

# Mapping and Assessment of the Economic Impact of Small-Scale Surface Mining of Alluvial Gold Concentration in Talensi-Nabdham District, Ghana

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## Abstract

Mapping and analysis of alluvial gold concentrations as well as assessment of the impact of mining activities on the people of Talensi-Nabdham District, Ghana was undertaken. The mining concessions allocated to small-scale miners were surveyed and mapped using Total Station and Electrometric distance measurement equipment. Forty concessions were investigated: the largest covered 28.3ha. Analysis of ore bodies and slope percentage shows that Manganiferous Rock has the highest percentage rate of occupancy (46.5 %) with a slope percentage rate of 0-90%. Sandstone follows with 26.8% rate of occupancy and a slope rate of 0-100%. Sandstone and Quartz field-Spar Porphyry have the highest slope rate within 0-100%. Predictive terrain analysis indicated that the concentrations of the deposits are geographically located within the North-East and South East regions of the study area. Gold production evaluation shows that maximum increment was experienced in the year 2001 with a production unit of 85,596 (Oz). Employment criteria evaluation of socio-economic impact revealed that the number of individuals engaged in the gold mining activity increases annually: from 7.3% of the population in 2004 to 20.5% in 2010.

**Keywords:** Assessment, Socio-economic impact, Surface mining, Terrain analysis, Talensi-Nabdham district.

## 1. Introduction

The Ghanaian small-scale mining industry is well over 2,000 years old. Vestiges of alluvial gold extraction and winning activities have been found as far back as the sixth century and there is a wealth of evidence indicating that precious metals recovered from regional artisan activities were attracting Arab traders to certain areas of the country as early as the 7<sup>th</sup> and 8<sup>th</sup> centuries A.D (Hilson, 2001). In fact, it was the rich gold deposits of the Western Sahara that were largely responsible for the wealth and strength of large Ghanaian empires and cultures, by the 15<sup>th</sup> and 16<sup>th</sup> centuries, and at the peak of European colonial exploration, Ghana was finally labeled the 'Gold Coast' (Hilson, 2001).

Small scale and (artisanal) mining has been defined differently around the world. United Nations, (2013) and International Intermediate Group, (2010) definition describe small scale mining in terms of a given production ceiling or the level of sophistication with which minerals are exploited. Small-scale mining is any single unit mining operation having an annual production of unprocessed material of 50,000 tones, or less as measured at the entrance of the mine (United Nations, 2013): small scale miners are "poor people; individuals or small groups who depend upon mining for a living and who use rudimentary tools and techniques (e.g. picks, chisels, Sluice and pans) to exploit their mineral deposits. World Bank (2009) documented that "small scale mining is largely a poverty-driven activity, typically practiced in the poorest and most remote rural areas of a country by a largely itinerant, poorly educated population with few employment alternatives. Aryee et al., (2003) opined that small-scale mining is mining (Gold) by any method not involving substantial expenditure by an individual or group of persons not exceeding nine in number or by a cooperative society made up of ten or more persons.

Small-scale mining in Ghana, as in most developing countries, was for decades treated as an informal industrial sector, employing thousands of people but featuring largely rudimental, unmonitored and uncontrolled practices (Hilson, 2001). Since, the regularization of small-scale mining in 1989 over 1.5 million troy ounces of Gold have been produced by the sector (Ghana Mineral Commission, 2004). The legal frame work for registration of small-scale gold and diamond mines, minerals production and sales in the sector was established in Ghana in May 1989. The small-scale mining law, PNDCL 218 (Anon, 1989a) led to the establishment of the small-scale mining project within the Ghana minerals commission. The small-scale mining project (now small mining department) has the responsibility for providing technical assistance to prospective and registered small-scale miners in Ghana and promoting their activities. The Mercury Law, PNDCL 217 (Anon, 1989b) legalize the purchasing of mercury for gold recovery purposes from authorized dealers and the precious minerals marketing

cooperation (PMMC) law, PNDCL 219 (Anon, 1989c), created an authority to buy, sell gold and diamonds.



Figure 1: (a) Mine operator extracting gold through washing, (b) Remains of the Ore, which contains the Gold after the washing process

Since the regularization exercises two types of small-scale miners have emerged –legal and illegal. Legal small-scale miners comprise of those who have acquired miner’s license, while illegal small-scale miners include those mining and processing ones without the requisite mining license and they usually operate on concessions held by other companies. Illegal small-scale gold or diamond mining is popularly known in local parlance as “Galam Sey” a corruption of the phrase gather them (The Gold and Sell). With assistance from the Federal Institute for Geosciences and Natural Resources of Germany and the World Bank, the minerals commission successfully tested and introduced hammer mills to the Ghanaian small-scale mining industry in 1999. The first plant was built at -Talensi Nabdam district in the upper East Region of Ghana (Anon-Sackey, 2001).

The small-scale mining of these precious minerals has had significant socio-economic impact on many individuals and communities since it is the only source of income available to the people. In rural communities where mining takes place, particularly in the Talensi Nabdam district, the activity has reduced rural exodus, promoted local economic development and contributed towards poverty reduction. In addition, the mining operations are useful in basic skill development and contribute to the transformation of unskilled labor into semi-skilled and skilled to others. In the Talensi- Nabdam district, where other jobs are low paying or non-existent, small-scale mining appears as a valuable source of employment. However, there are principal environmental problems caused by these activities such as mercury pollution gold processing degradation. This study focuses on the mapping and economic assessment of small scale mining activities in the Talensi Nabdam district. The specific objectives are to: (i) coordinate and map the mining concessions in the area; (ii) examine the metric and geometric properties of the mining concessions, using surveying techniques; (iii) analyze the relationship between alluvial gold deposit and terrain descriptors and (iv) assess the socio economic impact of mining sites on the populace in Talensi-Nabdam district.

