

Received:
12 September 2017
Revised:
23 December 2017
Accepted:
31 January 2018

Cite as: F. Owusu-Nimo, J. Mantey, K. B. Nyarko, Eugene Appiah-Effah, A. Aubynn. Spatial distribution patterns of illegal artisanal small scale gold mining (*Galamsey*) operations in Ghana: A focus on the Western Region. *Heliyon* 4 (2018) e00534. doi: 10.1016/j.heliyon.2018.e00534



Spatial distribution patterns of illegal artisanal small scale gold mining (*Galamsey*) operations in Ghana: A focus on the Western Region

F. Owusu-Nimo^b, J. Mantey^{a,*}, K. B. Nyarko^b, Eugene Appiah-Effah^b, A. Aubynn^c

^a Gold Fields Ghana Limited, Environmental Department, P.O Box 26, Tarkwa, Ghana

^b Kwame Nkrumah University of Science and Technology (KNUST), Civil Department, Kumasi, Ghana

^c Ghana Minerals Commission, Accra, Ghana

* Corresponding author.

E-mail address: mybryanjones@yahoo.co.uk (J. Mantey).

Abstract

Recently, there have been efforts by stakeholders to monitor illegal mining (*galamsey*) activities, foster their formalization and reclaim the many abandoned wastelands in Ghana. However, limited information exists on the locations, abundance, scope and scale of *galamsey* types, which hinders the development of effective policy response.

This study attempts to map and analyze the distribution patterns, abundance, activity statuses and the extents of nine (9) *galamsey* types within eleven (11) Municipal and District Assemblies (MDAs) of Ghana's Western Region. It explores the utility of field-based survey, using the Open Data Kit (ODK) system, ArcGIS and Google Earth Imagery to map and visualize different *galamsey* types under a hostile working environment. A total of 911 *galamsey* sightings, of which 547 were found in clusters (corresponding to approximately 7106 individual operational units) and 364 in stand-alone mode. Overall, a total of 7470 individual *galamsey* operations were encountered in 312 different communities (towns and villages).

Operationally, the Alluvial Washing Board, Mill-House and Chamfi were found to be the three most popular and practiced galamsey types. The three main galamsey hotspot districts (out of the 11) are the Tarkwa Nsuaem (294 sightings and 3648 individual galamsey sites), Amenfi East (223 sightings and 1397 individual galamsey sites) and Prestea Huni-Valley Districts (156 sightings and 1130 individual galamsey sites). In terms of their activity statuses, 199 abandoned operations (entailing 1855 individual operations), 664 active (entailing 5055 individuals operations) and 48 semi-active (comprising 560 individuals within clusters) galamsey operations were sighted at the time of the study.

While *galamsey* is generally acknowledged to be widespread in Ghana, the results suggest a scale that probably surpasses any previous estimate or expectation. The findings will adequately inform the prioritization of reclamation efforts.

Keywords: Geography, Environmental science, Earth sciences

1. Introduction

Mantey et al., [1] defines “galamsey” as the practice of illicitly mining and/or extracting gold found either at or below soil and water surface in Ghana. It is an illegal or unregulated form of artisanal small scale gold mining (ASM) and could either be in a stand-alone mining mode, a stand-alone processing or gold extraction mode or in a simultaneous mining and processing fashion. Galamsey is illegal because operators involved work without regulatory approvals (from either the Ghana Minerals Commission, Environmental Protection Agency, Water Resources Commission, Forestry Commission or the host Municipal Assembly), pays no tax and statutory fees, operates in sensitive or prohibited areas (forest reserves, water bodies, sacred and culturally significant areas, residential zones etc.) and pays less or no attention to human rights [2, 3, 4].

This artisanal small scale gold mining business dates back to the colonial era where it started as a low-tech ‘pick and shovel’ or “gather and sell” enterprise using rudimentary or artisanal implements [5, 6]. Modern day ‘galamsey’ mining and gold extraction however is slightly advanced mechanically (excavators, dozers and other heavy duty equipment), chemically intensive (mainly mercury and liquid hydrocarbons) and requires an extensive network of infrastructure that disrupt and pollute the environment [1, 7, 8, 9]. Galamsey has assumed a status as one of the most talked about environmental issue and perhaps the greatest societal menace in Ghana today [10, 11]. The illegal ASM has infiltrated many mineralized district in Ghana and its operations are in many different forms [1, 12, 13, 14]. In the Western Region of Ghana for example, Mantey et al., [1] unearthed eleven (11) operational forms of galamsey grouped under five (5) broad categories. A summary and brief characteristics of the various operational forms identified are summarized in Table 1.

Table 1. Overview of the 11 galmsey types found within selected DMAs in Ghana' Western Region [1]

Broad galmsey categories	Galmsey types	Key resource/material use	Water relation	Comments
1. Placer/alluvial	1. Washing Plant	Washing plant/trommel, excavator, mercury, diesel, petrol and lubricants	Operates near water bodies and requires high volume of clean water for operation	Simultaneous mining and gold extraction
	2. Washing Board	Washing/slucice board, excavator, mercury, diesel, petrol and lubricants	Operates near water bodies and requires high volume of clean water for operation	
	3. Anwona or Pit Dredging	Pits, Suction Dredge, mercury, diesel, petrol and lubricants	Operates within mini pit lakes or mine-out pits and require water	
	4. Stream/River Dredging	River/Stream, Suction Dredge, mercury, mercury, diesel, petrol and lubricants	Within water bodies-with adequate current	
	5. Dig and Wash & 6. Panning ("poolepoole")	Pan, shovels, pick axes, manual, sluice board, mercury	In wetland areas, rivers/creeks/streams banks	
2. Underground mining	7. Abandoned Underground Shaft/Tunnels	Shaft, blasting, dewatering, load and haul of ore	Underground/land-locked areas	Mining Only
	8. Sample Hole/Pit or "ghetto"	Manually dug out pit, blasting, dewatering, mining	Underground/land-locked areas	
3. Mill house	9. Mill-house Operation	Chan Fa Engine, Crusher, Smoothing Machine, Retort, Mercury, Hydrocarbons	Land-locked areas; near road side, within urban centers or may be near mining sites	Processing Only
4. Chamfi/surface operation	10. Chamfi	Chan Fa diesel powered engine, mercury, retort, mercury, diesel, petrol and lubricants	Land-locked areas; either near or far from water bodies...but requires water for operation	Simultaneous mining and gold extraction
5. Selection ("pilfering mining")	11. Selection (normally from LSM & Licit ASM sites)	Manual selection, Chan Fa, mill house, mortar & pestle/slucice board	Land-locked areas; either near or far from water bodies...but requires water for operation	Mining Only

Varying degrees of health, injuries and fatalities are reported to be associated with galmsey; as many operators, host community personnel and wildlife are on daily basis exposed to very hazardous environmental, safety and health conditions [8, 15, 16, 17]. Galmsey is characterised by violent conduct of some illegal mine operators and an appreciably high level of crime within and around host community [18, 19, 20]. Regarding land impacts, the illicit activity has left many wastelands (pits, waste piles, deforested lands etc.) abandoned, flooded and unreclaimed [21, 22, 23], often posing dangers to local residents, especially children, women and to livestock. Additionally, extensive damage to farm lands (cocoa, rubber plantations,

food crops etc.) and forests, as well as pollution of water bodies have been reported [7, 24, 25, 26]. Mercury and hydrocarbon contamination to humans, soils/land, and water, are also mentioned among the many different impacts resulting from galamsey [16, 27, 28, 29, 30, 31, 32, 33, 34].

The need for a sustainable solution to the menace caused by galamsey operations has become critical. Discussions on formalization of galamsey and reclamation of the many reported wastelands are increasing [35, 36, 37]. There is however lack of adequate knowledge of the various galamsey types and operational attributes as well as their spatial distribution pattern across the ten regions of Ghana. Currently, there is limited or no reliable mapping data on the types and whereabouts (host villages and communities) of galamsey, their abundance and spatial extent, site activity statuses and hotspots in Ghana. This kind of information is critical to address the menace associated with galamsey [1, 36, 38, 39, 40]. Many of the initiatives currently used to address galamsey issues have been adhoc and resulted in policies and solutions that do not take into account the specifics of the challenge on hand [41].

This study therefore aims at mapping galamsey types accurately (their locations, abundance and scope), ascertain hotspots and assess their contemporary activity statuses within eleven assemblies of Ghana's Western Region.

2. Materials and methods

2.1. Study site selection and description

The Western Region which was selected for the study represents the most active gold mining region in Ghana. It has the highest concentration of large scale gold mining companies (LSMs) and regulated artisanal small scale gold mining companies (ASMs) as well as being the highest producer of Gold in Ghana [42, 43, 44, 45]. Out of the fourteen (14) large scale gold mining companies (LSMs) actively operating (extracting gold) in Ghana, ten (10) are located in the Western Region (Table 2). Again, approximately 396 (representing 30%) of the 1,342 registered and actively operating small scale gold mining (SSM) companies in Ghana operates within the Western region of Ghana [46]. It is believed that galamsey activities are prevalent in areas with LSMs and regulated ASM operations.

Eleven (11) out of the twenty-two (22) metropolitan, municipal and districts assemblies (MMDAs) in the region was chosen for the study (Fig. 1). In selecting the eleven districts for the study, all the nine districts hosting LSMs were selected. Two additional district assemblies were randomly selected from the remaining 13 MMDAs known to be hosting ASMs and having a rich galamsey history. Table 2 shows the eleven selected districts indicating the number of LSMs and regulated

Table 2. The eleven (11) selected municipal and district assemblies (MDAs), their respective sizes, coordinates and LSM/ASM overviews within the Western Region [48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62]

	Selected MDAs	Capital	Size of MDAs (sq. km.)	Location/Coordinates (Lats/Long)	Registered SSM	Active LSM
1	Wassa Amenfi Central	Manso Amenfi	1,845.9	Details not yet available	4	Nil
2	Wassa Amenfi East	Wassa Akropong	1,558.0	Latitudes 5, 30 N, 6,15 N, Longitudes 1, 45 W and 2, 11 W	38	Golden Star Bogoso-Prestea/ Perseus Mining (Ghana)
3	Amenfi West	Asankragua	1,448.56	Latitude 400'N and 500 40'N and Longitudes 10 45' W and 20 10'W.	61	Nil
4	Bibiani-Anhwiaso-Bekwai	Bibiani	833.7	Latitude 60 N, 30 N and longitude 20 W, 30 W	86	Noble Gold Bibiani Limited/Kinross (Chirano) Gold/Awaso Bauxite Mines, Limited/Ghana Bauxite Company
5	Ellembelle	Nkroful	995.8	Latitude 40 40''N and 50 20''N and Longitude 20 05''W and 20 35''W	2	Adamus/Nzema Mines
6	Mpohor	Mpohor	524.533	Latitude 5.1040° N, and Longitude 1.6731° W	3	Golden Star Wassa Mines
7	Wassa East	Daboase	1,651.992	Details not yet available	10	Golden Star Wassa Mines

(continued on next page)

Table 2. (Continued)

