	43223.76	4.91

The 2018 image analysis also showed massive signs of Galamsey Activities. The total area of land degraded by Galamsey activities amounts to 43223.76 Hectares and occupied 4.91% of

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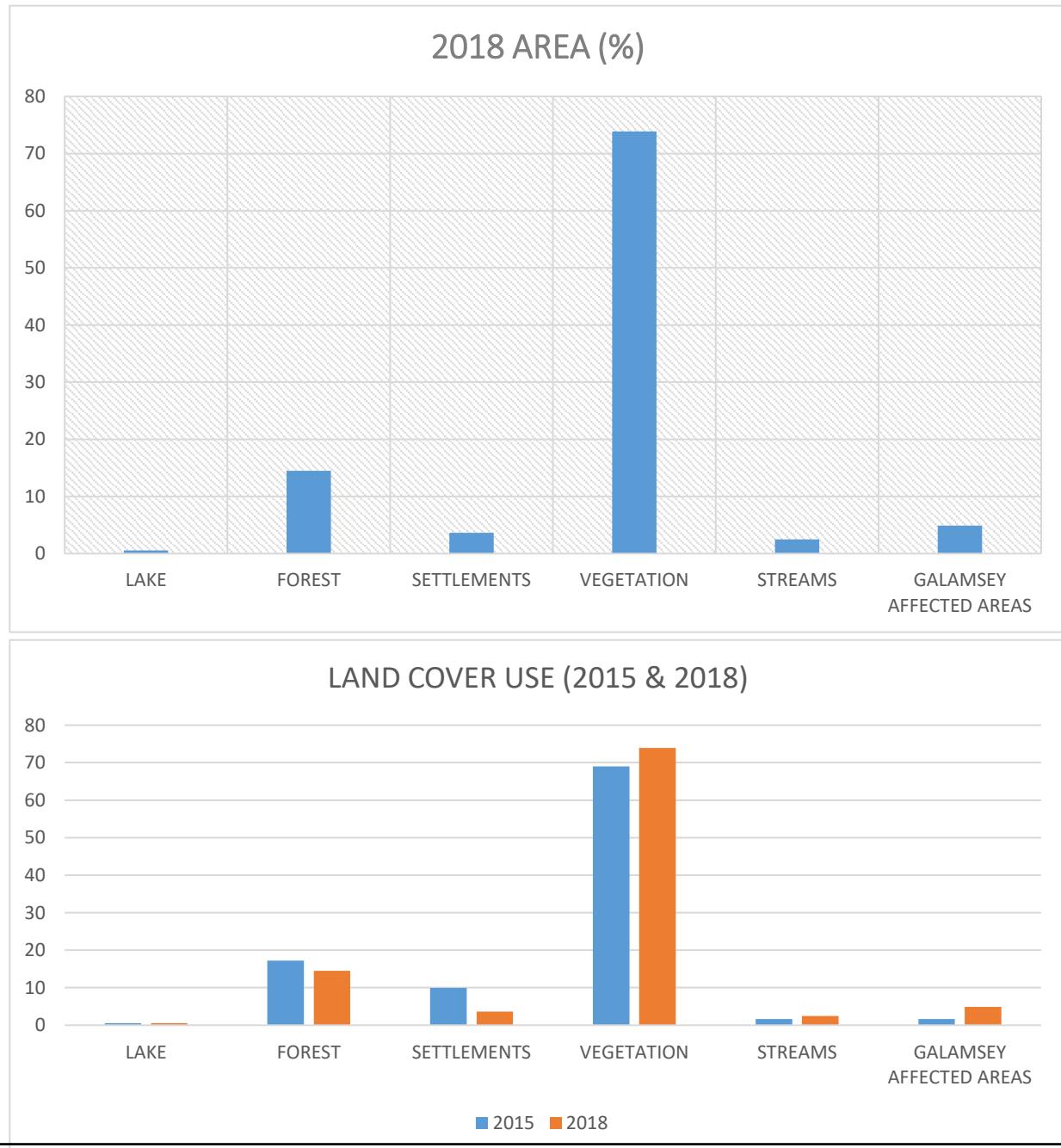
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the total Land Cover. This shows that there has been an increase in the area degraded since 2015.

The 2018 Image was dented by cloud cover and haze and so the Area covered by forest and Human Settlement was heavily impacted. This resulted in a decrease of land cover occupied by forest and human settlement which is inconsistent with the 2015 Image. Some settlements that were omitted due to cloud cover include Boko, Twedie, Afrancho, Yabi, Jachi, Kokoben, Trabuom, Akyeremade, Nwiniso Nyadieyeyea, Asarekrom and a few others. The forest zones affected by the clouds are the Tano Suraw Forest and the Anwiaso East Forest. The Water body



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that was prominent during visualization and analysis is the Bosomtwe Lake. Below is a Bar chart showing the distribution of land cover within the selected districts in percentages.