## 2. The Study Area

The study location is Talensi-Nabdam District, Ghana (figure 2). It is one of the newly created districts carved out from the then Bolgatanga Municipal Assembly. Talensi-Nabdam is in the upper East Region of Ghana and has its capital at Tongo. It is bordered to the North by the Bolgatanga Municipality, South by the West and East Manprusi district (both in the Northern Region), Kassena-Nankana district to the West and the Bawku West district to the east. Talensi-Nabdam lies within latitude  $010^{\circ} 15' N$  to  $010^{\circ} 60' N$  of the equator and longitude  $00^{\circ} 31' W$  to  $01^{\circ} 05' W$  of the Greenwich Meridian.

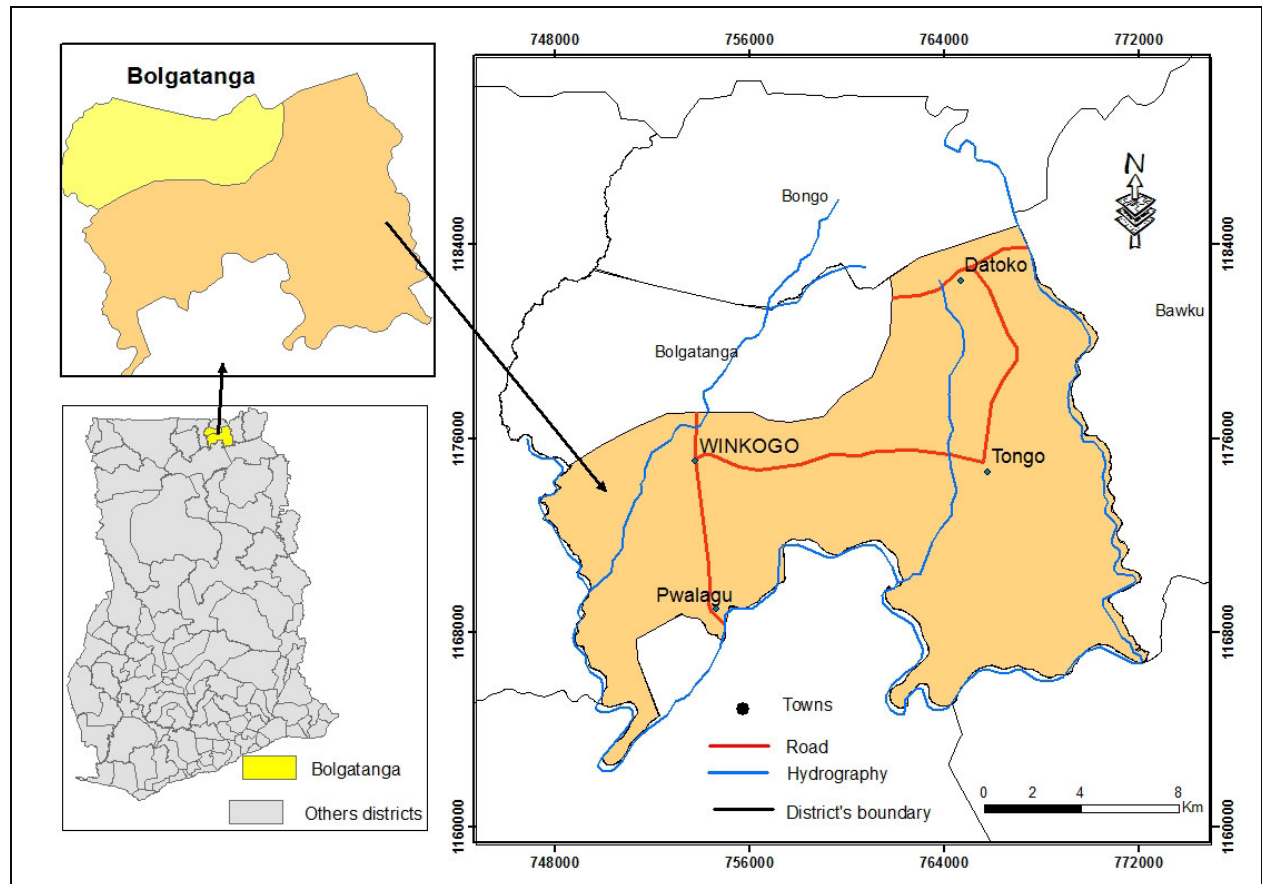


Figure 2: Study Area

Geologically, the area is within the voltarian rocks of Ghana and with strong presence of GOLD. The topography of the district is dominated relatively by undulating low lands gentle slopes. The climate is classified as tropical and has two distinct seasons: a wet rainy season which is erratic and runs from May to October, and a long dry season that stretches from October to April with hardly any rains. The mean rainfall ranges between 88mm-110mm, but with an annual rainfall of 950mm. The area experiences a maximum temperature of 45°C in March and April and a minimum of 12°C December. The vegetation is guinea Savannah wood land consisting of short widely spread deciduous trees and a ground flora of grass, which get burnt by fire or the scorching sun during the long dry season. The district has a total population size of 115,020.

Generally, the economic significance of small scale mining can be evaluated using three criteria: employment, production and earnings. The importance of small scale mining as a source of local employment is evident. A large number of people are engaged in small scale mining activities within the mining communities and their environs in Ghana. A report, presented by the Ghana Chamber of Mines, (2010) noted that 60% of the country's mining labor force was in fact employed at small-scale mines. Hilson, (2001) highlighted the socio-economic impacts of small-scale mining in Ghana noting that majority of those involved directly in the extraction of gold and diamond in the country are "galam Sey" (illegal miners). Ghana Mining Commission (2004) estimated that in 2003, the registered small-scale gold and diamond mines employed 100,000 people with almost an equal number working illegally, with 10% of women directly involved in the activity.

### 3. Materials and Methods

The methods used involved the interpretation and integration of spatial data with field observations for geospatial assessment and mapping of small scale surface mining.