	Selected MDAs	Capital	Size of MDAs (sq. km.)	Location/Coordinates (Lats/Long)	Registered SSM	Active LSM
8	Nzema East	Axim	1084.0	Latitudes 40 40' and 50 20' North of the Equator and Longitudes 2005' and 2035' west	16	Adamus-Nzema Mines
9	Prestea Huni Valley	Bogoso	1,809.0	Details not yet available	89	Gold Fields Tarkwa/Golden Star Bogoso-Prestea/ Golden Star Wassa Ltd./Sankofa Gold Limited/ AngloGold- Iduapriem Limited
10	Sefwi Wiawso	Sefwi Wiawso	1,101.6	Latitudes 60N and 60 300 N and Longitudes 20 450 W and 20 150 W.	1	Noble Gold Bibiani Limited/Kinross (Chirano) Gold Mines Limited
11	Tarkwa–Nsuaem	Tarkwa	905.2	Latitude 400'N and 500 40'N and Longitudes 10 45' W and 20 10'W.	10	Gold Fields Tarkwa Mines/ Nsuta Manganese Mines Limited/AngloGold- Iduapriem Limited
	Total		13,758.29		320	

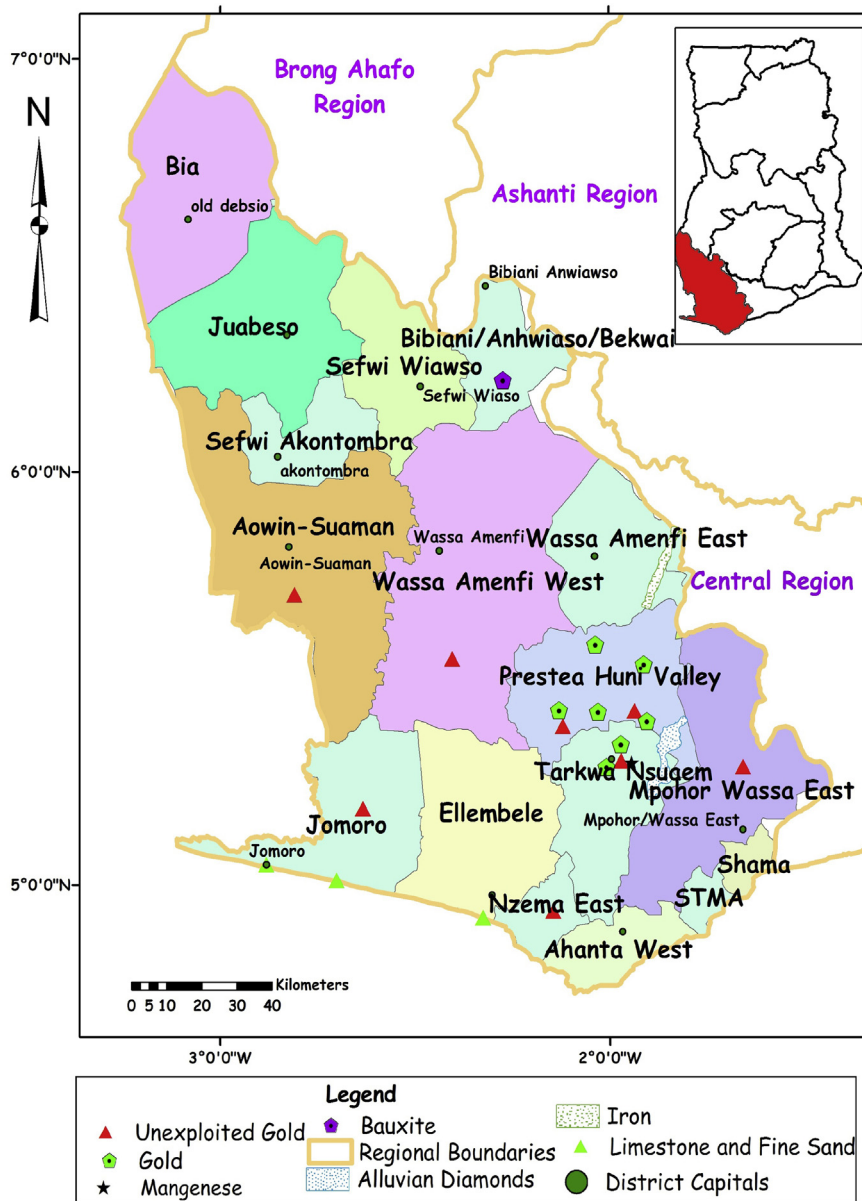


Fig. 1. Map of the Western Region and its assemblies showing mineral deposits (Sourced from: Ref. [47])

ASMs. The total land size of the selected districts was 13,758.29 km² which represents approximately 57.5% of the total land area of the Western Region.

2.2. The data collection framework

The data collection for the study involved two distinct phases namely the planning and preparatory phase and field data collection phase. The planning and preparatory phase involved review of relevant literature and interviews with key informants, and the development of mobile based survey questionnaire. Literature on the various

types of galamsey from published and unpublished reports [1, 34, 63, 64] and media reports [11], were reviewed. This was done to obtain information on the characteristics and operational dynamics of the various galamsey forms being operated.

A review of literature and information on the selected districts was undertaken to obtain names of towns and villages hosting galamsey, as well as their physical, demographic, social and economic characteristics.

Additionally, Key informant interviews were conducted with a wide range of mining stakeholders including the Ghana chamber of mines, Ghana Environmental Protection Agency (EPA), Ministry of Environment, Science, Technology and Innovation (MESTI), Minerals Commission, Forestry Commission, Water Resources Commissions, Large Scale Mining firms, District Chief Executives and Coordinators of the selected MDAs, security personnel (police, military and other private security companies) and traditional authorities. After gathering all the necessary information, a survey questionnaire was prepared to capture basic demographic characteristics of the communities hosting galamsey operations, GPS coordinates of galamsey site, type and organization of galamsey operation, status of the operation, land take estimates and visual assessment of environmental impacts. This questionnaire was uploaded on android mobile device using the Open Data Kit (ODK) applications to enable field data to be collected using the ground-based mobile data collection approach.

The field data collection phase included field identification of galamsey operations, their GPS location, and site activity. A brief description of each activity is provided below.

2.2.1. Field identification of operations

Eleven types of galamsey operations were identified from the review [1], however only nine were mapped during the field survey. The other two galamsey operational types (panning and selection galamsey) were not considered in the mapping exercise due to their transient, elusive and unstable nature; constantly changing their working environment and generally difficult to pin down.

Locating and identifying galamsey operation can be an arduous task, due to their illegal, scattered, clandestine nature (of some operations), access restrictions (to some sites), safety and security challenges, and difficulty in distinguishing one from the other operations with similar spectral resolution and outlook. Whilst a great number of them are located within forests, highly remote areas and deep under the earth (underground tunnels/holes), some require the crossing of bridges, rivers and many hours of journey. In localities known to be heavily populated with underground and mill house galamsey operations, such as the Tarkwa Nsuaem, Prestea-Huni Valley, Wassa Amenfi East districts and Daboase, it is not difficult sighting

galamseyers by road-sides and in urban centres. Whilst some galamsey types are in clustered status or having many similar operations positioned on the same piece of land, others are singularly stationed or in stand-alone mode.

To limit confusion over which operation is illegal or legal, the operational attributes of the various galamsey types identified during the review [1] was very helpful. These attributes included resources or materials used and the relation of the site operation to water and water bodies. On-sight signages and labels (where available), use of existing ASM maps (blocked out areas for small scale miners by Minerals Commission), personal experiences with the galamsey business, field engagements and interviews (where possible) and the involvement of community personnel or locals (women, students and surveyors) in the data collection were also very helpful in locating and identifying galamsey operations (where possible and available).

2.2.2. Location (GPS) and site activity data collection

How permission is gained and who to contact at a galamsey site was very key to the success of the investigations and had to be done in a cunning manner to avoid failures. It was ensured that traditional and socio-cultural conditions within visited sites are respected and adhered to. Constraints such as religious, cultural days and superstitious observations (popularly called locally as “*adiim*”, thus a forbidden working day), taboos, national holidays (including Independence Day celebrations, etc.) or specific weather conditions (seasons) were all noted and observed [65]. Due to the violent and radical nature of some galamseyers, it is possible to encounter a number of security risks when undertaking the study and was prepared to anticipate in advance and circumvent any potential security pitfalls [8, 9, 66, 67, 68, 69, 70, 71].

The enumerators used in the study were mostly locals, including females from the various galamsey communities with some level of experience in galamsey and appreciable level of education. They were trained on how to use ODK Collect on cell phones and how to download new surveys from ODK Aggregate while in the field. Given the widespread familiarity with mobile phones in developing countries [72, 73, 74, 75, 76, 77, 78, 79], the enumerators were quickly able to navigate the phones and within only a few trials they had cut in half the time required to conduct interviews or gather data. Where entry permission is received, galamsey operators were asked questions concerning their personal and site histories, type of operation, activity status, resource use inventory and GPS points were taken. One questionnaire took approximately 5–10 minutes to complete. Where limited or no entry access is granted, it was still possible to rapidly collate core information needed from the peripheries of the site and from inhabitants of the community and engaged locals. The GPS coordinate, which is one of the core information required, is picked up using the mobile data collection system (ODK) at an unsuspected point adjacent the galamsey operation.

In picking the location data, it was ensured that where related or similar types of operations of galamsey (e.g. all sample holes/pits) are found to be concentrated or clustered at a particular area (often separated by a few meters or so), the GPS coordinate of the entire site was picked as one point and the total number within the clusters recorded. However, in situations where galamsey operations are positioned apart, say approximately 100 m and above, their position data is picked individually, irrespective of their operational differences or similarities. Site activity status of the various galamsey operations, be it active, semi-active or abandoned, information was also gathered.

2.2.3. Data clean-up, validation and mapping approach

The clean-up process involved correcting wrongly spelt village and town names, wrongly allocated MDAs, operational types, GPS coordinates etc. ArcGIS and Google Earth Imagery were used to map, visualize and validate the ODK ground-survey data gathered [72, 73]. The spatial resolution of the images of the Google Earth was quite high enough to allow clear visual interpretation of the land cover. For each point, the true position of galamsey operation was ascertained by manual interpretation of the fine spatial resolution Google Earth imagery [72]. The ArcGIS software was used to plot the GPS coordinates onto the respective base maps of the districts to observe their distribution patterns.

3. Results and discussion

3.1. Abundance of galamsey types

The study made a total of 911 galamsey sightings, of which 547 were found in clusters (corresponding to approximately 7106 individual operational units) and 364 in stand-alone mode (see Tables 3 and 4, and Figs. 2, 3, 4, 5, 6, and 7). Overall, a total of 7470 individual galamsey operations were identified. These operations were observed in approximately 312 communities (towns and villages) within the 11 districts considered for the study. In terms of their activity statuses, 628 galamsey operations were found to be active, whilst 45 and 195 operations were respectively found to be semi-active and abandoned (Fig. 2).

Tarkwa Nsuaem district was found to have the highest number of galamsey sightings (294) with Sefwi Wiawso district having the least number of galamsey sightings of 4. This high number of galamsey operations at Tarkwa Nsuaem district can be attributed to the presence of large mineral deposits, high concentration of large scale gold mining companies and very rich history of galamsey in the district [1, 49, 55]. The other two galamsey hotspot districts found were Amefi East (223 sightings) and Prestea Huni-Valley (156 sightings).

