Geospatial Assessment of Vegetation Changes around the Odublasi Quarry in Ghana

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Abstract

This study examined drivers of vegetation cover changes around the Odublasi quarry, analyzed trends of the change, and areas around the quarry prone to these drivers. Stakeholders were interviewed to identify drivers of vegetation cover change, while satellite imagery of the area from 2007, 2012, 2013, and 2014 were used for trend analysis. Field mapping of trees in the area was undertaken to acquire baseline data of vegetation for use in future studies and restoration projects. Identified drivers were; the construction of a new access road; switch in livelihoods of the local community members from small-scale quarrying to extracting biological resources around the quarry site; unsustainable farming and wood logging practices around the quarry; social exclusion; and afforestation programme around the quarry. A rising and falling trend in vegetation cover was observed in satellite images of the quarry site from 2007 to 2014. Activities around the quarry like shifting cultivation farming was a key driver of this undulating trend. Habitats along the access road to the quarry were identified to be vulnerable to the drivers of vegetation cover change and needed critical attention in any environmental restoration efforts.

Introduction

It is estimated that 5% of Ghana's GDP is derived from the mining sector (Ghana Chamber of Mines, 2014). The earnings from mining contribute significantly to improving the economic lives of communities through the development of water and electricity supply, road network expansion, schools and hospitals, and also provide direct and indirect employment avenues.

Despite the obvious benefits of mining to society, certain undesirable consequences of mining on the environment remain a challenge. It is well documented that biological diversity of areas surrounding mining sites change due to exploratory, operational and closure activities at the mine site (Kujala et al., 2015; Sonter et al., 2014; Antwi, 2009). Preoperational mining activities, such as the construction of access roads and development of the mining site, are known to contribute to the reduction in vegetation surrounding mining sites with possible implication to the surrounding biodiversity. Changes in biodiversity, in this case, is initiated when fragmentation of habitats in the area occurs. Fragmented habitats gradually begin to lose their species and structural similarity with adjacent habitats. The fragmentation also inhibits the easy movement of species across habitats. This creates a condition where habitats are most susceptible to dwindling in species diversity and geographical size (Sonter et al, 2014; Lindenmayer & Fischer, 2013). Meanwhile, higher levels of biodiversity enhance the resilience of vegetated habitats, as respective distinct species are better able to withstand natural environmental impacts (Dyke, 2016).

In addition, mine operational activities can generate dust and other atmospheric particles/ gasses, and noise pollution (above 70 dB). These impact many plants and animal species, negatively affecting their population and distribution in and around the mine, and in the long run modifying the biodiversity around the mining site.

Mining may also catalyze the modification and degradation of the environment indirectly. For instance, the establishment of access roads to a mine site make it easier to access hitherto, inaccessible areas. This leads to extraction of biological resources available there. Depending on the culture and practices of the surrounding community, extraction of biological resources may be potentially unsustainable to the biodiversity of the area (eg. Negative farming practices or excessive animal hunting) (Naeem & Bunker, 2009; Kitula, 2006).

With the use of Geospatial technologies, modifications that may have occurred within the environment surrounding a mining site can be identified. Identifying the kind of land-cover and vegetation changes that have occurred in the past, could assist in understanding the trend of change in the vegetation of an area, subsequently assisting in predicting habitats that are/or will become most vulnerable to modification in the future (Antwi, 2009). In principle, it is possible to identify critically sensitive areas around a mining site, that may require substantial planning and efforts in sustainably managing its vegetation cover and biodiversity pre/post the closure of the mine, using GIS mapping.

West African Quarries Limited has operated the Odublasi quarry site for more than a decade. The quarry is approaching its closure stage and plans to remediate disturbances to the biodiversity of the area are being drawn. The planning stage would require critical information on drivers of biodiversity change in the area. This is to ensure that positive contributory factors to biodiversity are enhanced while negative contributory factors are minimised. In doing so, the restoration of the damaged ecosystem/s to their original state can be adequately facilitated. The implications that vegetation cover has on biodiversity makes it a critical environmental element that must be properly understood and analysed in order to restore the biodiversity of the degraded environment.