**3.1 Data and Sources:** The data used included: (i) topographic map (scale 1:50,000, sheet 1001A4) produced in 2004, which was obtained from Survey & Mapping Division of Ghana. The map was used in extracting the drainage systems, road network settlements as well as place names and served as positional check and demarcating study area; (ii) Field data: Scenes of the mining sites were captured using Samsung digital camera 16 megapixels; also a dual frequency GPS, Sokkia brand was also used in establishment of control points within the study and in delineating each of the mining concessions; (iii) elevation data from Shuttle Radar Topographic Mission (SRTM); (iv) statistical data: regarding the socio-economic impact of the activity which includes;

production of gold from the District (from 1989 to 2009) and employment data (from 2004 to 2010) which were obtained from the Regional office of the Mineral Commission of Ghana in the Upper East of Ghana; and Average Annual Absolute Change (AAAC) of Population given as:  $AAAC = (P_1 - P_b) / n$  eq. 1  
Where  $P_1$  = population in the launch year,  $P_b$  = base population and  $n$  = number of years. This was used in estimating the projected population of the District from 2001 to 2009 to aid in analyzing the economic impact of the activity in the study area.

**3.2 Data Processing and Analysis:** Field observation data from the dual frequency GPS instrument was downloaded with Survey spectrum software and processed with ArcGIS 9.3 and AUTOCAD 2007 software. Linear tape measurement was used to determine the geometric (Depth) properties of the mining concessions. Mining concessions maps were produced. These aided in analyzing metric and geometric properties of the mining concessions. The documentary records and population data obtained from Mineral Commission of Ghana were analyzed in the form of cumulative curve with Microsoft excel software for soci-economic impact of the small scale mining activity on the people.

**3.3 Alluvial Gold Deposit and Terrain Descriptors Modeling:** The geological map shows the different categories of rocks which contains the alluvial gold deposits, namely: Manganiferous rocks, Sandstone, Metabasalts with local Metadacites, Granodiorite with local Tonalities, Volcaniclastic rocks, Cherts, Quartz field-spar Porphyry and Fault which shows a discontinuity between the geological objects which occurs as a result of volcanic eruption or tectonic processes. The various rocks are grouped under the Birimian and Tarkwanian group of the sedimentary rocks which is believed to contain about 60% of gold deposits in Talensi-Nabdam District as well the country at large (Hilson, 2001).

Two types of selection were performed in the processing and analysis in ArcGIS environment. They are selection by attribute which is a standard query language and selection by location which is a spatial query to ascertain the geological objects that dominate in the study area. Geological Map of the study area was overlaid with the 3D Terrain model of the study area in Surfer 10.7 environment and was used as input for surface roughness and mineral deposits modelling. This particular analysis depicted the relationship between the terrain descriptors and the mineral deposits.

#### 4. Results and Discussion

Forty mining concession sites were investigated in this work. Their metric and geometric properties, perimeter and depth respectively are reported (Table 1). The locations of the sites were also coordinated. Scene of a concession; the site illustrating depth measurement with linear tape from ground surface level is shown in figure 3.



Figure 3: Mining Concession with Gold Diggers Removing Placer Gold (Source: Field Work, 2013)

Table 1: Metric and Geometric properties of the Mining Concessions

S/N	X (M)	Y (M)	AREA (HA)	DEPTH (METERS) Z
1	753234.74	1187983.36	10.0	-12
2	753725.35	11888012.22	3.6	-7
3	753826.35	1188041.08	1.2	-7.8
4	754618.4	1188083.26	1.2	-4.5
5	754645.82	1187088.72	1.2	-9.1
6	754538.34	1186821.99	1.2	-4.6
7	754846.45	1187138.08	1.2	-3.9
8	754585.03	1187432.55	1.2	-10.1
9	75186.7	1184067.89	1.2	-8.9
10	751200.15	1184577.96	2.0	-12.5
11	751915.43	1184951.35	1.2	-6.9
12	751647.47	1184664.53	1.2	-15.1
13	749238.97	1184528.99	1.2	-13.9
14	749890.49	11844450.98	3.6	-8.8
15	749483.02	1184318.22	3.6	-10.9
16	750680.68	1183120.56	3.6	-6.8
17	750868.27	1183221.57	1.2	-17.1
18	751070.28	1183337	2.0	-13.9
19	751156.86	1183452.44	3.6	-19.2
20	751184.8	1180240.97	10.0	-12.5
21	752088.8	1180410.47	10.0	-26.3
22	751788.14	1179841.81	1.2	-8.7
23	752060.32	1179841.81	1.2	-9.6
24	754369.07	1180431.82	3.6	-16.1
25	755891.15	1185690.34	3.6	-20.3
26	757062.62	1185357.16	10.0	-18.1
27	756934.35	1184972.37	3.6	-7.5
28	757267.84	1185228.9	1.2	-7.9
29	757036.96	1185664.99	28.3	-30
30	757986.11	1185947.17	1.2	-8.9
31	758653.09	1186485.88	10.0	-13.5
32	756908.7	1186485.88	3.6	-11.8
33	763480.09	1188133.36	10.0	-9.9
34	763708.11	1187722.92	10.0	-8.1
35	763662.51	1186674	1.2	-14.7
36	764620.21	1187677.31	1.2	-16.2
37	763252.06	1189775.14	1.2	-8.6
38	755453.61	1176732.12	1.2	-13.3
39	757825.07	1177598.62	1.2	-17.5
40	755864.06	1179924.47	1.2	-12.5
41	758856.88	117003.92	1.2	-16.3
42	758583.25	1172388.25	1.2	-10.6
43	757386.12	1171977.81	1.2	-8.9
44	763713.81	1177005.75	1.2	-10.9

(Source: Author's fieldwork, 2013)

#### 4.1 Analysis of Concentration of Alluvial Gold and Terrain Descriptors Relationship

Statistical analysis of the percentage rate as well as the slope rate of the different categories of rocks in the area shows that Manganiferous Rocks have the highest percentage rate of ore occupancy of 46.5 %; and a slope percentage rate of 0-90%. Sandstone follows with 26.8% rate of occupancy with a slope rate of 0-100%. Sandstone and Quartz field-Spar Porphyry has the highest slope rate within 0-100%. Cherts and Metabasalts with Metadacites have the least slope rate within 0-50% (Table 2). Figure 4 shows slope percentage rate within the study area, from the minimum slope rate of 0-5% to the maximum slope rate (from 29-100%).