Table 3. Summary data showing broad categories of galamsey operations, their sightings, individuals within clusters and their abundance across the eleven MDAs

MDAs	Simultaneous mining and processing galamsey		Mining only galamsey category		Processing/Extraction only galamsey category		Overall Sighting Total	Total Sum of Operations within clusters
	Sightings	Individuals within Cluster	Sightings	Individuals within Cluster	Sightings	Individuals within Cluster		
Amenfi Central	50	239	7	382	3	6	60	627
Amenfi East	194	1217	9	148	20	32	223	1397
Amenfi West	37	185			1	3	38	188
Bibiani Anhwiaso Bekwai	31	101	11	31	12	12	54	144
Ellembele	6	29					6	29
Mpohor	12	64	3	25	1	1	16	90
Nzema East	6	20					6	20
Prestea Huni Valley	52	379	36	665	68	86	156	1130
Sefwi Wiawso	2	2			2	2	4	4
Tarkwa Nsuaem	129	1061	54	2432	111	155	294	3648
Wassa East	48	149	2	40	4	4	54	193
Grand Total	567	3446	122	3723	222	301	911	7470

All the three identified hotspot district hosts two or more actively operating LSMs on their lease or concessions (see Table 2). These districts have a long and illustrious history of surface and underground mines and are a good example of the old adage, ‘the best place to find a new mine or gold is at the site of an old mine’ [44]. Historical exploration booms, excellent drainage networks and abundance of old tailings make these mining districts attractive to not only regularized operations, but galamseyers as well. The Bonga, Ankobra and Huni rivers and their numerous tributaries including Buri, Anoni, Sumin, Ayiasu drain the area depicting a dendritic pattern and a safe haven for alluvial galamsey (Dredging, Washing Plant, Washing Board, Dig and Wash and Anwona) operations [80, 81, 82].

In terms of the galamsey operational forms, the alluvial washing board, mill-house and chamfi galamsey were found to be the three most popular galamsey types practiced. Stream/river dredging galamsey, which is the fourth most practiced galamsey, was encountered in major water bodies such as the River Ankobra, River Bonga and River Pra in the Tarkwa Nsuaem, Wassa East, Prestea Huni Valley and Mpohor districts.

3.2. Scope and operational dynamics of galamsey types

Galamsey used to be an artisanal, traditional, localized, rudimentary or a “hand-to-mouth” venture meant to gather some small pieces of gold to sell for daily upkeep. It

Table 4. Abundance of galamsey types across the eleven selected MDAs

Galamsey types	Host MDAs for Galamsey Operations												Total		Total									
	WAC		WAE		WAW		BAB		Ell		Mpoh		NE		PHV		SW		TN		WE		Clust	Singles
	Sightings	IWC	Sightings	IWC	Sightings	IWCs	Sightings	IWC	Sightings	IWC	Sightings	IWC	Sightings	IWC	Sightings	IWC	Sightings	IWC	Sightings	IWC	Sightings	IWC		
AWB	36	104	109	374	34	151	29	95					6	25	2	2	7	63	11	23	234	837		
AWP			9	32			2	6					3	9			3	6	1	1	18	54		
ANW			5	14	1	1											5	46	10	55	21	116		
Cham	7	92	61	703	1	18			5	25	9	52	5	16	29	254			35	583			152	1743
D&W	7	43	15	105	1	15			1	4	2	11	1	4	12	78			25	173			64	433
MH	3	6	15	21	1	3	12	12			1	1			67	83	2	2	111	155	4	4	216	287
R/S Dred										1	1				3	16			56	209	26	70	86	296
AUS/T							6	6							6	9			10	15			22	30
USP	7	382	9	148			5	25			3	25			30	656			42	2398	2	40	98	3674
Grand Total	60	627	223	1397	38	188	54	144	6	29	16	90	6	20	156	1130	4	4	294	3648	54	193	911	7470

Galamsey Types: Chamfi = Chamfi; AWP = Alluvial Washing Plant; MH = Mill House; R/S Dredg = River/Stream Dredging; USP = Underground Sample Pit/Hole; AUS/T = Abandoned Underground Shafts/Tunnels; AWB = Alluvial Washing Board; ANW = Anwona; D&G = Dig and Wash; ND = No Data recorded.

Host MDAs: WAC = Amenfi Central, WAE = Amenfi East, WAW = Amenfi West, BAB = Bibiani Anhwiaso Bekwai, Ell = Ellemebele, Mpo = Mpohor, NE = Nzema East, PHV = Prestea Huni Valley, SW = Sefwi Wiawso, TN = Tarkwa Nsuaem, WE = Wassa East, Cluster = grouped similar operation on the same piece of land, Singles = galamsey operations in stand-alone mode

Sightings: number of galamsey operations observed per site, including clusters; IWC = Individual number of galamsey operations within clusters recorded

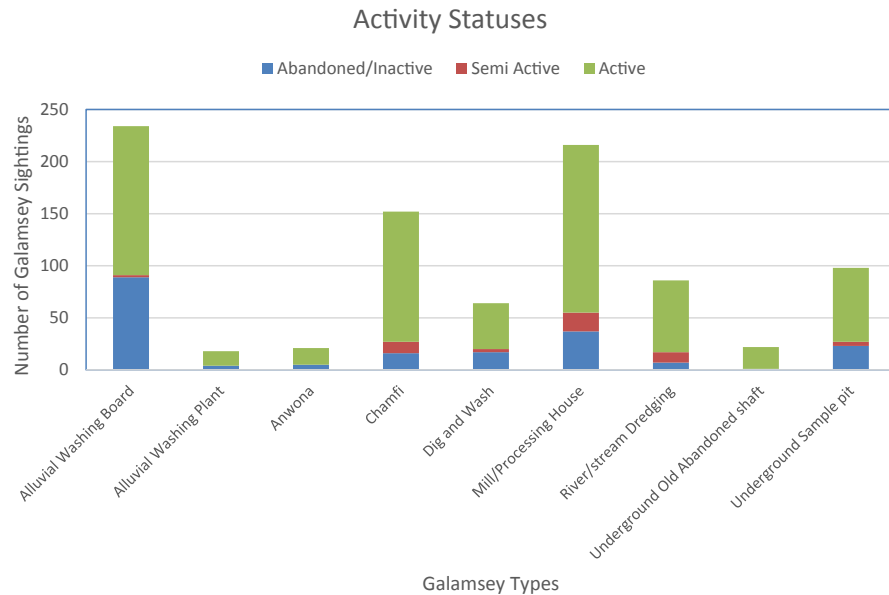


Fig. 2. Activity statuses of galamsey across the eleven MDAs between December 2014 and April 2016

is now a capital intensive, mechanically and politically driven cash generating venture with many players including local businessmen, politicians, security personnel, traditional leaders and other foreign nationals [2, 83, 84]. These galamsey operators therefore patronize the best and profitable forms of galamsey, that is, the alluvial washing board, mill-house and chamfi. These three galamsey types were found from the study to be the most popular ones (Fig. 2) and below is a brief description of the predominant galamsey operational forms.

The washing board galamsey, recording a total of 234 sightings and 837 individuals within clusters, is most popular due to the abundance of alluvial deposits and water bodies across the entire stretch of the Wassa Amenfi East district and some vast portions of the Tarkwa Nsuaem and Prestea Huni Valley districts. The washing board represents the most economical way or profitable means of commercially extracting low grade and alluvial deposits. Although somehow cumbersome to transport (as it requires either a Kia truck or low-bed), the washing board equipment are easy to set-up on the field and operationally require no special skill or education. Unlike the mill-house and chamfi, which can be done in the heart of towns and villages, the washing board is normally confined to remote, vegetated and well drained areas with limited security or enforcement protocol to permit the free movement of the washing board machine, its accompanying excavators or earth moving equipment and other core resources such as diesel. Washing board is also very popular within all three Amenfi Districts (East, Central and West) considered due to the very rural setting they present, their alluvial deposits and drainage networks, poor law enforcement. With the exception of the Nzema East, Mpohor and Ellembele, the eight

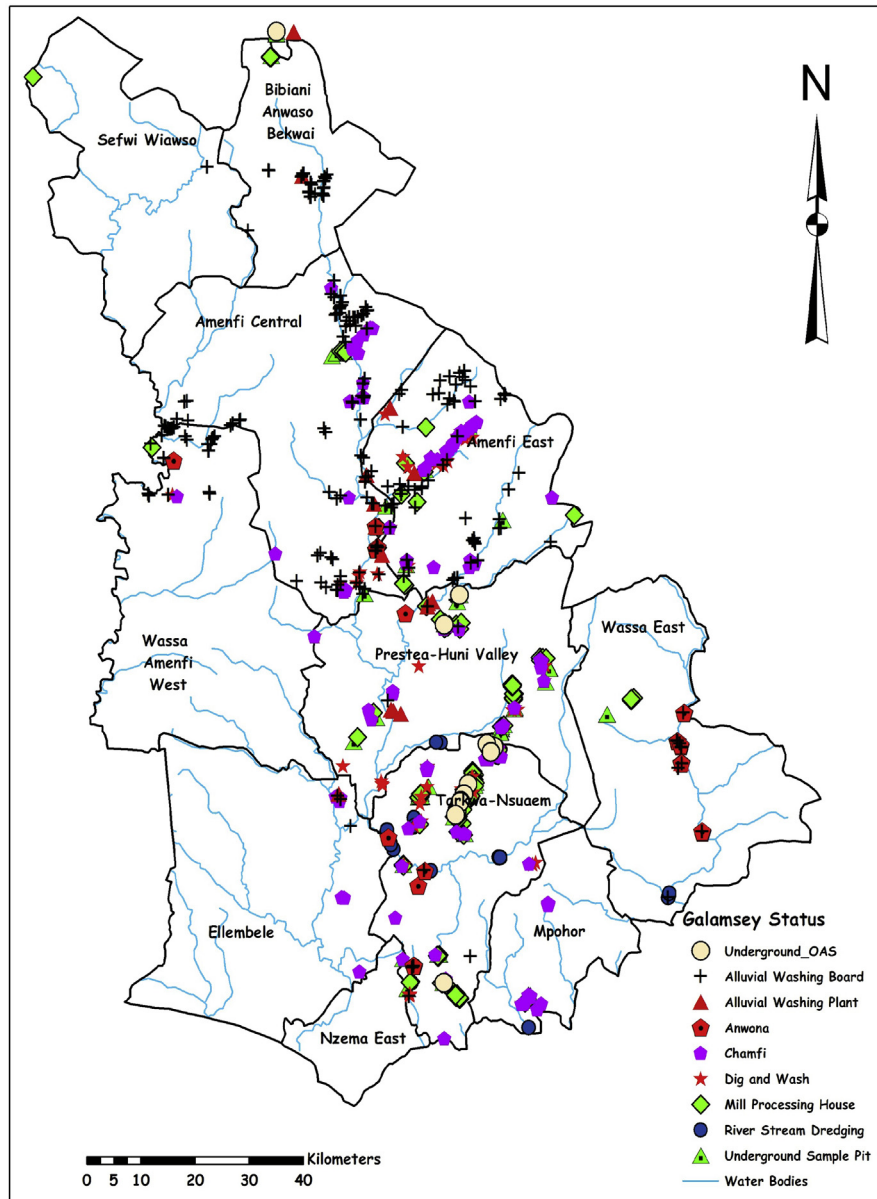


Fig. 3. General distribution of galamsey types across the 11 selected Districts

remaining MDAs considered in the research were found to be hosting alluvial washing board galamsey.