This study sought to understand changes in the vegetational cover that may have occurred around the Odublasi quarry site. Specific objectives of the study were:

- ■To identify drivers of vegetation cover change of the study area.
- ■To identify the trend in vegetation cover change using satellite imagery of the area.
- ■To identify vegetation (trees) that are locally abundant around the Odublasi Quarry.
- ■To identify vulnerable areas in the study area based on their level of exploitation.

Materials and methods

Study Area

The project site is located at Odublasi which is in the Yilo Krobo District of the Eastern Region of Ghana (Figure 1). The Yilo Krobo District lies within the semi-deciduous forest zone of the country. Parts of the municipality are within the dry semi-deciduous zone (fire zone). Tree types that are widespread in the District include *Elaeis guineensis, Mangifera indica, Azadirachta indica, Ceiba pentandra and Acacia auriculiformis.* The area experiences a substantial amount of precipitation during a bi-modal rainy season in May – June, and September – October. Temperature ranges 24.9°C to 29.9°C (GSS, 2014). The land rises from a height of about 100m in the Southeast to over 600m above sea level on the ridge in the West. The main occupation in the district is agriculture (57.3% of households, and rises to 72.2% in rural areas) (GSS, 2014).

The study site covers approximately 5 km2 with a geographical midpoint with coordinates 6°11’43.36” N, 0°04’30.31” W (Figure 2). The study area encompasses a quarry owned by West African Quarries Limited. The quarry supplies limestone to

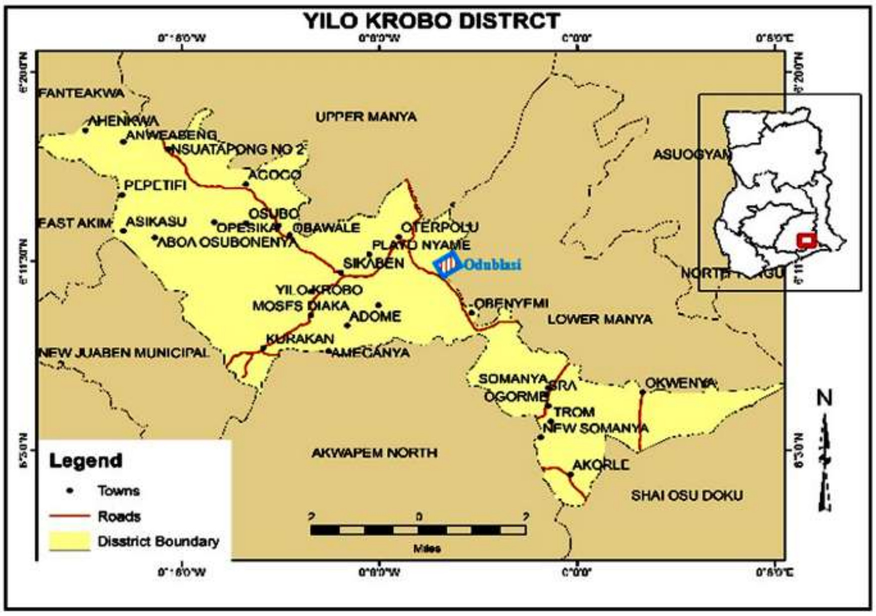

Figure 1 Yilo Krobo District Map

Ghacem Ltd in the production of their cement products. The quarry itself covers a smaller area of approximately 0.85 km2 of the study area (Figure 2), while the remaining portions of the study area consist of patches of forest, farms, bare land, grassland, and small human settlements.

Site Survey and Literature Review

Various literature materials (Kujala et al., 2015; Lindenmayer & Fischer, 2013; Kitula, 2006; Naeem & Bunker, 2009; Szaro & Johnston, 1996) were reviewed to seek information applicable to the research site and also derive some methods. In addition, Environmental Impact reports of the site, population and housing census reports, and academic research reports were reviewed. A reconnaissance exercise was subsequently undertaken to the site by the study team.