Table 2: Results of the Analysis of Ore bodies and Slope Percentages

Rock Type	Percentage / %	Slope %
Manganiferous Rocks	46.5	0-90
Sandstone	26.8	0-100
Cherts	17.8	0-50
Granosiorite with local Tonalities	2.23	0-90
Volcaniclastic Rocks	2.23	0-90
Metabasalt with Metadacites	2.23	0-40
Quartzfield-Spar Porhyry	2.23	0-100

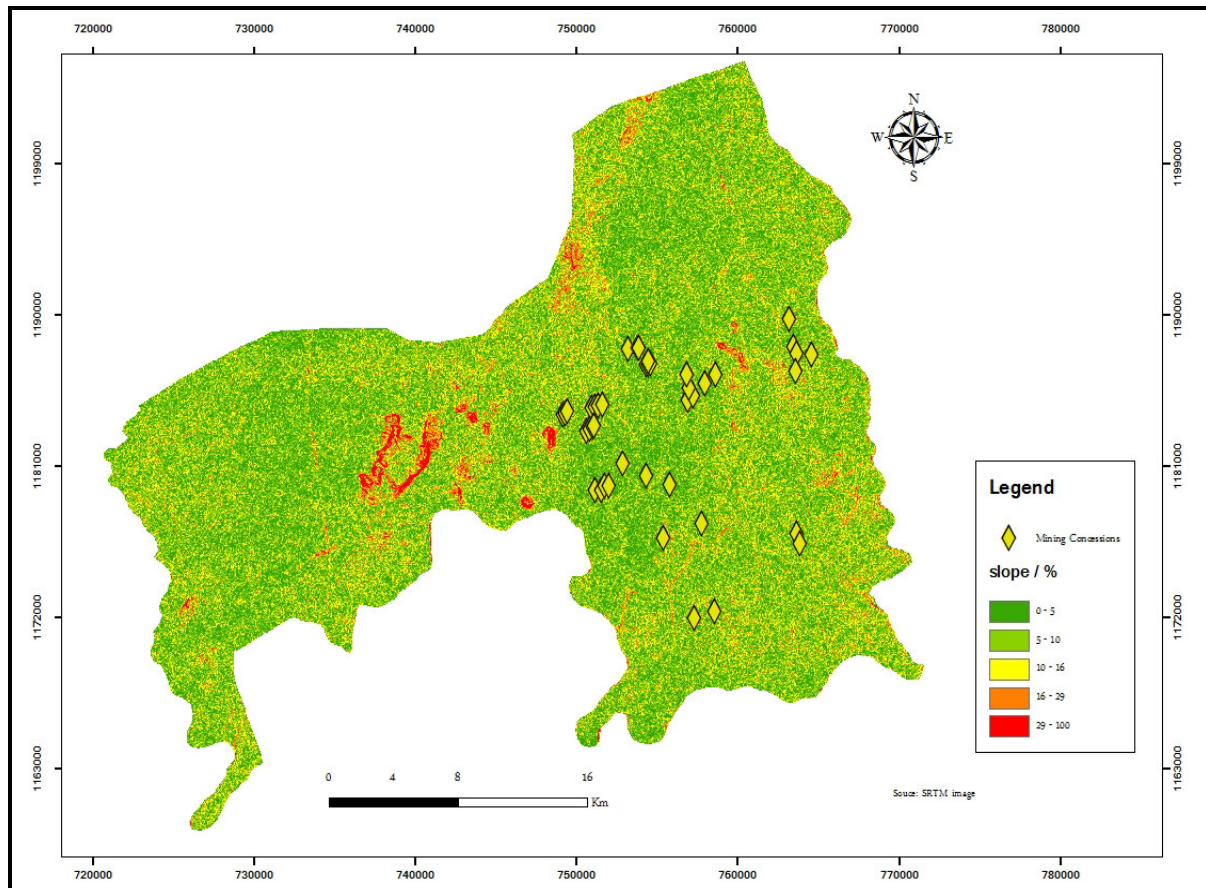


Figure 4: Slope Map

Overlay analysis of geological map, 3D terrain model revealed that most of the geological objects within the study area were spatially located within flat and hilly regions (figure 5) and also presented a better understanding and analysis of where to exactly explore the ore.

Geostatistical analysis using kriging tool in ArcGIS 9.3 was adopted in determining the concentration of the mineral deposits in the study area. The gold indices as well as the geological map were reclassified together and used as the input parameters for predicting precisely the concentration of the alluvial deposits. The prediction analysis indicated that the concentration of the deposits were geographically located within the North-East and South East regions within the study area. The mining concessions are located around these regions however not precisely on the concentrated regions but close. The deeper blue shows higher concentration whilst deeper red shows lower concentration; the North-West and South-West regions indicate lower or little concentrations (figure 6).