The mill-houses (216 total sightings and 287 individuals within clusters) were found to be fairly distributed across the selected districts, except Ellembele and Nzema East where none was encountered. It was observed that almost all the locations where hard-rock or underground mining predominates had Mill houses present. This is because they serve as the processing bay for mined ores from abandoned underground shafts, underground sample pits/holes and selection galamseyers. They

can be set up anywhere so long as vehicular access, electricity and constant water supply are assured; most especially along road sides, and adjacent school premises. Mill-house operation employing the use of a crusher and smoothing machine (and not just the diesel powered Chang-Fa machine for the entire processing) requires constant power/electricity supply.

The chamfi galamsey (with 152 total sightings and 1743 individual operations within clusters), which operates using the Chan-Fa diesel engine machine for simultaneous mining and gold extraction was introduced about a decade ago in Ghana by the Chines. It has since its introduction enjoyed much popularity among galamsey operators. It generally requires a small parcel of gold-laden land and a relatively low start-up cost. It is a highly efficient, easy to use, mobile and can handle both alluvial and lode/vein deposits with ease. The low feeding rate or loading capacity is compensated for by having many set-ups per an area; thus having them in clusters.

The sample pit/hole galamsey (with 98 total sightings and 3674 individual operations within clusters), also presents an excellent opportunity to tap underground resources without the use of sophisticated machinery. The digging or mining is done rudimentarily and manually and the grades mined are relatively high; hence its popularity within the selected study districts.

From [Table 4](#), it is observed that the alluvial washing board, chamfi and mill house are the three main galamsey operations usually found in clusters or having more than one operation on the same piece of land. These operations are commercially driven and are testaments of the high intensities involved for the clustered operations recorded. The least clustered operation is the Alluvial Washing Plant.

The study also revealed that the galamsey operations which were mostly abandoned were the alluvial washing board, mill house and underground sample pit ([Fig. 2](#)). These are the operations practiced mostly for high profit margins or commercially purposes. The factors that tend to drive galamsey operators away from their activities or lead to their closure (either permanent or temporarily) include high rainfall and flooding events, ore shortages, low gold price and intensified security patrol programs.

3.3. Distribution of galamsey operations within the three hotspot assemblies

3.3.1. Tarkwa Nsuaem Municipal Assembly

The district is an attractive destination for galamsey operators, as it hosts all the nine galamsey operational types considered in this study ([Fig. 4](#)). The abundance of lode/vein and alluvial gold deposits, the network of rivers, streams and wetlands, very large forest reserves (Bonsa, Ekumfi, Neung South and Neung North), unique

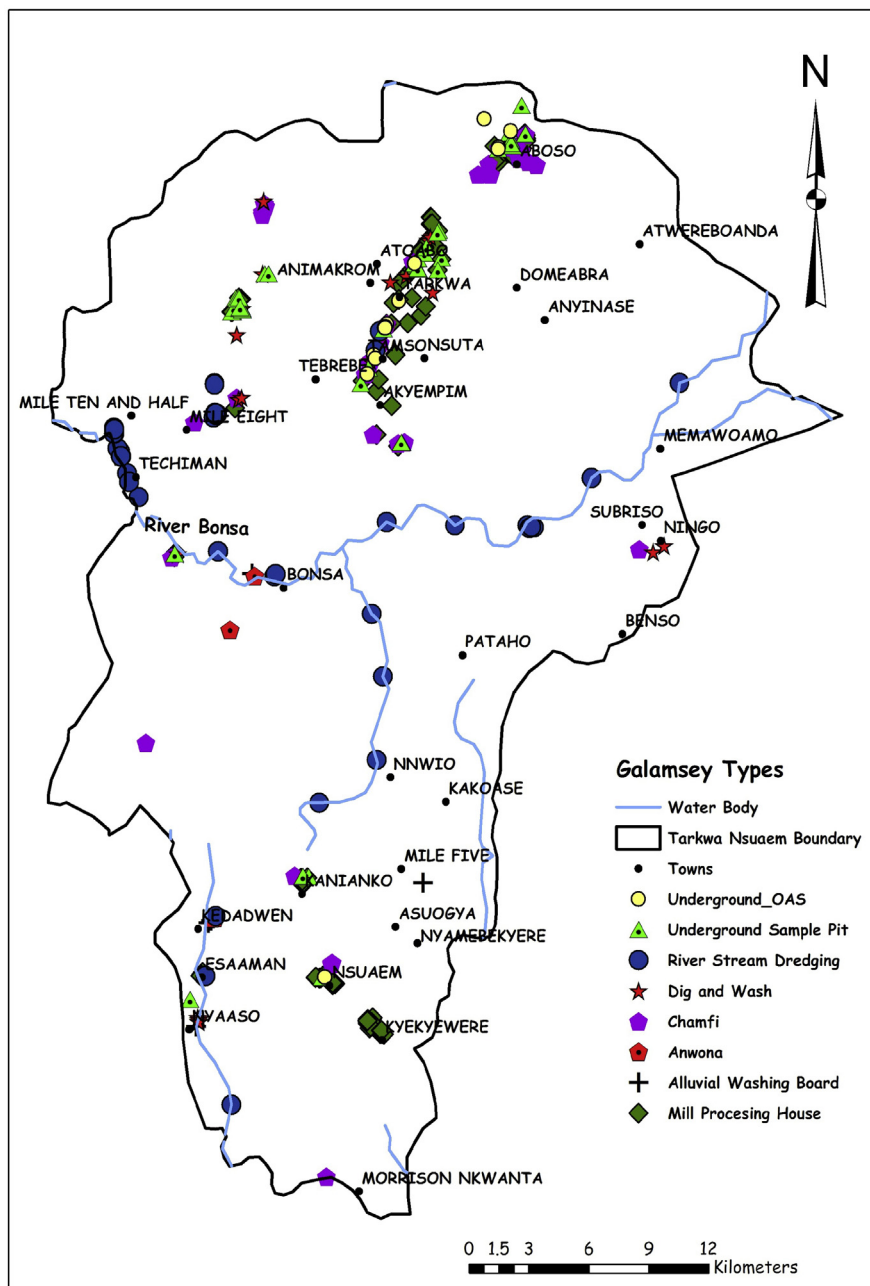


Fig. 4. Distribution of galamsey types within the Tarkwa Nsuaem Municipality

rainfall pattern, the high concentration of LSMs, the long and lustrous underground and surface mining history, the high number of abandoned underground operations (which usually require higher workforce and more processing centres in the shape of mill-house and chamfi operations), the cosmopolitan nature as well as the relatively low security and law enforcement regimes ensured by most LSMs and regularized ASMs in the municipality makes the Tarkwa Nsuaem district a safe haven for galamsey.

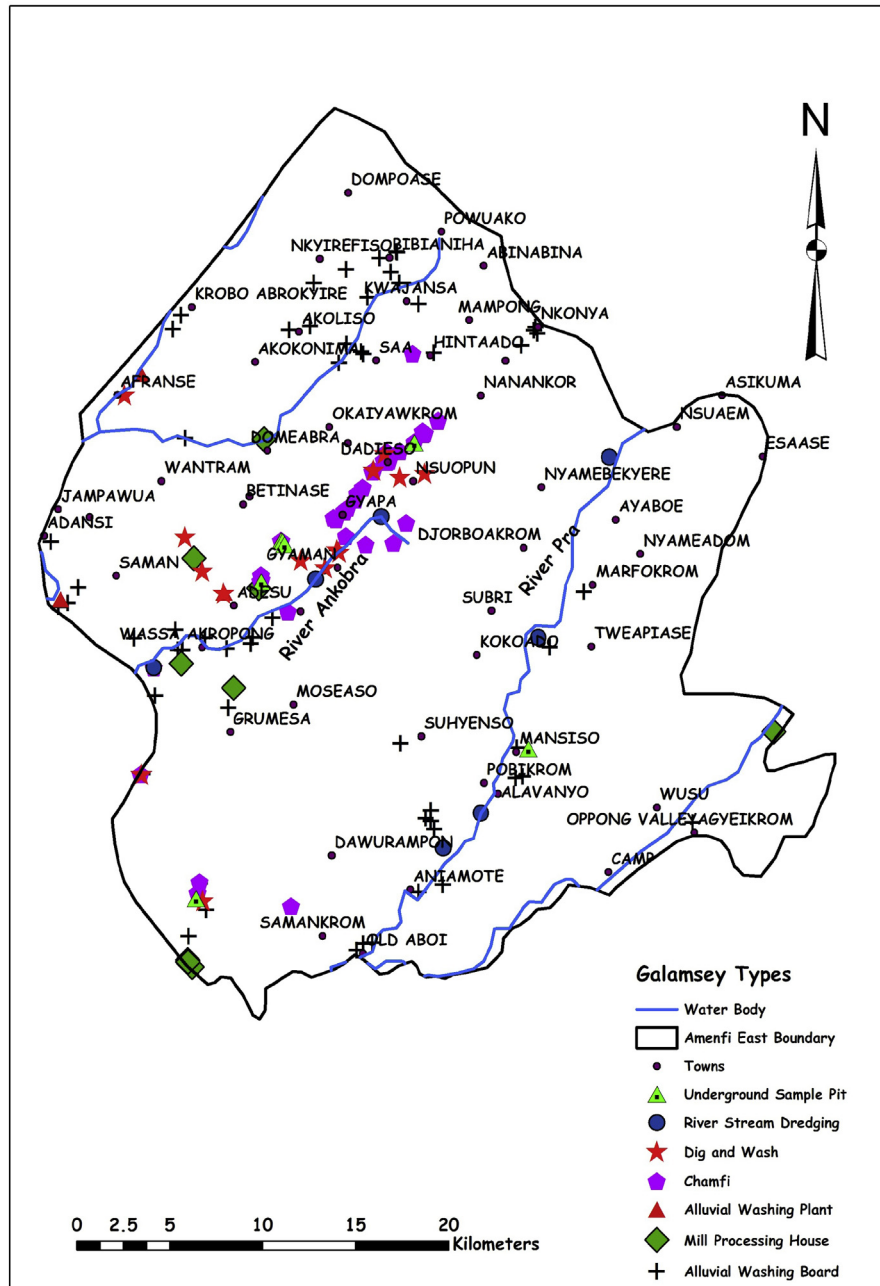


Fig. 5. Distribution of galamsey types within the Amenfi East District

The Municipality shares boundary with the Prestea Huni-Valley to the north, the south by Ahanta West, the West by Nzema East and the East by Mpohor Wassa East [49]. The municipality currently have four (4) actively operating large scale gold and or manganese mining firms, namely the Gold Fields Ghana Limited/ Tarkwa Gold Mines (leading producer of gold in Ghana), Golden Star Bogoso-Prestea Mines, AngloGold Iduapriem Mine, Nsuta Manganese and Gold Mines.