Satellite Image Acquisition

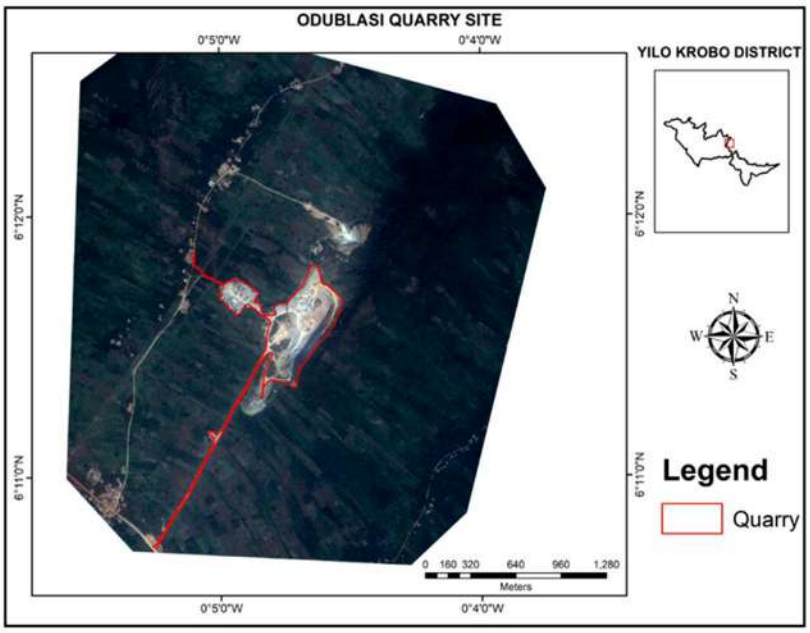

Figure 2 Geographical Location of the Odublasi quarry site

After the reconnaissance visit, four satellite images of the study area were acquired from Airbus Defense and Space for analysis. The selection of the images was conditioned by factors of availability, and absence of cloud cover. Very few high-resolution satellite images exist for the study area, while cloud cover over the area made it impossible to use some images. The satellite images of the study area acquired for use were 2007 (Spot 5), 2012 (Spot 5), 2013 (Pléiades) and 2014 (Pléiades). These images were captured during the dry season and thus had little interference from cloud cover. Table 1 presents specifications of the satellite images acquired.

TABLE 1
Satellite images acquired from Airbus Defense and Space

Satellite	Date	Image description
Pléiades ORTHO	2014/12/27	Area: Yongwa Ghana = 5km^2 Resolution: 50cm, 4 bands (G,B,R,NIR), Ortho UTMWGS84 Geotiff 16 bits
Pléiades ORTHO	2013/04/07	Area : Yongwa Ghana = 5km^2 Resolution: 50cm, 4 bands (G,B,R,NIR), Ortho UTMWGS84 Geotiff 16 bits
SPOT ORTHO	2012/12/26	Area : Yongwa Ghana = 5km^2 Resolution: 2.5m, color 3 bands (G,R,NIR), Ortho UTMWGS84 DIMAP GeoTiff
SPOT ORTHO	2007/01/29	Area : Yongwa Ghana = 5km^2 Resolution: 2.5m, color 3 bands (G,R,NIR), Ortho UTMWGS84 DIMAP GeoTiff

Image Processing and Analysis

All images were processed and analysed using ArcGIS 10.1 and ENVI 5.0 software. All four images were first enhanced (using the Interactive stretching tool in ENVI 5.0) before a subset (5km^2 area) was extracted from each image (using the Region of Interest tool in ENVI 5.0) based on observations from field reconnaissance exercise. Images from 2013 and 2014 were resampled (using the Layer Stacking tool in ENVI 5.0) to have the same resolution as 2007 and 2012 (10m resolution). An unsupervised classification of the images (using the algorithm Iterative Self-Organising Data Analysis Technique in ENVI 5.0) was undertaken to get up to six various land use and land cover types. This was followed by a supervised classification with maximum likelihood algorithm which generated the land use land cover types. The land area covered by each land cover type was calculated for each year, and this was used to determine the total percentage of the area that each land cover type represented in and around the 5m^2 radius of the quarry site.

High-resolution images from 2013 and 2014 were geo-linked (using the Geographic-Link option in ENVI 5.0) and attention was given to areas where clusters of forest trees and shrubs were found. These clusters were marked out with a red boundary line in 2014 images and blue boundary line in 2013 images.