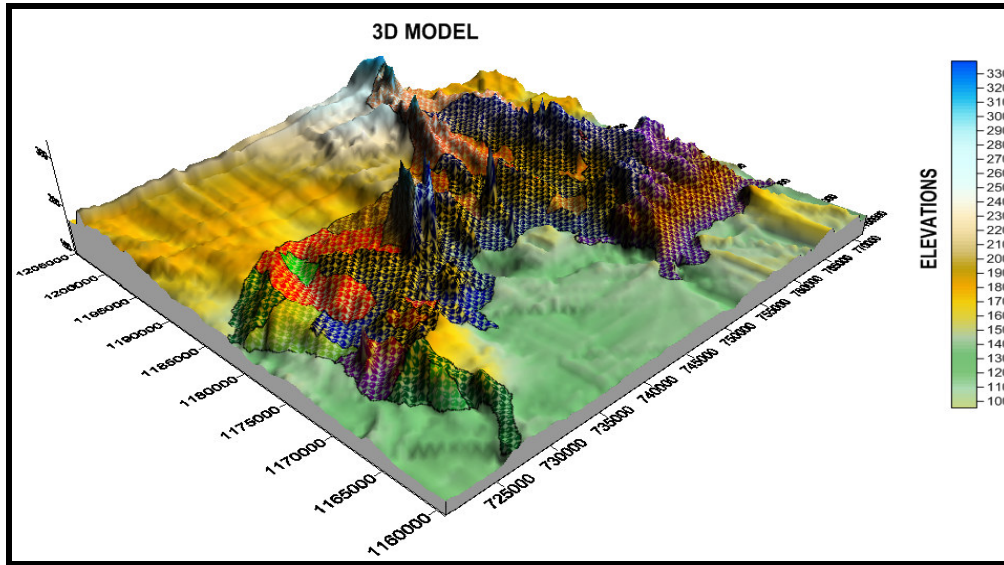


Figure 5: Superimposition of Digital Terrain Model and Geological Map

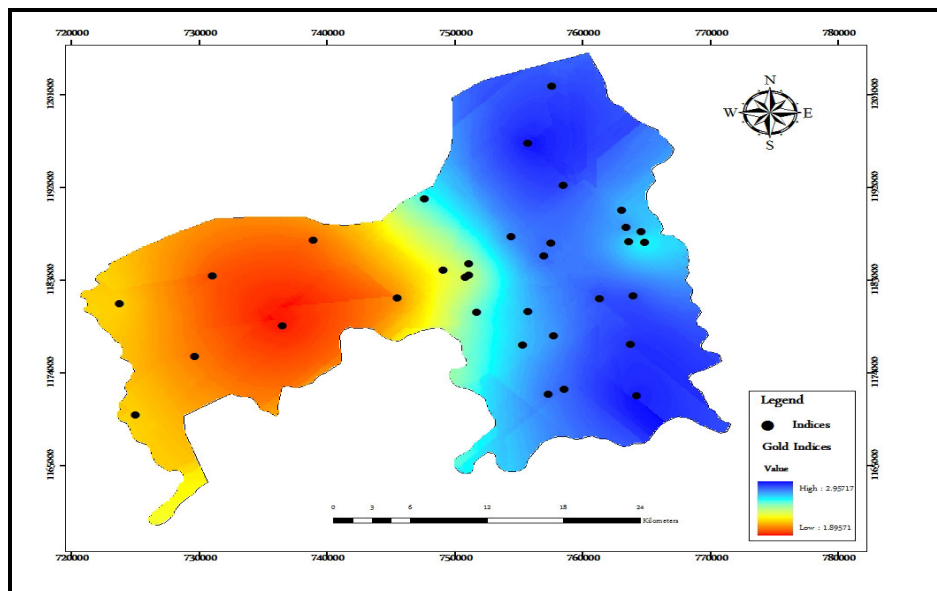


Figure 6: Predictive Map for concentration of the alluvial gold deposits

A reclassification and overlay analyses were carried out to ascertain the relationship between the geological objects, the gold indices and the fault (figure 7). This was to further aid in understanding the relationship between the terrain and the mineral deposits as well as new concentration areas relative to the alluvial gold deposit. Reclassification analysis and analysis for slope and gold indices in the study area indicate that slope is related to the gold indices in that even at minimum slope rate one could find lower concentrations of the gold indices and at maximum slope rate one could also find higher concentrations of the gold indices (see figures 7 to 9).