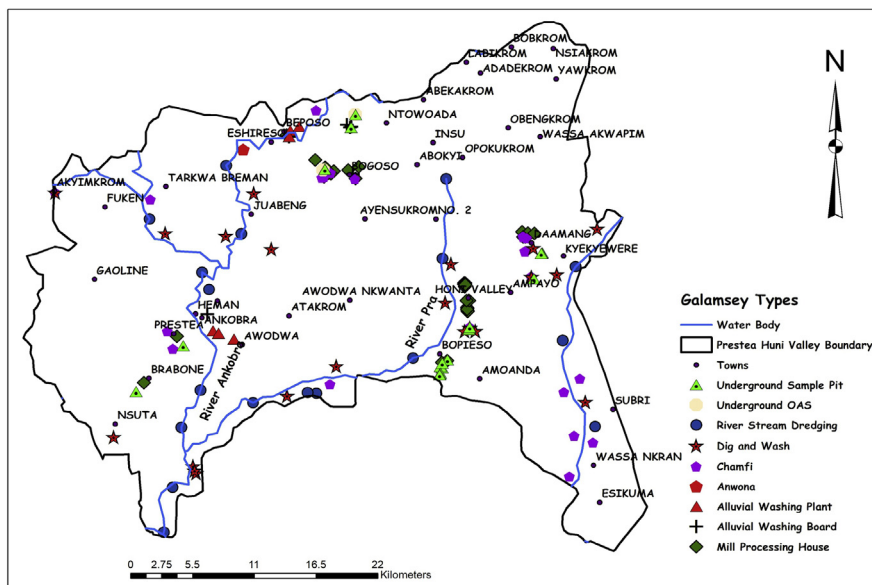


Fig. 6. Distribution of galamsey types within the Prestea Huni Valley District

The Tarkwa Nsuaem District is known to be the single most concentrated mining area in West Africa, having the administrative offices and operating plants (Carbon-in-leach (CIL)) of three LSMs (Tarkwa Mines, AngloGold Iduapriem mine, Nsuta Manganese and Gold Mines), numerous mining support services companies, gold marketing firms, laboratories and other consulting firms. The district was the focus of attention for the earliest European prospectors and promoters who first entered the hinterlands of the Gold Coast Colony in the late 1870s, just after the region had been declared a British colony. It has since remained an important gold producing district and an administrative centre for the mining industry in Ghana [49].

The Birimian and Tarkwain geological formations of Tarkwa have proven excellent for underground, surface and placer mining activities. Underground mining has been carried out for over 100 years during which about 7 million ounces of gold have been produced. Underground mining, has been carried out at old Tamsu Mine, extending across the Ankobra basin to the Iduapriem concessions and Fanti Mine, but has since the late 1990s ceased in the Tarkwa, Abosso and Nsuaem areas, making them an excellent haven for illegal operators [49].

Approximately 12,000km labyrinth of underground workings and passageways (shafts and adits) extends across the Nsuaem, Tarkwa, Abosso and all the way to Bompieso [49]. A large community of illegal miners operates in these areas at any one time, supporting perhaps their families and people in the nearby settlements dotting the municipality. Until the recent modifications in the Wassawest Districts, the Tarkwa mining district used to extend from close to the Bonsa River in the south all the way to the Damang area in the north, a distance of about 45km. The majority

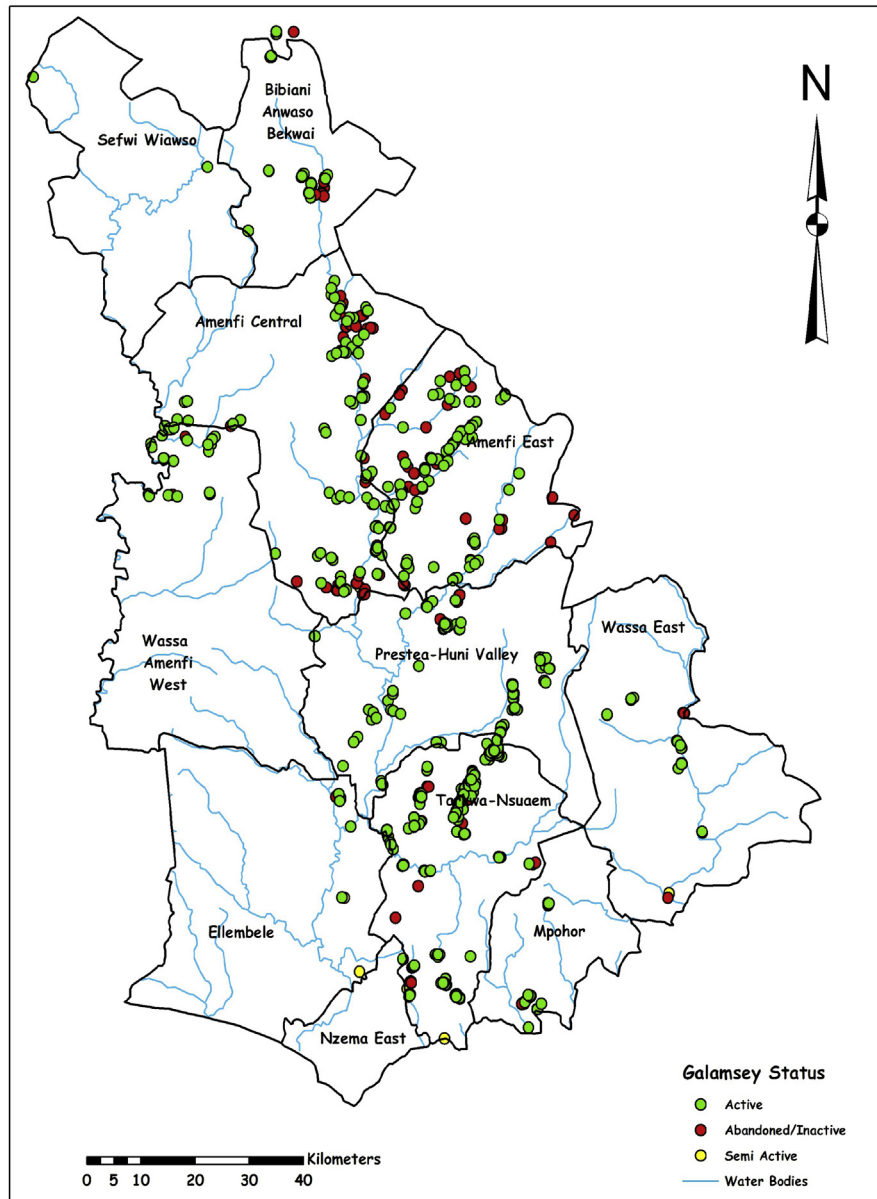


Fig. 7. Distribution of the activity statuses of galamsey within the 11 MDAs

of past underground production occurred along the approximate 11km stretch from the old Taquah mine to Abosso/AdjaBippo. The eastern boundary occurs just east of the line of old mines and the town of Tarkwa and it extends westwards to the prominent Kotraverchy-Adjopa ridge.

With the creation of the Prestea Huni Valley district (out of the then Wassa West District Assembly), the Abosso mining areas have been excluded from the Tarkwa Nsuaem Municipality [44]. Nonetheless, substantial volumes of ore mined are still transported from Abosso to Bogoso Junction, Boboobobo and other suburbs of

Tarkwa for extraction due to proximity and Tarkwa's cosmopolitan nature (having abundant gold sales point (buying agents), gold extraction/processing centres and material supplies).

From Tables 3 and 4, it is observed that the Tarkwa Nsuaem district recorded the highest number of underground operations and a corresponding high number of mill-house sightings due to their operational interdependence. Dredging is also very popular in this district due to the abundance of gold within the Ankobra and Bonsa Rivers which drain the area. Prominent galamsey communities in the district are Kadedwen, Amantin, Gold Fields Areas, Efuanta, Tarkwa Township, Nsadweso, Daboase, Nsuaem, Badukrom, Kyekyewere and Nkwanta.

3.3.2. *Wassa Amenfi East district*

The Amenfi East district recorded the second highest number of galamsey activities among the eleven selected districts for the study (Table 3). The district recorded the highest number of alluvial washing board, alluvial washing plant and chamfi galamsey. Substantial sightings of dig and wash galamsey types were also made within the district. The reasons for the high prevalence of these galamsey types may be due to the abundance of rich alluvial deposits and water resources (Manse, Ankobra, Ashire and Oppong), it's very rural settings, very low law enforcement programs and many ongoing exploration activities [57].

Out of the 182 communities (towns and villages) within the district visited during the study, approximately 91 (representing 50%) of them were found to be hosting galamsey; an indication that gold can indeed be found almost everywhere within the district. Among the very vibrant galamsey communities encountered are: Subriso, Akropong, Ankonsia, Abrokyirekrobo, Asesensu, Akatrika, Dikoto, Nsuaem, Babianiha, Manseso, Adiembra, Abrehyia, Bodie, Gyamang, Asuopong, Gyamang, Mamieso, Mensakrom, Manpong, Japa, Edwumako, Dompuae, Dadieso, Adonoi, Adesu, Abrehyia, Esikuma, Adamanso, Wassasaa, Wassa Kumasi, Subriso, Asomdwee, Asesensu, Ankonsia, Aniamote, Akatrika and Adonoi.

There are four forest reserves (Opon-Manse, Bowie, Tonton and Angoben) in the district with agriculture taking place at the subsistence level. Most of the arable lands have therefore been released or ceded for galamsey purposes which many believe is more profitable than even cocoa farming [57].

The neighbouring districts are Wassa Amenfi West District (West), Mpohor Wassa East District (East), Prestea Huni Valley District (South) and Upper Denkyira West and East District (North). The three main geological soil formations in the district are the Upper Birimian, Lower Birimian and Granites. The granite deposits in the district make most parts of it rich in minerals like gold. The district lies within the Kumasi Basin and partly within the Sefwi Gold belt with large deposit of alluvial gold within

the Tano River, Ashire and Manse rivers basins [44, 57]. The mineralization within the geological structures accounts for the wide distribution of gold resources across the communities within the districts.

Other reasons for the very high number of galamsey activities within the Amenfi East District are:

- Relative ease at which land is acquired for galamsey operations;
- On-going exploration projects (Golden Star Resources, GoldStone Resource, Asasemu etc.), which tend to attract galamsey;
- The presence of Golden Star Bogoso/Prestea Limited and Perseus Mining Limited (relatively low gold producing firms); indication of high presence of gold deposition;
- Inadequate Employment Opportunities: Agriculture remains the main source of employment for majority of the people but largely remain at a rudimentary level with resultant lower productivity. The implications are that a significant number of people are not gainfully employed. Employment avenues in other sectors are equally not adequate and/or inappropriate to absorb these large numbers; hence the shift of attention to gold mining;
- Availability of large mineral deposits such as Kaolin, Bauxite, Diamond and Gold. Availability of Water Bodies;
- Generally low law enforcement; the district is a safe haven for foreign operators in galamsey. There are large communities of Chinese and other foreign nationals undertaking galamsey; and
- Poor road networks mean the monitoring and enforcement of mining and environmental laws within the district will be a challenge by security agencies;

3.3.3. Prestea Huni-valley district

The Prestea Huni-Valley District, underlain with Precambrian rocks of the Birimian, shares boundaries with mineral-endowed districts such as Wassa Amenfi East and Wassa Amenfi Central Districts in the North, Wassa Amenfi West District to the West, Ellembele District to the South West, Tarkwa Nsuaem Municipality to the South, Mpohor/Wassa East District to the East and to the North East by Twifo-Atimokwa District in the Central Region. This situation tends to permit easy and free movement of galamsey operators to and fro the district [58].