Vegetation Identification and Mapping

Two field visits were made to the site to identify and map the different kinds of tree species that were found at the site and to verify the results of the classification exercise undertaken with the satellite images. The geographical coordinates of identified tree species were recorded using a GPS device (Garmin Dakota 20) according to the UTM 30N coordinate system. The time of encounter of tree species was also recorded.

Stakeholder Engagement

Various stakeholders were engaged in this project at different levels to help achieve the aim of this project. These included stakeholders in academia, municipal and traditional authority, management of the quarry and local community members.

Stakeholders in the management category included the management of the Odublasi quarry. This engagement was to identify how the quarry had impacted the environment, especially vegetation, and how new approaches were constantly being explored by the quarry to minimize and control such undesired impacts.

Farmers and wood loggers in the area were equally engaged to investigate the contributions their activities made towards modifying the vegetation in the area. Municipal and traditional authorities of the area were also engaged. Traditional authorities were engaged to share their indigenous knowledge of the vegetation and biodiversity of the area and the changes they had observed over the years.

Results

The aerial view of the quarry site and its nearby surroundings are presented in Figure 3 to Figure 6. Figure 3 - 6 highlights changes in vegetation density in and around the quarry site between 2013 and 2014. The northeastern boundary of the quarry is shown in Figure 3,

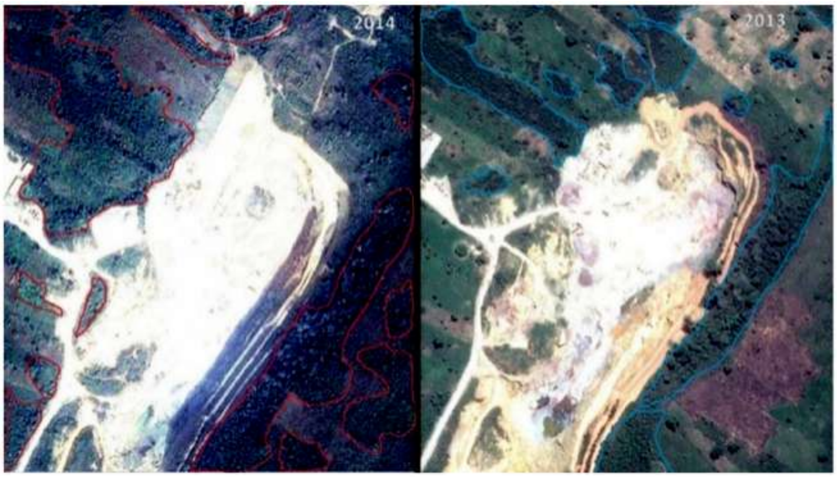

Figure 3 Aerial view of the North Eastern boundary of the Odublasi quarry in 2014 and 2013

Figure 4: Aerial view of the South Eastern boundary of the Odublasi quarry in 2014 and 2013

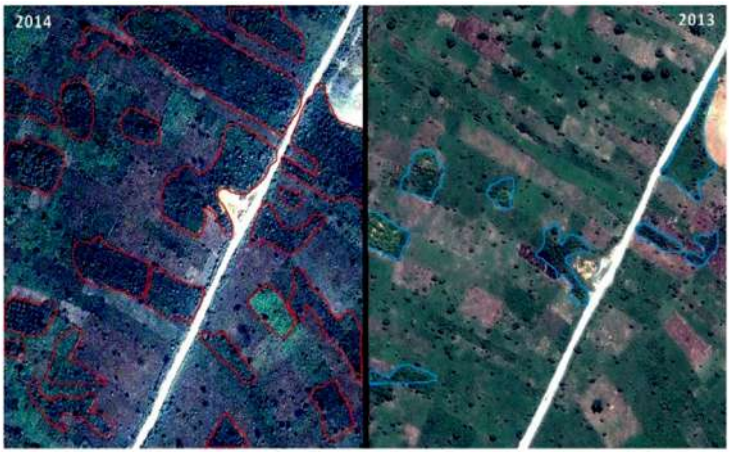

Figure 5 Aerial view of the South Western boundary of the Odublasi quarry in 2014 and 2013

Figure 6 Aerial view of the North Western boundary of the Odublasi quarry in 2014 and 2013