5.1. Land Cover Use

Forest Zones was second to Agricultural Lands in the Land Cover Use Chart in terms of Area. There is a decline in our forest density from 2015 to 2018 partially because of cloud and haze cover limitations. Galamsey sites have also increased from barely existing in the 1990s to physically occupy a concerning area in the land cover use for 2015 and 2017. Water bodies were affected by cloud cover for 1991, 2001 and 2018 images making it difficult to access the rate of change over the years. Human settlements have also sharply increased but the 2018

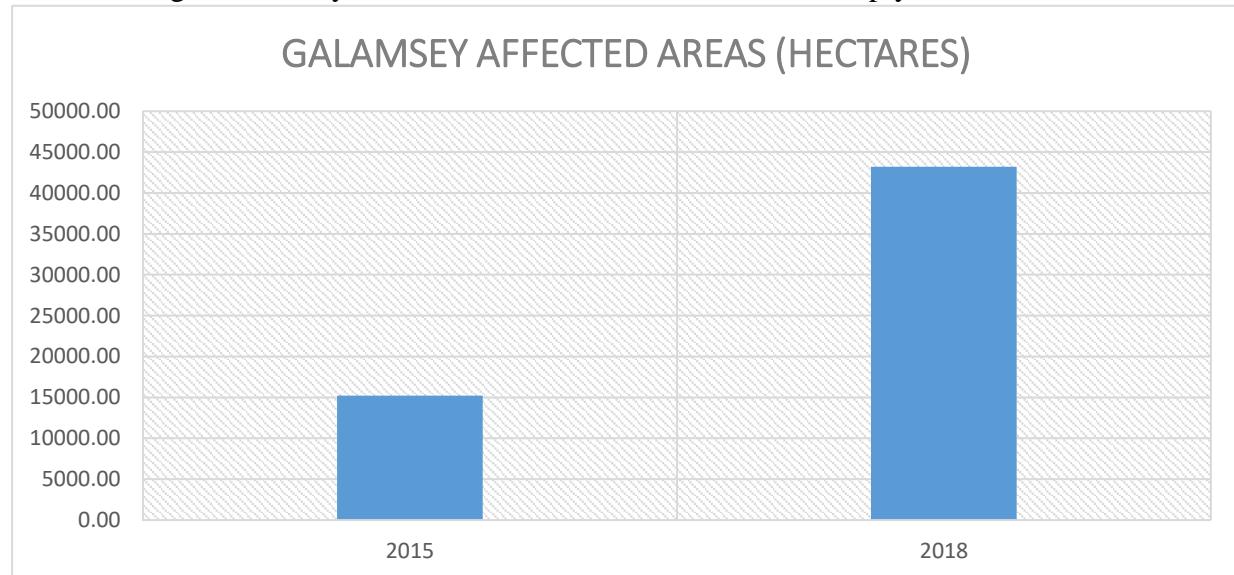


Figure 15. Area of Land Affected by Galamsey for 1991, 2001, 2015 and 2017

image is inconsistent due to cloud cover effects. This can be visualized in the Figure .. above. Below is figure .. showing the alarming growth of Galamsey activities over a three year period.

CONCLUSION & RECOMMENDATIONS

The area of land destroyed by Galamsey activities has risen through time to a new high of 43223.76 Hectares in 2018.

The Offin, Tano, Jeni, Oda and Birem Rivers have turned muddy due to Galamsey activities along their tributaries.

The Anwiaso East, Jeni River, Tano Suraw, Apamprama, Oda River, Subin Shelterbelt, Supuma Shelterbelt and Denyau Shelterbelt Forests are all in danger of deforestation due to Galamsey activities in those areas.

The main source of water in over 148 communities within the selected districts have been destroyed as a result of Galamsey activities. Some of these communities are Okyerekrom, Odumase, Anyinam, Obuasi, Dunkwa, Oseikrom, Odaho, Mpatasie, Manso Nkuntini, Manso Akropong, Manso Nkwanta, Asamang, Manso Atwere, Odumase, Assin Praso, Assin Breman, Foso, Akropong, Domenase, Onwe, etc.

It has become more eminent that as a country we require modern technologies and research techniques to be able to monitor our natural resources.

Remote Sensing provides the potential for constant monitoring of our lands and seashore for better decision making now and in the future.

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BIOGRAPHY

Joseph Osei Ababio is a highly motivated Surveyor, Spatial Analyst and Researcher with an excellent track record in Engineering Survey, Geodatabase management, Geospatial Analysis, Map Design and Amateur Computer Programming from various disciplines including health, mining, construction, science and technology. He is a graduate from the University of Mines and Technology with Bachelors in Geomatic Engineering. He also has training and certification from various specialized programs including Coastal Ocean Environment (Certified), Our Energy Future, Municipal Solid Waste Management, Geospatial Intelligence (Certified), Monitoring Climate from Space, Google Map Making (Certified), Geospatial Analysis, Designing Cities, Oil & Gas Industry Operations and Management, Global Warming I; The Science and Modeling of Climate Change and many others. He has contributed primarily to various research programs as a trainee for the Survey and Mapping Division of the Lands

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Commission (Kumasi – Ghana) and the Geomatic Engineering Unit of the Building and Road Research Institute (BRRI) in the Ashanti Region of Ghana. Joseph is a graduate member of the Ghana Institute of Engineers (GHIE) and a trainee member within the Ghana Institute of Surveyors (GHIS). He is currently undergoing a Postgraduate Diploma in Engineering Business and Safety Management at Confederation College in Thunder Bay, Ontario, Canada while working for J. D. Barnes Limited (Land Information Specialist).

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