The district recorded large numbers of chamfi, underground sample pit, abandoned shaft, mill-house and alluvial washing plant galamsey operations (see Fig. 6). Abandoned underground shafts in Abosso, Bogoso and Kroboline are currently under the domain of galamsey operators and contribute significantly to the relatively high galamsey numbers within the district. There are also several mineral rich water bodies

that flow through the Prestea Huni-Valley District. Notable among them are the Ankobra, Huni, Oppon, Bogu, Peme, Subri, Bonsa and Mansi River. These water bodies serve as a rich source of water for alluvial galamsey operations. The vegetation of the District is tropical rainforest with forest reserves including Bonsa Reserve (Aboso), Ben West (Huni-Valley) and Nkontoben (Huni-Valley), which also provide safe hiding place for illegals mining operators [58].

The district hosts the main processing plants and administrative centres of Abosso Goldfields, Golden Star Bogoso-Prestea Mines, New Century Underground Mines and Sankofa Gold Limited. Again, some portions of the concessions of the Tarkwa Gold Mine, Golden Star Wassa Mines and AngloGold Iduapriem Mines overlaps into the district. In spite of the high LSM numbers operating within the district, it was the third galamsey hot spot. This is partly due to the relatively low gold production and richness of concessions in the district. For instance, the combined total annual gold productions of all four LSMs are still way below that recorded by the Tarkwa Gold Mine alone. Again the presence of high security patrols on the concessions of GSBPL, AGL and Wassa Mines contributes to the low number of galamsey sightings relative to Tarkwa Nsuaem and the Amenfi East districts.

The relatively low number of galamsey operations could also stem from the fact that the district has the highest number of registered ASM companies, approximately 90, among the 11 selected districts [46]; a situation that is perhaps limiting the growth of galamsey activities. Also the rejuvenation of the Prestea Underground operations implies limited grounds for galamsey operators in the Prestea and Bondaye areas. A large number of workforce from Prestea and its environs are being recruited for the underground mining, instead of being left to pursue galamsey. Among the most active galamsey mining communities are; Awodua, Kumsono, Aboso, Bompieso, Damang, Prestea, Atta ne Atta, Pepesa-Ankwahu, Bogoso and Huni valley.

3.4. Distribution of galamsey operations within less proliferated assemblies

3.4.1. Amenfi Central, Bibiani-Anwhiase-Bekwai and Amenfi West

Districts like Amenfi Central, Bibiani and Amenfi West recorded appreciable sightings of galamsey activities. Although the Amenfi Central and Amenfi West district assemblies lack any notable LSM company, they do have a number of registered ASMs operating within them (Table 2), which indicates the availability of ore for mining. The two Amenfi districts are underlain by the lower Proterozoic Volcanic and the Flyschoid Meta sediments of the Birimian System- Asankrangwa-Manso-

Nkwanta Gold Belt which are endowed with gold, bauxite, manganese and iron-ore [44]. Alluvial washing board is the most practiced galamsey within these two Amenfi districts. The tributaries of River Tano and River Ankobra in the communities are mined for alluvial gold within the two districts [61, 59, 60]. Prominent among communities hosting galamsey within the Amenfi Central district is: Ayiemu, Kongo, Hiawa, WassaBekwai, Subinho, Dwabo and Nkakaa. Active galamsey villages and towns within the Amenfi West district are Asankragua, Odakotoumso, Adaase, Asankransaa, Odakotoumso and AboiNkwanta.

Restrictions implemented by Samatex Timber Company Limited at Samreboi (Amenfi West) and the high interests in Agro-based Industry, due to the availability of oil palm, rubber and cocoa husk tend to suppress galamsey within these two Amenfi districts.

The Bibiani-Anwhiase-Bekwai district host the administrative and processing plants for Noble Gold Bibiani Limited, Awaso Bauxite and Kinross (Chirano) Gold, and employ a substantial number of locals. The concessions of the two gold mining companies, which happen to be most endowed portions of the district, are heavily guarded by security personnel [56]. The underground operations (Akwaabe Deeps) by Chirano gold has resulted in the recruitment of many youth and locals from the district, thereby suppressing the interest and impact of galamsey greatly [85]. Some portions of the Bibiani deeps, which are currently inactive, have been ceded to galamsey operators for mining; thereby keeping most youth in the locality busy and employed. The district also has approximately 86 registered ASM operations [46], thereby limiting the room for galamsey operations. The most active galamsey communities encountered were Asawinso-A, Beposo, Bukamso, Asempaneye, Bugamso, Chirano, Nkatieso, Bibiani, Lineso and Donkoto.

3.4.2. *Ellembelle, Nzema East and Sefwi-Wiawso*

The three districts with the lowest galamsey sightings are Ellembelle, Nzema East and Sefwi Wiawso. Although associated with LSMs (Noble Gold Bibiani Limited, Kinross (Chirano) Gold Mines Limited, Ghana Bauxite and Adamus Resource) in one way or the other, the high level of security and difficulty in acquiring lands for galamsey appears to have waned the interest in the illegal business. These districts are known to have very moderate galamsey or ASM histories [48, 54, 55].

Whilst the Nzema East has 16 registered ASMs, Ellembelle and Sefwi Wiawso have 2 and 1 respectively [46]. Whereas farming, especially cocoa farming, is seen to be very important than mining in the Sefwi areas, marine fishing is very dear to the people of Nzema East and Ellembelle [48, 54]; hence the very low patronage of galamsey operation. Popular galamsey sites within the Ellembelle district include: Bamiago Enyinase, Nkroful and Eshiem site. Within the Nzema East Municipality

Table 5. Activity Statuses of gamalsey operations across the eleven MDAs

MDAs	Operational statuses of gamalsey operations						Total Sightings	Total Sum of Individuals within cluster
	Abandoned/inactive		Active		Semi active			
	Sightings	Individuals within cluster	Sightings	Individuals within cluster	Sightings	Individuals within cluster		
Amenfi Central	27	301	33	326			60	627
Amenfi East	67	335	154	1045	2	17	223	1397
Amenfi West	9	39	29	149			38	188
Bibiani Anhwiaso Bekwai	15	54	39	90			54	144
Ellembele	1	4	1	5	4	20	6	29
Mpohor			15	87	1	3	16	90
Nzema East	2	4			4	16	6	20
Prestea Huni Valley	17	72	133	1041	6	17	156	1130
Sefwi Wiawso			4	4			4	4
Tarkwa Nsuaem	49	1020	220	2158	25	470	294	3648
Wassa East	12	26	36	150	6	17	54	193
Grand Total	199	1855	664	5055	48	560	911	7470

Akanko, Awroso, Abeliba, Buale, Eziose and Gwira are the main galamsey areas [54]. The Sefwi Wiawso locality also has galamsey within Dansokrom, Nsuosua and Asawinso [55].

3.5. General activity statuses of galamsey operations within the study area

In terms of their activity statuses, 199 abandoned operations were sighted (corresponding to 1855 individuals within clusters), 664 active galamsey sightings (corresponding to 5055 individuals within clusters) and 48 semi-active operations (560) were also seen. The Amenfi East (67 sightings with 335 individuals within clusters), Tarkwa Nsuaem (49 sightings, with 1020 individuals within clusters) and Amenfi Central (27 sightings with 301 individuals within clusters) districts respectively recorded the highest number of abandoned operations as seen in Table 5 and Fig. 7.

The reasons for abandonment or inactivity of a galamsey operation normally stems from either the receipt of too much rains within a particular season (leading to flooding of pits, decline/ramp, inclined vertical shaft or adit, accesses and other working areas), intensified patrols by responsible security agencies (Police, Military teams, Mine Security Team etc.), depletion of ore resources, low gold prices, lack or resources for mining/processing, land disputes or from an imposed ban on galamsey and its related trades in a particular area.

4. Conclusions

From the study, it can be concluded that;

- The study generally made a total of 911 galamsey sightings, of which 547 were found in clusters (corresponding to approximately 7106 individual operational units) and 364 in stand-alone mode. An overall total of individual galamsey operations observed is 7470. These operations were observed in approximately 312 different communities (towns and villages) within the 11 districts considered. In terms of their activity statuses, 628 galamsey operations were found to be active, whilst 45 and 195 operations were respectively found to be semi-active and abandoned.
- The three galamsey hotspots districts identified from the study were Tarkwa Nsuaem, Wassa Amenfi East and Prestea Huni-Valley districts with Sefwi Wiawso being the district with the least galamsey activities.
- The study revealed that the three most popular galamsey types practiced in the districts studied are the alluvial washing board, mill-house and chamfi galamsey.

The study further identified that the illegal ASM, popularly called galamsey in Ghana, take place almost everywhere from remote, inaccessible locations to urban centres. The operations were encountered in a variety of locations ranging from forests, rivers and other water bodies, underground and within urban centres (adjacent school premises, churches, residential areas, along roadsides, market places etc.). The mill house, chamfi and “dig and wash” galamseys are predominantly situated right in the heart of villages and towns (mostly along roadsides, school premises, market areas and also within residential locations), others like the alluvial and underground galamsey types typically takes place in very remote, vegetated areas and along the banks and within water bodies.

Also, the presence of high mineralization, LSMs, regularized ASM and rich history of galamsey may alone not be adequate to cause galamsey proliferation within a locality; thus, a locality may possess all the ingredients and resources for a booming galamsey business, yet one may not encounter galamseyers. Factors that may reduce or discourage the proliferation of galamsey within a particular area or locality include (but not limited to); existence of strict security regime (military, police, company security patrol etc.), the presence of an actively operating underground mining operations (which tends to engage more youth and locals than other mining ventures), the existence of other important and more profitable economic ventures (factories, agri-businesses etc.) and where locals or youth are traditionally prohibited from engaging in galamsey due to some taboos and superstitious beliefs.

Based on the conclusions, the study makes the following recommendations;

- Due to the ever-growing nature of the illegal operation, it may be important to periodically undertake reassessments and update of the information obtained in this study;
- The use of other advanced and high resolution satellite imagery could be exploited by government where possible to complement the approach used in this research;
- Further studies to assess how much land has been taken by different galamsey types should be undertaken;
- Studies to assess the relationships between different galamsey types and impacts caused should also be considered;
- A costed reclamation plan for the respective galamsey operations could also be modelled;
- The solution to galamsey hinges on the unwavering commitments from security services (police, the military etc.), government, traditional authorities and politicians. Education and public awareness on galamsey should also be intensified and enforcement of existing legal systems ensured.

Declarations

Author contribution statement

Jones Mantey: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Frederick Owusu-Nimo, Kwabena Nyarko, Anthony Aubynn, Eugene Appiah-Effah: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by the International Growth Centre (IGC) (1-VCC-VGHA-VXXXX-33205).

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors would like to acknowledge the support of the Ghana Minerals Commission for their constructive contributions and invaluable directions. We are also grateful to the Ghana Chamber of Mines and the Ministry of Environment, Science, Technology and Innovation of Ghana for their audience and fruitful suggestions. Finally, our thanks go to Mr. Christian Abaidoo, Ms Agnes Osei Ansah and Mr. Clifford Tetteh for their support during the data collection phase.