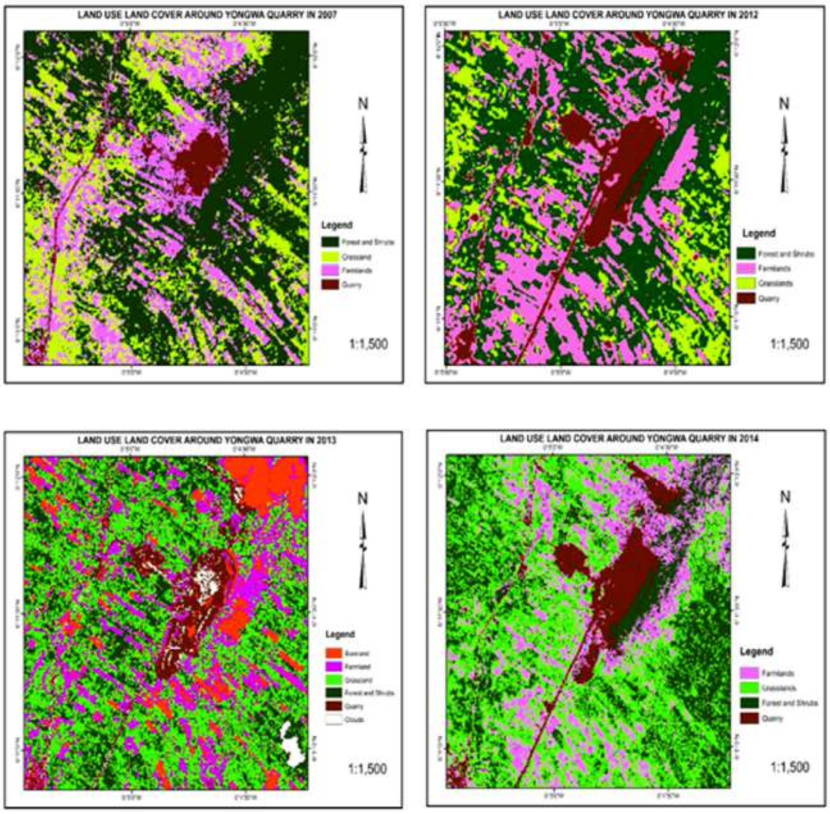

Figure 7: Classified satellite images of the Odublasi quarry area in 2007, 2012 2013 and 2014

while the southeastern boundary is shown in Figure 4. Similarly, the southwestern boundary of the quarry is shown in Figure 5 while the northwestern boundary is shown in Figure 6.

Figure 7 illustrates the various land use and land cover types that prevailed around the quarry site in 2007, 2012, 2013, and 2014. It shows a trend in how the vegetation in the area around the quarry site was modified with potential implications on the biodiversity of the area.

Table 2 below presents data on the land area in acres that each land cover type covered in the year 2007, 2012, 2013, and 2014. It shows that the forest cover in 2007 was relatively significant, but continued to dwindle as the years went by. Table 3 further presents data on the acreage and percentage increase/decrease that was recorded for each land cover type from 2007 to 2014.

Data in Figure 8 below shows that the percentage of each land cover type around the quarry changed from year to year. In both 2007 and 2012, forest cover contributed the largest land cover type surrounding the quarry site. While in 2013 and 2014, grassland represented the largest land cover type around the quarry site. It is also observed that the area covered by the actual quarry site and areas of bare land (including road network) increased from 2007 through to 2013, before reducing in size in 2014 (Figure 8).

Results for the tree mapping exercise

TABLE 2
Coverage area of land cover types around the Odublasi quarry site from 2007 to 2014

Land Use Land Cover Type	Total Cover Area in 2007 (Acres)	Total Cover Area in 2012 (Acres)	Total Cover Area in 2013 (Acres)	Total Cover Area in 2014 (Acres)
Quarry/Bareland	56.09	170.85	324.63	116.48
Farmland	559.59	739.76	428.11	484.52
Grassland	821.47	445.31	720.71	793.58
Forest	1,157.39	1,234.07	522.07	600.95