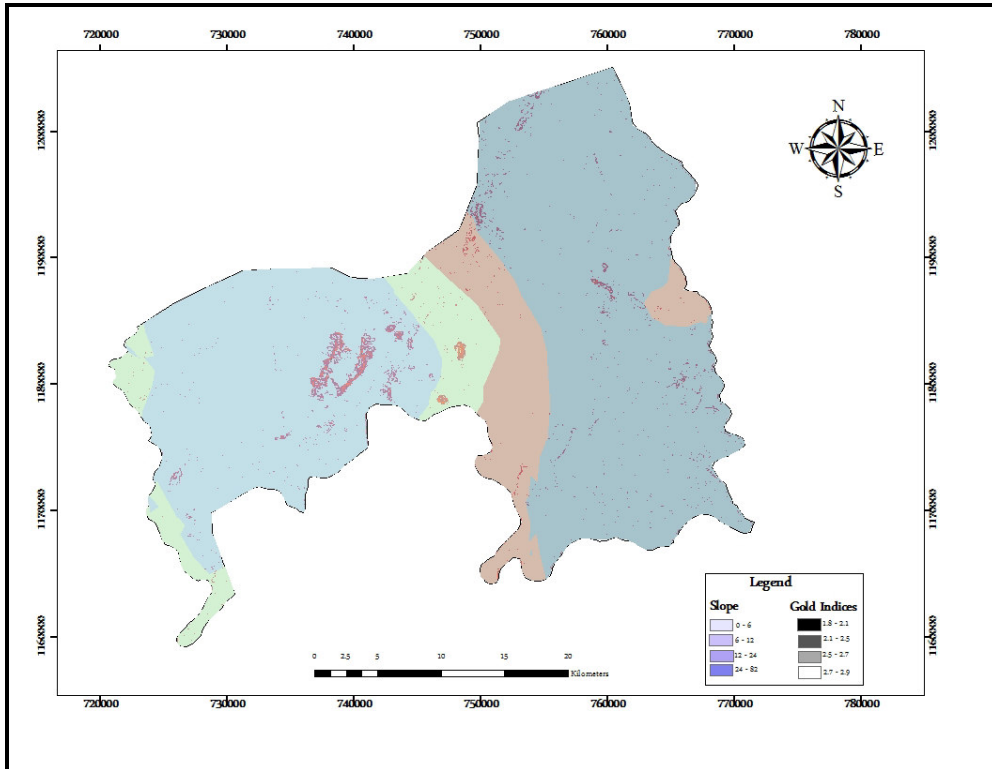


Figure 7: Spatial patterns between geological map, gold indices and fault

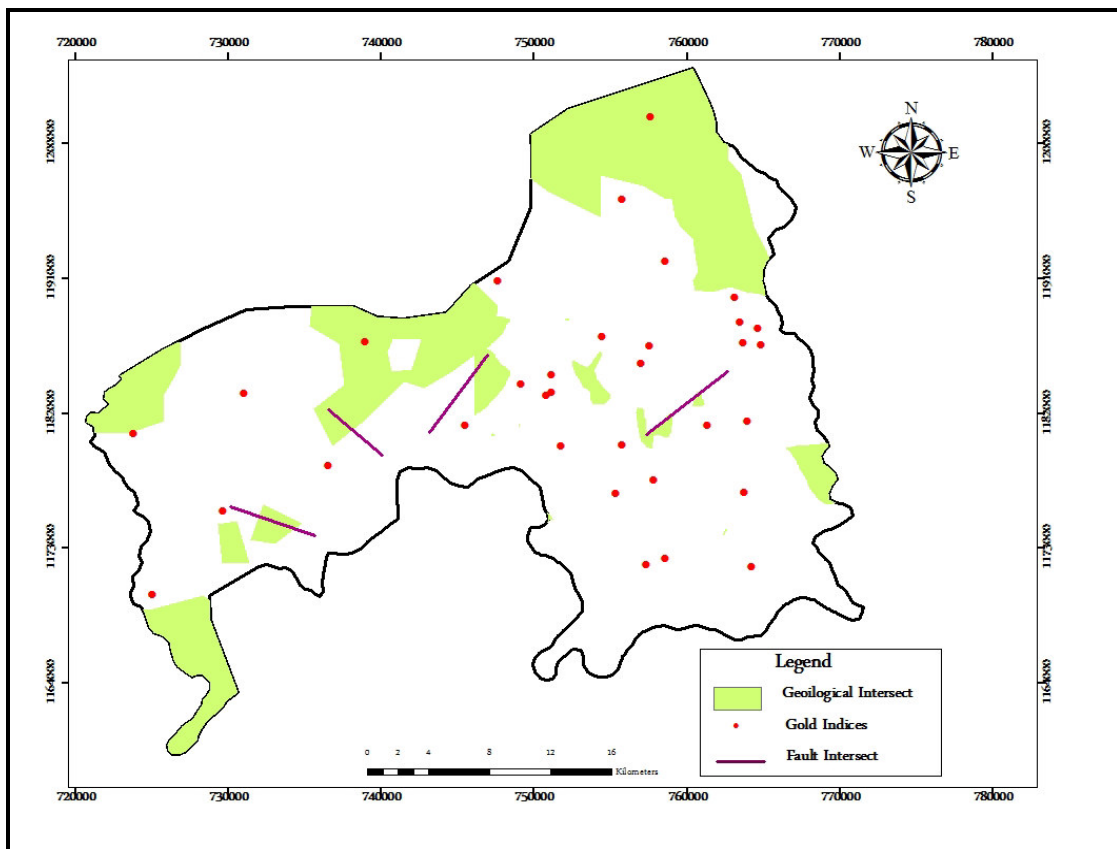
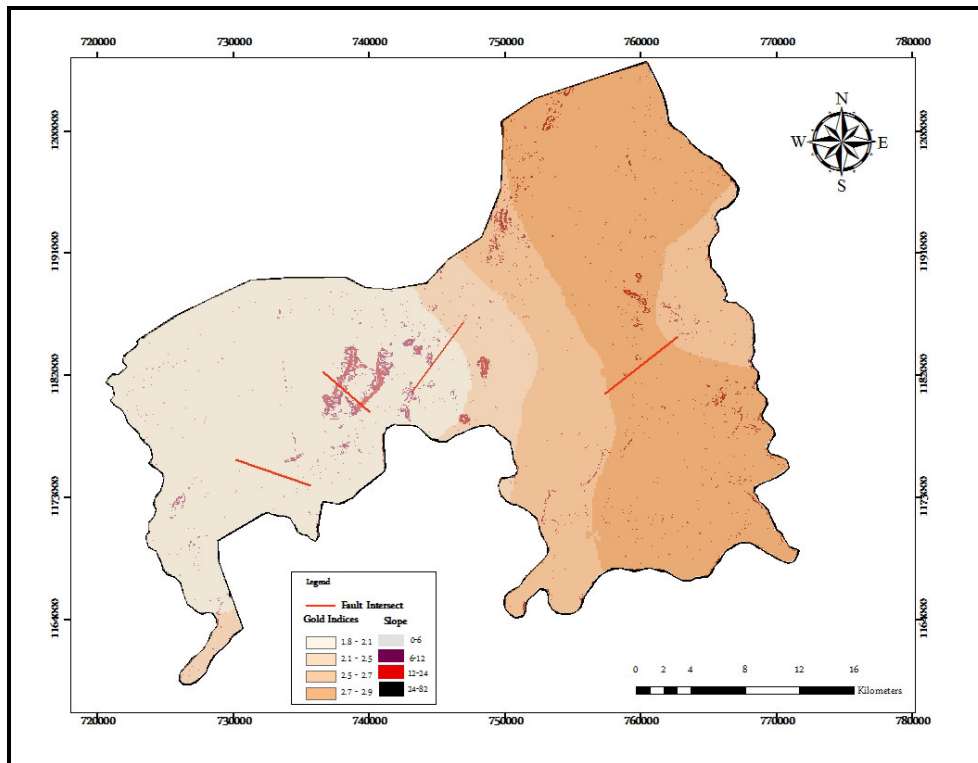


Figure 8: Relationship between Slope and gold indices





*Figure 9: Slope, gold indices and fault relationship map*

The study shows that apart from the concentrated areas of the alluvial gold deposits which are geographically located within the North-East and South East regions of the study area, a new concentration area was also discovered which is geographically located in the South-West hilly region. This is because, an intersection between geological objects and faults axes indicate presence of ore deposit or (an ore body) in mass of rock from which a concentration of the mineral deposits can be mined, processed and marketed at a profit (Sumner, 2004). Concentration of alluvial gold deposits falls within the North-East and South-East regions of the study area with much of the concentrations within minimum and maximum heights of 140 meters to 280 meters above mean sea level, although the alluvial gold deposits could also be located in the lower regions but not much, where most of the mining concessions are located.