References

- [1] J. Mantey, F. Owusu- Nimo, K.B. Nyarko, A. Aubynn, Operational dynamics of “Galamsey” within eleven selected districts of western region of Ghana, *J. Mining Environ.* (2016). Published online: 23 May 2016, http://jme.shahroodut.ac.ir/article_627_d5977af6c7b7d894aca62dea95238d8b.pdf.
- [2] G. Crawford, C. Agyeyomah, G. Botchwey, A. Mba, The Impact of Chinese Involvement in Small-scale Gold Mining in Ghana, IGC Policy brief 33110|May 2016, 2016, <https://www.theigc.org/wp-content/uploads/2016/08/Crawford-et-al-2016-Policy-brief.pdf>.

- [3] The Extractive Industries Transparency Initiative (EITI) http://www.gheti.gov.gh/site/index.php?option=com_content&view=article&id=187:special-report-the-cost-of-galamsey&catid=1:latest-news&Itemid=29 (Accessed 12 December 2016).
- [4] Ghana Today, Galamsey Killing Oda Forest Reserve but Gov't Looks Unconcerned, 2016. <http://www.todaygh.com/galamsey-killing-oda-forest-reserve-govt-looks-unconcerned/>. (Accessed 10 January 2017).
- [5] G.H. Hilson, Gold Mining as Subsistence: Ghana's Small-scale Miners Left behind, 2003, 27.1 (Spring 2003). *The Troubled Taiga. Lands, Resources, and Environments*, <https://www.culturalsurvival.org/publications/cultural-survival-quarterly/ghana/gold-mining-subsistence-Ghana's-small-scale-miners-l>. (Accessed 23 February 2016).
- [6] B.N.A. Aryee, B.K. Ntibery, E. Atorkui, Trends in the small-scale mining of precious minerals in Ghana: a perspective on its environmental impact, *J. Clean. Prod.* 11 (2003) 131–140. <http://www.ddiglobal.org/login/resources/trends-in-the-small-scale-mining-of-precious-minerals.pdf>.
- [7] K.A. Mensah, I.O. Mahiri¹, O. Owusu, O.D. Mireku, I. Wireko, E.A. Kissi, Environmental impacts of mining: a study of mining communities in Ghana, *Appl. Ecol. Environ. Sci.* 3 (3) (2015) 81–94. Available online at <http://pubs.sciepub.com/aees/3/3/3> ©Science and Education Publishing.
- [8] Ghanaweb, Galamsey Plunges Ghana into Water Crisis. Regional News of Friday, 2016, 19 February 2016, <http://www.ghanaweb.com/GhanaHomePage/regional/Galamsey-plunges-Ghana-into-water-crisis-417011>. (Accessed 15 January 2017).
- [9] E. Opoku, 'Galamsey' a Canker in Western Region, 2013. <https://www.modernghana.com/news/472110/1/galamsey-a-canker-in-western-region.html>. (Accessed 12 December 2016).
- [10] EPA-Ashanti Region, Curbing Environmental Impacts from Small Scale Mining/(Galamsey)-EPA Ashanti Region, 2013. <http://slideplayer.com/slide/3178726/>. (Accessed 5 November 2016).
- [11] Ghanaweb, DOSSIER: Galamsey Menace, 2017. <http://www.ghanaweb.com/GhanaHomePage/NewsArchive/dossier.php?ID=202>. (Accessed 11 August 2017).
- [12] B.K. Boadu, Galamsey on the Rise – WACAM, 2014. <http://citifmonline.com/2014/04/30/galamsey-on-the-rise-wacam/>. (Accessed 20 December 2016).

- [13] A. Blessing, Illegal Mining – How Ghana’s Forgotten Scourge a Nation for Gold, 2014. <https://www.ghanabusinessnews.com/2014/01/04/illegal-mining-how-ghanas-forgotten-scourge-a-nation-for-gold/>. (Accessed 12 December 2016).
- [14] The Chronicle, Galamsey: a Crime beyond Environmental Savagery, 2014. <http://www.peacefonline.com/pages/local/news/201407/208752.php>. (Accessed 4 October 2016).
- [15] E. Kyeremateng-Amoah, E.E. Clarke, Injuries among artisanal and small-scale gold miners in Ghana, *Int. J. Environ. Res. Publ. Health* 12 (2015) 10886–10896. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4586649/pdf/ijerph-12-10886.pdf>.
- [16] S. Adjei, N.K. Oladejo, I.A. Adetunde, The impact and effect of illegal mining (galamsey) towards the socio-economic development of mining communities: a case study of Kenyasi in the Brong Ahafo region, *Int. J. Mod. Soc. Sci.* 1 (1) (2012) 38–55. ISSN: 2169-9917, Florida, USA, <http://modernscientificpress.com/Journals/ViewArticle.aspx?YTDXIp8pwb35qABc+2BV/2sxro7nTbAPwEKec1E3+qjxSterX62iOIFJYQs0xAkr>.
- [17] M.E. Taylor, 35 Illegal Miners Feared Dead in Galamsey Pit Collapse, 2015. <http://pulse.com.gh/news/disaster-35-illegal-miners-feared-dead-in-galamsey-pit-collapse-id4208436.html>. (Accessed 12 December 2016).
- [18] I.A. Alhassan, Galamsey and the making of a deep state in Ghana: implications for national security and development, *Res. Humanit. Soc. Sci.* 4 (16) (2014). ISSN (Paper) 2224-5766 ISSN (Online) 2225-0484 (Online).
- [19] M. Katie, Latin America: Violence and Illegal Mining Tarnish Gold Supply Chains, 2016. Retrieved from, <https://maplecroft.com/portfolio/new-analysis/2016/09/15/latin-america-violence-and-illegal-mining-tarnish-gold-supply-chains/>. (Accessed 12 January 2017).
- [20] The Guardian, 2016. <https://www.theguardian.com/global-development/2013/apr/23/influx-chinese-goldminers-tensions-ghana> (Accessed 6 September 2016).
- [21] O. Tawiah, Abandoned Galamsey Pits Kill 17 – People in Amansie West District within 8-months, Nhyira FM |Ohemeng Tawiah, |Amansie West District, 2014, <http://www.myjoyonline.com/news/2014/january-25th/abandoned-galamsey-pits-kill-17-people-in-amansie-west-district-within-8-months.php>. (Accessed 12 November 2016).
- [22] Ghanaweb, Regional News of Monday 5 September 2016. Residents Worried over Abandoned Galamsey Pits, 2016. <http://www.ghanaweb.com/>

- GhanaHomePage/regional/Residents-worried-over-abandoned-galamsey-pits-467469. (Accessed 12 December 2016).
- [23] J. Ontoyin, I. Agyemang, Small-scale mining and its impacts on the natural environment: a case of Yale, Datuku and Digare communities in the Talensi-Nabdam district of northern Ghana, *Pacesetter J. Sci. Res.* 1 (1) (2014) 7–18. May 2014, <http://pacesetteronlinepublishers.org/pjsr/pdf/2014/June/Ontoyin%20and%20Agyemang.pdf>.
- [24] The Daily Graphic, Special Report: the Cost of Galamsey, 2016 http://www.ghanai.gov.gh/site/index.php?option=com_content&view=article&id=187:special-report-the-cost-of-galamsey&catid=1:latest-news&Itemid=29. (Accessed 5 December 2016).
- [25] F. Arhin, Heavy Metal Pollution of Farmlands by Illegal Mining (Galamsey) Activities and its Effects on the Fertility of Farmlands in the Prestea/Huni Valley District of the Western Region, Ghana, 2012. A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Science, KNUST.
- [26] E. Essabra-Mensah, GREL Worry about Illegal Miners Invading Rubber Plantations, 2016. <http://thebftonline.com/business/agribusiness/20800/grel-worry-about-illegal-miners-invading-rubber-plantations.html>. (Accessed 12 September 2016).
- [27] M. Abedi-Lartey, Rehabilitation and Greening of Mine-degraded Areas of Saaman-Juaso Communities Eastern Region, Ghana, 2016. <https://www.cbd.int/doc/meetings/ecr/ecrws-2015-01/other/ecrws-2015-01-presentation-session95-en.pdf>. (Accessed 5 September 2016). Presentation at Alisa Hotel.
- [28] T.M. Akabzaa, Mining in Ghana: implications for national economic development and poverty reduction, in Bonnie, in: Campbell (Ed.), *Mining in Africa: Regulation and Development*, Pluto Press/IDRC, 2009.
- [29] G. Hilson, S. Pardie, Mercury: an agent of poverty in Ghana's small-scale gold mining sector? *Resour. Policy* 31 (2006) 106–116.
- [30] C. Adrián, S. Isaza, The Tragedy of the Commons in Artisanal Gold Mining: Evaluation of Mechanisms of Cooperation with Simulation and Economic Experiments, 2013. Diss. Universidad Nacional de Colombia-Sede Medellín, <http://www.bdigital.unal.edu.co/10297/1/70327512.2013.pdf>. (Accessed 9 December 2016).
- [31] PDA, 2016. Understanding Galamsey (Illegal Mining) in Ghana. The Perspectives of Tony Deegbe by Aseda Mensah. PDA (Participatory Development

- Associates Ltd.) Interviews and Expert Opinions, vol. 1 (2). http://www.pdaghana.com/images/opinion_papers/2016/Galamsey_Illegal_Mining.pdf.
- [32] S. Nuhu, An Assessment of an Environmental Problem in Ghana and Proposed Solutions Based on Environmental Economic Principle, 2013. <http://www.ghanaweb.com/GhanaHomePage/features/artikel.php?ID=294578>. (Accessed 8 May 2015).
- [33] K.D. Kessey, B. Arko, Small scale gold mining and environmental degradation, in Ghana: issues of mining policy implementation and challenges, J. Stud. Soc. Sci. 5 (1) (2013) 12–30. infinitypress.info/index.php/jsss/article/download/263/190.
- [34] N.A. Amegbey, P.A. Eshun, Mercury use and occupational exposure in the Ghanaian small-scale gold mining industry, Ghana Mining J. 7 (2003) 54–61.
- [35] D. Adogla-Bessa, Gov't has been Proactive in Combating 'Galamsey' but... – Inusah Fuseini, 2016. See more at: <http://citifmonline.com/2016/09/11/govt-has-been-proactive-in-combating-galamsey-but-inusah-fuseini/#sthash.pdMsnFOt.dpuf>. (Accessed 5 September 2016).
- [36] GNA, 2016. Government is determined to address galamsey – Osah Mills Category: General News September 14, 2016 251 <https://www.ghanabusinessnews.com/2016/09/14/government-is-determined-to-address-galamsey-osah-mills/>. (Accessed October 25, 2016).
- [37] M. Vinorkor, Parliament Passes Minerals, Mining Law, 2015. <http://www.graphic.com.gh/news/politics/parliament-passes-minerals-mining-law.html>. (Accessed 12 October 2016).
- [38] N. Acquah – Hayford, Former Lands Minister Calls for Regulation of Galamsey Operations, 2016. See more at: <http://citifmonline.com/2016/09/18/former-lands-minister-calls-for-regulation-of-galamsey-operations/#sthash.ItQo6DUS.dpuf>. (Accessed 16 September 2016).
- [39] E. Appiah, Minister Gives up on Fighting Illegal Mining; Wants New Approach, 2016. Source: Ghana|myjoyonline.com|Edwin Appiah|edwin.appiah@myjoyonline.com|additional files from GNA. Date: 15th-September-2016; Time: 10:38:49 am, <http://m.myjoyonline.com/marticles/news/minister-gives-up-on-fighting-illegal-mining-wants-new-approach->. (Accessed 5 September 2016).
- [40] ASMAN, Artisanal and Small Scale Mining Africa-Network (ASMAN) Blames Government for Galamsey Deaths, 2014. <https://www.modernghana.com/news/570262/asman-blames-government-for-galamsey-deaths.html/>. (Accessed 13 December 2016).