TABLE 3
Changes in land cover types around the Odublasi quarry from 2007 to 2014

Land Use Land Cover Type	Change in Cover Type Between 2007 and 2012		Change in Cover Type Between 2012 and 2013		Change in Cover Type Between 2013 and 2014	
Quarry/Bareland	114.76 acres	204.58%	153.79 acres	90.01%	-208.15 acres	-64.12%
Farmland	180.16 acres	32.20%	-311.65 acres	-42.13%	56.41 acres	13.18%
Grassland	-376.12 acres	-45.79%	275.4 acres	61.84%	72.87 acres	10.11%
Forest	76.68 acres	6.62%	-712 acres	-57.70%	78.86 acres	15.11%

Positive values signify an increase in acreage of the land cover type while negative values signify a reduction

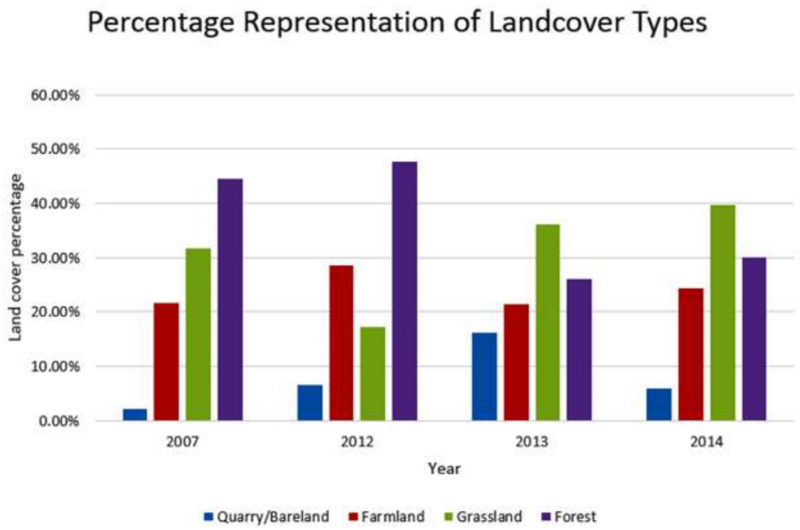

Figure 8 Percentage of land cover types around the Odublasi quarry site from 2007 to 2014

undertaken during the study have been presented in Table 4 below, indicating the geographical location where some of the identified species can be located.

Discussion

TABLE 4
Changes in land cover types around the Odublasi quarry from 2007 to 2014

Plant Name (Local)	**Scientific Name**	**IUCN Status**	**GPS Coordinates**
Redwood (Mahogany)	*Khaya senegalensis*	Vulnerable	6°10’ 48.6804” -0°5’ 13.175”
Caccia	*Cassia siamea*	Lower Risk/least concern	6°10’ 48.81” -0°5’ 13.499”
Nim tree	*Azadirachta indica*	Extant	6°10’ 48.6804” -0°5’ 13.567”
Acacia	*Acacia auriculiformis*	Least concern	6°10’ 48.4824” -0°5’ 12.98”
Chenchen (white tree)			6°10’ 48.054” -0°5’ 12.073”
Palm tree	*Elaeis guineensis*	Extant	6°10’ 47.928” -0°5’ 12.401”
Onyina	*Ceiba pentandra*	Extant	6°10’ 49.6524” -0°5’ 12.358”
Pototso			6°10’ 52.2768” -0°5’ 10.914”
Timbetso			6°10’ 53.742” -0°5’ 11.166”
Bagotso			6°10’ 52.8996” -0°5’ 11.588”
Nyagbotso			6°10’ 53.2848” -0°5’ 10.583”
Odum	*Milicia regia*	Vulnerable	6°10’ 55.38” -0°5’ 7.321”
Nyamedua	*Alstonia boonei*	Extant	6°11’ 1.5468” -0°5’ 4.654”
Biterstso			6°11’ 3.1848” -0°5’ 6.922”

TABLE 4 cont.
Changes in land cover types around the Odublasi quarry from 2007 to 2014

Ntome	*Dracaena arborea*	Least concern	6°11' 3.1812" -0°5' 6.302"
Bamboo	*Bambusoideae/ Bambusa sp.*	Extant	6°11' 9.5856" -0°5' 0.258"
Mango	*Mangifera indica*	Data Deficient	6°11' 12.3864" -0°5' 0.402"
Papaku			6°11' 13.1892" -0°4' 58.904"
Mantso			6°11' 15.9468" -0°4' 57.493"
Soursop	*Annona muricata*	Extant	6°11' 35.4516" -0°4' 49.714"
Wawa	*Triplochiton scleroxylon*	Lower Risk/least concern	6°11' 37.3452" -0°4' 51.002"
Teak	*Tectona grandis*	Extant	6°11' 36.6792" -0°4' 53.933"