#### **4.2 Analysis of the Socio-economic Impact of Small Scale Gold Mining**

Generally, the economic significance of small scale mining can be evaluated using three criteria: employment, production and earnings. In assessing the socio-economic impact of small scale surface gold mining in the study area, the production evaluation criteria was first analyzed (Table 3). A historical documentary record which was obtained from the Ghana Mineral Commission office shows the statistics of the production of gold from 1989 to 2009 pertaining to the Talensi-Nabdam District: with the production unit in ounces as well as the percentage rate of the production. Cumulative data (figure 10) of the production unit against the years of production was graphically illustrated in order to comprehend the socio-economic impact in the study area as relative to the production evaluation criteria.

Table 3: Analysis of Gold Production in Talensi-Nabdam District

Year	Gold Production (Oz)	Total District Production (%)
1989	1,272	0.2
1990	3,234	0.4
1991	5,601	0.7
1992	7,297	0.9
1993	18,520	2.4
1994	27,025	3.5
1995	45,014	2.5
1996	19,349	3.9
1997	25,094	2.5
1998	30,334	3.9
1999	49,833	6.5
2000	55,663	7.2
2001	85,596	12.5
2002	60,879	7.9
2003	70,414	10.5
2004	66,253	8.6
2005	45,698	5.9
2006	23,999	3.1
2007	35,698	4.6
2008	58,952	7.6
2009	36,548	4.7

(Source: Minerals Commission of Ghana)

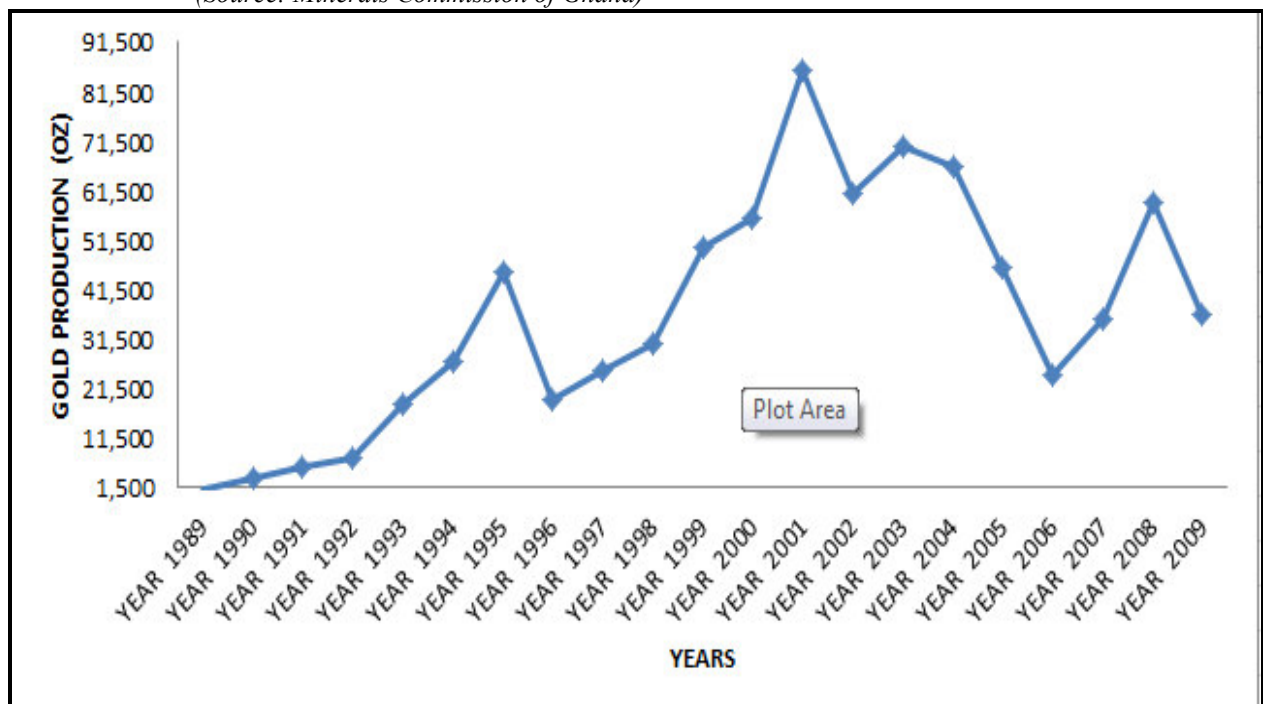


Figure 10: Gold production cumulative Curve (1989-2009)

The analysis reveals that the production of gold in 1989 when small scale surface gold mining was officially legalized in Ghana was below 1,500 (oz). This is believed to be due to the fact that much attention was not paid to the activities as it was regarded as illegal. The trend started increasing periodically and a maximum increment was experienced in the year 2001 with a production unit of 85,596 (oz). Further statistical analysis of the production evaluation criteria from 1989 to 2009 of the production of gold in the Talensi-Nabdam district was done by relating the production unit against production percentage rate. Again the production percentage was seen to be very low in 1989, increased tremendously in the following years with maximum peak percentage rate of 12.5% in 2001.

Employment criteria evaluation was the last criteria that was adopted in evaluating the socio-

economic impact of the small scale surface gold mining activities on the people in the Talensi-Nabdam district. Table 4 shows the statistical analysis of the number of inhabitants who are gainfully employed by this activity from 2004 to 2010 as well as the employment percentage rate with respect to the various years. Employment information regarding years preceding 2004 were not available. A total of 2,409 people were employed over the last six years from 2004 to 2010 (available data from the Mineral Commission of Ghana).