- [41] N. Collins, L. Lawson, *Investigating Approaches to Working with Artisanal and Small-scale Miners: a Compendium of Strategies and Reports from the Field*, 2014.
- [42] Ghana Statistical Service, 2010 Population and Housing Census-regional Analytical Report Western Region, June, 2013. http://www.statsghana.gov.gh/docfiles/2010phc/2010_PHC_Regional_Analytical_Reports_Western_Region.pdf. (Accessed 15 July 2016).
- [43] Ghana Chamber of Mines, Report on the Performance of the Mining Industry (2014), 2015. http://ghanachamberofmines.org/wp-content/uploads/2016/11/Performance_of_the_Mining_Industry_in_Ghana_2014.pdf. (Accessed 15 July 2016).
- [44] R.J. Griffis, Kwesi Barning, F.L. Agezo, F.K. Akosah, Gold Deposits of Ghana, Minerals Commission, Accra Ghana, 2002. www.ghanamincom.gsf.fi. (Accessed 17 August 2016).
- [45] ICMM & Ghana Chamber of Mines (GCM), Mining in Ghana –What Future Can We Expect?, 2015. <http://www.tabforestmines.com/wp-content/uploads/2015/10/Ghana-Chamber-of-Mines-report.pdf>. (Accessed 10 April 2016).
- [46] Ghana Minerals Commission, Small Scale Mining Database, Obtained from the Office of the Small Scale Mining Department, 2014.
- [47] Western Regional Coordinating Council, 2016. <https://www.wrcc.gov.gh/en/> (Accessed 16 December 2016).
- [48] Ghana Statistical Services (GSS), District Analytical Report – Ellembele District Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Ellembele.pdf. (Accessed 15 July 2016).
- [49] Ghana Statistical Services (GSS), District Analytical Report – Tarkwa Nsuaem Municipal Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Tarkwa%20Nsuaem.pdf. (Accessed 15 July 2016).
- [50] Ghana Statistical Services (GSS), District Analytical Report – Mphohor District Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Mphohor.pdf. (Accessed 15 July 2016).
- [51] Friedrich-Ebert-Stiftung Ghana, A Guide to District Assemblies in Ghana, 2010. <http://library.fes.de/pdf-files/bueros/ghana/10487.pdf>. (Accessed 25 June 2016).

- [52] Ghana Statistical Services (GSS), Ghana Poverty Mapping Report, May 2015. <http://www.statsghana.gov.gh/docfiles/publications/POVERTY%20MAP%20FOR%20GHANA-05102015.pdf> (Accessed on 4th July 2016, Accessed on July 15, 2016).
- [53] <http://www.ghanadistricts.com/regional.aspx?Western&r=10> (Accessed 11 April 2016).=53.
- [54] Ghana Statistical Services (GSS), District Analytical Report – Axim Municipal Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/NZEMA%20EAST.pdf. (Accessed 11 April 2016).
- [55] Ghana Statistical Services (GSS), District Analytical Report – Sefwi Wiawso Municipality Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Sefwi%20Wiawso.pdf. (Accessed 11 April 2016).
- [56] Ghana Statistical Services (GSS), District Analytical Report – Bibiani-Anwhiase-Bekwae District Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Sefwi-%20Bibiani%20Ahwiaso%20Bekwai.pdf. (Accessed 11 April 2016).
- [57] Ghana Statistical Services (GSS), District Analytical Report – Amenfi East District Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Wassa%20Amenfi%20East.pdf. (Accessed 11 April 2016).
- [58] Ghana Statistical Services (GSS), District Analytical Report – Prestea Huni-Valley District, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Prestea%20Huni-Valley.pdf. (Accessed 11 April 2016).
- [59] Ghana Statistical Services (GSS), District Analytical Report – Amenfi Central District Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Wassa%20Amenfi%20Central.pdf. (Accessed 11 April 2016).
- [60] Ghana Statistical Services (GSS), District Analytical Report – Amenfi West District Assembly, 2010 Population and Housing Census, 2014. http://www.statsghana.gov.gh/docfiles/2010_District_Report/Western/Amenfi%20West.pdf. (Accessed 11 April 2016).
- [61] Ghana Statistical Services (GSS), District Analytical Report – Wassa East District Assembly, 2010 Population and Housing Census, 2014. (Accessed 11 April 2016).

- [62] Ghana Districts (<http://www.ghanadistricts.com/Region-Links.aspx?s=3077&r=10>, Accessed 12 April 2016).
- [63] R.K. Amankwah, C. Anim-Sackey, Strategies for sustainable development of the small-scale gold and diamond mining industry of Ghana, *Resour. Policy* 29 (3-4) (2003) 131–138. =63.
- [64] B.K. Ntibrey, *Small Scale Mining of Precious Minerals in Ghana – a Strategy to Improve Environmental Performance*, M.Sc. thesis, School of Mines, Institute of Mining and Mineral Engineering, Kwame Nkrumah University of Science and Technology, 2001, 2001.
- [65] J. Hinton, M.R. Hollestelle, *Artisanal and Small-scale Mining in and Around Protected Areas and Critical Ecosystems Project*, 2012. Methodological toolkit for baseline assessment and response strategies to artisanal and small-scale mining in protected areas and critical ecosystems, <http://www.profor.info/sites/profor.info/files/docs/Methodological%20Toolkit.pdf>.
- [66] L. Iddrisu, Caught in ‘Galamsey’ Gun Battle – a Reporter’s Near Death story, 2016. <http://www.myjoyonline.com/opinion/2016/december-2nd/caught-in-galamsey-gun-battle-a-reporters-near-death-story.php>. (Accessed 12 December 2016). Source: Ghana | [Myjoyonline.com](http://www.myjoyonline.com) | Latif Iddrisu | Joy News, Date: 02-12-2016 Time: 07:12:20: pm.
- [67] Y. Meng, Sweltering Heat, golden Dreams: Chinese Galamsey in Ghana, 2015. <http://china-africa-reporting.co.za/2015/01/sweltering-heat-golden-dreams-chinese-galamsey-in-ghana/>. First published in Chinese in Southern Weekly on 9 January 2014.
- [68] N.K. Amoah, ‘Galamsey Youth’ Plots Violent Takeover of Edikan Mine, 2015. Social News | 15 October 2015 00:26 CET, <https://www.modernghana.com/news/649334/galamsey-youth-plots-violent-takeover-of-edikan-mine.html>. (Accessed 12 December 2016).
- [69] B. Kankam-Boadu, Galamsey: The Untold Truth, 2013. Thursday 23rd May, 2013 11:56 am, <http://citifmonline.com/2013/05/23/galamsey-the-untold-truth/>. (Accessed 12 December 2016).
- [70] Global Initiative Against Transnational Organized Crime (GIATOC), *Organized Crime and Illegally Mined Gold in Latin America*, 2016. [https://raisg.socioambiental.org/system/files/2016_04_20_Global%20Initiative%20-%20Organized%20Crime%20and%20Illegally%20Mined%20Gold%20in%20Latin%20America%20-%20April%202016%20\(web\)_PDF.pdf](https://raisg.socioambiental.org/system/files/2016_04_20_Global%20Initiative%20-%20Organized%20Crime%20and%20Illegally%20Mined%20Gold%20in%20Latin%20America%20-%20April%202016%20(web)_PDF.pdf). (Accessed 18 November 2016).

- [71] L. Segbefia, Increase in Galamsey; Chamber of Mines Blames State Security, 2016. Wednesday 13th April, 2016 8:31 am – See more at: <http://citifmonline.com/2016/04/13/increase-galamsey-chamber-mines-blames-state-security/#sthash.FDTJkUk.dpuf>. (Accessed 23 April 2016) <http://citifmonline.com/2016/04/13/increase-galamsey-chamber-mines-blames-state-security/>.
- [72] Q. Hu, W. Wu, T. Xia, Q. Yu, P. Yang, Z. Li, Q. Song, Exploring the use of Google earth imagery and object-based methods in land use/cover mapping, *Remote Sens.* 5 (11) (2013) 6026–6042. <http://www.mdpi.com/2072-4292/5/11/6026/htm>.
- [73] A. Tilahun, Application of Google earth for the development of base map in the case of Gish Abbay Sekela, Amhara state, Ethiopia, *Int. J. Geogr. Reg. Plan. Res.* 1 (1) (2015) 13–20. March 2015 Published by European Centre for Research Training and Development UK (www.eajournals.org).
- [74] Y. Anokwa, C. Hartung, W. Brunette, G. Borriello, A. Lerer, Open source data collection in the developing world, *Computer* 42 (2009) 97–99.
- [75] F. Smart, Open Data Kit: Making it Work; for You, MSU and USAID, 2015.
- [76] C. Hartung, Y. Anokwa, W. Brunette, A. Lerer, C. Tseng, G. Borriello, Open data kit: building information services for developing regions, in: *Proc. ICTD, 2010, 2010*.
- [77] University of Notre Dame, Introduction to Open Data Kit; a Suite of Tools to Collect Data and Build Information Services, 2014. Workshop sponsored by: Center for Social Research, Eck Institute for Global Health, Initiative for Global Development, Kellogg Institute for International Studies, mobile ND, Once of Information Technologies.
- [78] OpenDataKit (<http://opendatakit.org>, Accessed 23 April 2016).
- [79] OpenDataKit, Training Guides (<https://opendatakit.org/help/training-guides/>, Accessed 23 April 2016).
- [80] Wassa West District Assembly, Medium Term Development Plan, 2002–2004, Wassa West District Assembly, Tarkwa, 2001.
- [81] E. Kwesi, A. Attimo, S. Appiah, B.I. Tackye, N.D. Taggoe, K. Tinadu, Impacts of ‘Galamsey’ on Drainage and Sanitation in the Mining Communities of Tarkwa, Ghana, 2015. FIG Working Week 2015 From the Wisdom of the Ages to the Challenges of the Modern World Sofia, Bulgaria, 17–21 May 2015 https://www.fig.net/resources/proceedings/fig_proceedings/fig2015/papers/TS08C/TS08C_kwesi_7864.pdf.

- [82] J.S. Kuma, A. Ewusi, Water resources issues in Tarkwa municipality, south-west Ghana, *Ghana Mining J.* 11 (2009) 37–46.
- [83] G. Sarpong, Galamsey Enterprise: a Threat to Ghana's Biodiversity, 2016. <http://lightmagazineafrica.com/2016/09/06/galamsey-enterprise-a-threat-to-ghanas-biodiversity.html>. (Accessed 23 April 2016). Home/Entrepreneurship/Agripreneur/Galamsey Enterprise: A Threat to Ghana's Biodiversity.
- [84] G. Hilson, A. Hilson, E. Adu-Darko, 'Chinese participation in Ghana's informal gold mining economy: Drivers, implications and clarifications, *J. Rural Stud.* 34 (2014) 292–303.
- [85] Kinross, Chirano, Ghana (<http://fb.kinross.com/operations/operation-chirano-ghana.aspx>), Accessed 5 January 2016.