Quarry expansion and vegetation modification

In Figure 7, Figure 8, and Table 2, it is clearly observed that the quarry expanded in size from 2007 to 2014. The size of the quarry increased by as much as 204.58% (114.76 acres) from 2007 to 2012 (Table 3). In 2012 an additional access road was constructed to connect the southern border of the quarry to the main road (Figure 7). It is noted that farms were heavily sited along the two access roads leading to the quarry site, especially in 2012. The roads may have created easy access for locals to exploit hitherto inaccessible forested areas. Field observations showed farmers in the area often employ unsustainable farming practices like slash and burn, clearing out forest trees and heavy application of pesticides. These may have had potential negative impacts on the vegetation and consequently the biodiversity in the area; the level of diverse lifeforms in the area declined. Negative implications of road constructions on forest ecosystems are cited in literature on a number of occasions (Sonter et al, 2014; Lindenmayer & Fischer, 2013).

Switch in community livelihood and

Plate 1 Spotted maize farm around the quarry site

biodiversity modification

Engagement with Chiefs, elders, and surrounding community members revealed the community's involvement and contribution in modifying the vegetation cover of the area. In a narration by a Chief, community members primarily occupied themselves with small-scale stone quarrying decades ago, to supply the local construction industry with flooring material (Terrazzo). The acquisition of the quarry site by Ghacem inevitably meant the majority of the community members lost their livelihoods in stone quarrying. Alternatives such as farming, hunting of game, wood logging and charcoal making became new sources of livelihood for the affected people. These alternative livelihoods, however, are considered as strong drivers of vegetational cover change with implications on the biodiversity of forested areas (Norrisa, et al., 2010; Gyasi, et al., 1995).

Plate 2 Spotted wood logging activities ongoing around the quarry site

Generally, these modifications have been reported to be negative impacts on biodiversity (Phalan, et al., 2011). This was confirmed by the unsustainable farming practices witnessed in the area during field visits, with little consideration for Agri-silviculture for example. In addition, wood logging was observed in the area and is partly used for charcoal and construction, among other things. Debatably, the switch in livelihoods has led to the degradation of the forest in the community and around the quarry, and the biodiversity of the area in general.

Modifications to surrounding vegetation around the quarry

Aquatic ecosystems are absent around the Odublasi quarry site; the biodiversity around the quarry is terrestrial in nature. Factors that positively contribute to biologically diverse terrestrial ecosystems are climate and soil conditions (Stuart et al, 2011). These conditions result in primary succession and an eventual boom in vegetation species (grass, herbs, shrubs, and trees). Other organisms (insects, reptiles, birds, and mammals) may be attracted to the area to seek food, shelter, and security. Microbes could then become common as they degrade and decompose dead organisms within that environment. An ecosystem of producers (plants), consumers (animals) and decomposers (fungus, bacteria) is thus created. It may be implied to a reasonable extent that, a vegetated terrestrial environment has a more biologically diverse community than one with little vegetation (Cardinale et al, 2011). It is imperative to indicate that, an area with more variety of habitats (in the case of this project, distinct habitats may be considered as forests, grassland, farmland and bare land) may hold more biodiversity potential than one with little (McGrady-Steed et al, 1997). Naeem and Bunker (2009), also pointed out that landscapes with a large number of small patches and fragmentation in space and time are prone to intense variations in species diversity in time. This according to them was caused by consistent extinction and colonization within the fragmented patches.