Table 4: Number Persons Employed from 2004-2010

Year	No. Employed	Rate of Employed (%)
2004	176	7.3
2005	230	9.5
2006	312	13
2007	365	15.2
2008	389	16.1
2009	444	18.4
2010	493	20.5
Total	2409	100

(Source: Mineral Commission of Ghana)

Population data from 2004 to 2009 was not available to analyse the employment pattern within the study area from 2004 to 2010. The population and housing census conducted in Ghana was in 2000 and 2010. Therefore, a projected population data was generated (Table 5) using Linear extrapolation method (line) ; this assumes that the population will increase (decrease) by the same number in each future year as average annual increase (decrease) observed over the base period.

Average Annual Absolute Change (AAAC) was computed. This was calculated using 2000 and 2010 population and housing census figures of the District.

Given  $P_1 = 100,789$  (PHC in 2000),  $P_b = 115,020$  (PHC in 2010), and  $n = 10$  years;

$AAAC = (P_1 - P_b)/n = (115020 - 100789)/10 = 1,423.1$  as the annual average absolute change,  $1,423.1 * 10 = 14,231 + 100,789 = 115,020$  as check and each estimated population year was calculated as  $AAAC + P_1 = 1,423.1 + 100,789 = 102,212.1$  for the year 2001, and **103,635.2** for the year 2002 and added cumulatively up to the year 2009 an estimated population of 113,596.9. This estimated analysis was computed so as to be able to infer the socio-economic impact of the mining activity on the people relating to the employment evaluation criteria of ascertaining the number of people employed relative to the population at that year. Cumulative employment record from 2004 to 2010 is shown in figure 11.

Table 5: Estimated Population from 2001-2009

Year	Estimated Population
2000	<b>100,789</b>
2001	102,212.10
2002	103,635.20
2003	105,058.30
2004	106,481.40
2005	107,904.50
2006	109,327.60
2007	110,750.70
2008	112,173.80
2009	113,596.90
2010	<b>115,020</b>

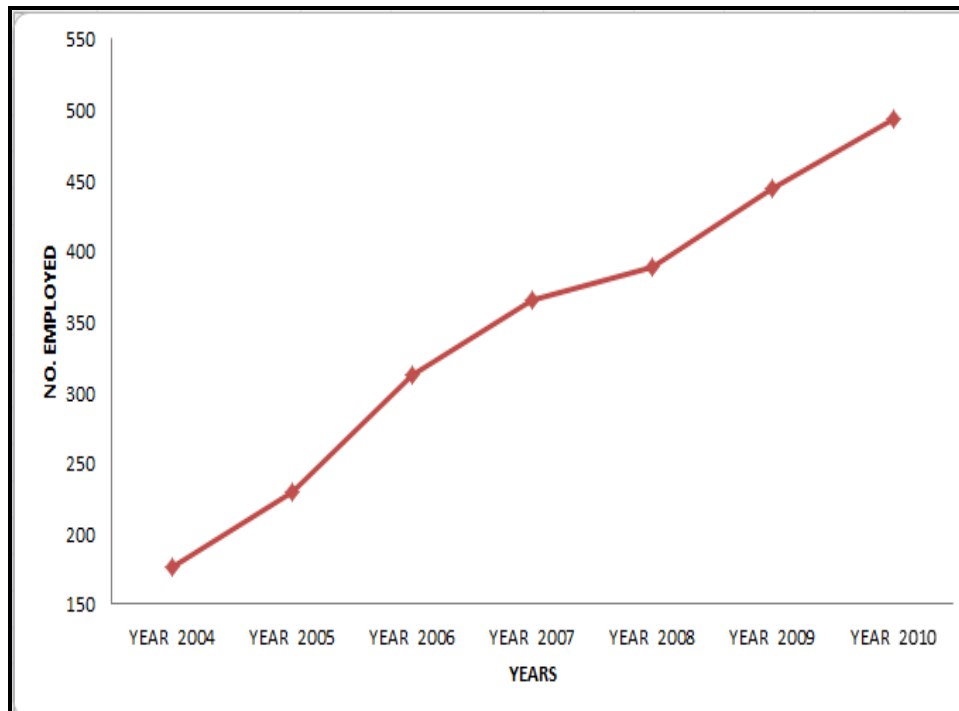


Figure 11: cumulative graph of employment evaluation criteria from 2004-2010

From the cumulative frequency graph, it is obvious or evident that the mining activity indeed serves as a source of employment for most people in the study area. The number of people employed from 2004 to 2010 increases tremendously year by year. For instance in 2004 the number engaged in this activity were only 176 people representing 7.3% of the population at that year; in 2010 493 people were engaged in the activity denoting 20.5% of the population at that year. This analysis is an emphatical evident of being able to quantify the socio-economic impact of the mining activity in the lives of the people in the Talensi-Nabdam district. In the same development, making a projected analysis of the economic trend, from 2010 to 2016 the number of people employed by this activity will continues to increase annually.

More importantly, in evaluating the socio-economic impact of small scale mining activity in the study area, using the employment evaluation criteria emphasises should be placed on the nature of labour and income distribution associated with the activity. The labour division of the activity is made up of sponsors or buyers also known as concession owners; people who wash the processed ore with white mercury known as extractors or processors; those who crush the orebody with rudimentary tools like hammers, chesels, pans, shovels known as crushers or panners; and those who dig the mining pits also known as miners or diggers. In the same vein, the income distribution is associated with the same group of people from the concession owners down to the carriers. From the statistical analysis above, about a total of 2,409 people are engaged in the activity from 2004 to 2010 representing 2.1% of the current population of 115,020.

## 5. Conclusion

Field observations, coupled with historical documentary records have been used in this study to map analyze and assess the socio-economic impact of small-scale gold mining activities on the lives of the people in the Talensi-Nabdam district of Ghana. Analysis of ore bodies and slope percentage shows that Manganiferous Rock has the highest percentage rate of occupancy, followed by Sandstone. Similarly, Sandstone and Quartz field-Spar Porphyry has the highest slope rate. Furthermore predictive terrain analysis indicated that the concentration of ore deposits were geographically located within the North-East and South East regions in the study area.

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