Bearing in mind these emphasis stated above, highly vegetated areas around the quarry were highlighted in aerial photographs taken in 2013 and 2014 as seen in Figures 1- 4. It is realized that larger forest patches existed around the quarry in 2014 than in 2013. Similarly, Figure 8 and Table 3 point to the fact that both grassland areas and forest areas increased in size from 2013 to 2014. Grassland increased by approximately 10.11% while forest cover increased by 15.11% from 2013 to 2014. This possibly indicated that the diversity of organisms found around the quarry increased in 2014 from 2013. This observation prompted further investigation into the contributory drivers to the phenomena. Engagement with various stakeholders (quarry management, community Chiefs and elders, local farmers and wood loggers) revealed two key contributory drivers: (i) The management of the Odublasi quarry implemented an intensive tree planting exercise in 2013, around the quarry, to beef up the tree population in the area. (ii) Crop yields were becoming un-encouraging from continuous farming in the area, and some farmers shifted to other areas further away from the quarry site to farm. The shift away from the quarry site by farmers was a very significant driver in this case, as it allowed the surrounding degraded land to fallow and increase in grass cover. The deliberate efforts by the quarry management also contributed to mitigating the disturbances to biodiversity around the quarry, through the increase in tree population and forest cover.

Less modified areas

Plate 3 highlights an area which is reasonably inaccessible due to its height above ground and sloping nature. Most people will consider it rather dangerous to venture into those parts around the quarry site. Per this observation, it is expected that plant diversity in the area could remain high and fairly constant

Plate 3 Vegetation cover of the quarry hill

over a longer period of time, due to little or moderate anthropogenic interference. The vegetation may eventually attract animals to it occasionally, but its proximity to the quarry could cause consistent fleeing of animals from it, especially during rock blasting episodes and the generation of loud noise by rock crushing machinery.

Locally abundant tree species

Comparing information found in Environmental Impact reports and Municipal/ District survey reports, to field survey exercise undertaken in this study, it was realised that all locally widespread tree species in the area *(Elaeis guineensis, Mangifera indica, Azadirachta indica, Ceiba pentandra and Acacia auriculiformis)* were still found around the quarry in appreciable numbers. The most abundant tree species found around the quarry site was *Acacia auriculiformis.*

Conclusion and recommendations

In conclusion, drivers that have contributed to the modification of the vegetation cover around the Odublasi quarry include; the development and expansion of the quarry site; the construction of a new access road; the switch in livelihoods of local community members to those that depend on extracting biological resources; unsustainable farming and wood logging practices; social exclusion; and reforestation programme around the quarry site.

A rising and falling trend in total vegetation cover was observed in satellite images of the quarry site from 2007 to 2014; the vegetation cover experienced continuous degradation up to 2013, before starting to show signs of recovery in 2014. This was due to deliberate tree planting efforts by the quarry management and the reduction in farming activities in the area (as a result of shifting cultivation farming).

A few areas were found around the quarry to be less vulnerable to these drivers of vegetation cover change. Noticeable among them is the area found on the mountaintop at the quarry site. Sections of the access road to the quarry may, however, be considered as the most vulnerable habitats to modification, which may need critical attention in any restoration efforts, as activities from both the quarry and the surrounding community have consistently led to the modification of its vegetation cover and biodiversity.

Recommendations

- Reforestation efforts around the Odublasi quarry sites are critical and strategic and need to be intensified if possible. This will contribute positively to enriching the vegetation cover and consequently the biodiversity around the quarry, and mitigate disturbances caused by surrounding communities of the quarry.
- Fruit trees, including Mango (*Mangifera indica*) and Soursop (*Annona muricata*), should be strongly considered during the plantation of trees in and around the quarry site. This will ensure that the surrounding community (Odublasi) gets more value out of the area in the form of food (fruits), and help to prevent them from invading the area to cut down all the trees for farming and other economic purposes.
- Regular educational exercises in collaboration with relevant state and private agencies in agriculture and forestry management need to be undertaken for members of the Odublasi community. This is to ensure sustainable farming and wood logging

practices are carried out in the area.

- The issue of social inclusion has to be critically considered prior to the closure of the quarry, as an exclusion in the past has inevitably steered community members whose dependence on biological resources has led to the heavy depletion of the vegetation around the quarry.
- In order to minimize the continuous modification of the vegetation in the area, we recommend that the quarry company (West African Quarries Limited), act as a facilitator in introducing alternative livelihoods, among community members, that do not dwell on excessively extracting and/or modifying natural resources in the area. These may include technically skilled jobs like engineering and artisanship, and services jobs like driving, trading, and repair of electronics.

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