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REVIEW

The Evil Couple: Illegal Mining in Water Bodies and Climate Change: A Case Study of Ghana

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ABSTRACT

For the past few decades, illegal mining sector in Ghana popularly known as galamsey has received public outcry due to its negative impacts on quantity and quality of water resources. The purpose of this study was to explore the combined effects of mining in water bodies and climate change on water resources in Ghana. The methodology explored in the study was quantitative approach. The quality and quantity of most water bodies in Ghana had been compromised due to extraction of minerals, and such contaminants (heavy metals) include mercury, zinc, cyanide, sulphur etc. This phenomenon had made most water resources (e.g. River Fena, River Pra) unwholesome or inhabitable. Apart from this, climate change had also dried up some streams and rivers such as Anyinam, Offin and Goa. These unfortunate events had made water resources precarious which could spike water scarcity in the country in the near future. This paper, therefore, commends that stringent measures are to be taken to protect water bodies in the country as a menace of climate will continue to get worse.

1. Introduction

Climate change is now universally recognised as a global threat. The main argument has been what might be the nature of climate for tomorrow and what can be done to adapt to tomorrow's climate which has the propensity to change the success story of human race. Another debate has to do with what can be done to mitigate the impacts which primarily emerge from greenhouse gas (GHG) emission and land cover change. Report of Intergovernmental Panel on Climate Change (Fifth Assessment Report) contents that since 2011, concentration of GHGs has continued to rise in the lower atmosphere as a result of anthropogenic forcing, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2), 1866 parts per billion (ppb) for methane (CH_4), and 332 parts per billion (ppb) for nitrous oxide (N_2O) in 2019. Over the past decade, the land and ocean have proportionately taken about 56% of GHG emission from human-induced radiative forcing. One of the causes of these effects was

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the significant increase in world temperature which has caused drastic impacts to the environment and society itself, which has become a worldwide concern regarding the maintenance and the cost of adapting to climate change in the face of its mitigation, which became the order of the day during the summit in Copenhagen in 2009. The summit clearly confirms the acceptance of the constraints that climate change presents to the globe by a larger community [1-3].

Access to good, reliable and adequate water supply augment the health status of people irrespective of age or class. According to International Water Association [4], 'access to good, safe and reliable drinking water is one of the most basic needs of human society'. An observation made by Global Water Partnership [5] states that a fifth of the global population is without access to safe drinking water, and service deficiencies mainly impact the poorest class of the population in the third world countries.

The scientific proof for global warming is currently realised irreversible [8]; it is evidenced by unparalleled rates of rise in air atmospheric and oceanic temperatures, and it is associated with swift rises in atmospheric carbon dioxide (CO_2). The unprecedented loss of icecap and glaciers on the world's mountaintops and unabated sea level rise which is 'swallowing' islanders and coastal stretches validate the unceasing warming trends of climate change phenomenon [3,9].

Developing countries such as those found in sub-Saharan Africa which are least contributors to greenhouse gases, as it has been reported and estimated would bear about 70%-80% of the cost of the damages that evolve from climate change [10]. Current projection shows that total cost of climate 'insurance' via mitigation actions to stabilize atmospheric temperature increase to 2 ^oC at carbon dioxide content of 450 parts per million (ppm) will be less than 1% of world Gross Domestic Product (GDP) in 2100 [11,12]. The changing climate would impact farming activities through higher air temperatures and irregular rainfall, with significant drop in precipitation likely in the mid-latitudes where the state of agriculture is perilous and normally irrigation dependent. It has been reported that rainfall for major and minor seasons has been compromised in duration and intensity in the transitional belt of Ghana [13] hence water resource availability and quality would not be spared either, as rainfall trend changes and evaporation increases. Hydrological alteration rising from change in climate would intensely affect aquaculture and inland fishery activities badly. The precarious rain-fed farming in the mid and low-latitudes would continue to suffer unlike those of higher latitudes (North America and northern Europe) which would experience rise in farming productivity [3,14].

2. Methods and Materials

Ghana is the study area, and it is located between 5^{o}N and 11^{o}N and longitude 4^{o}W and 2^{o}E. It borders with Togo in the East, Cote d'Ivoire in the West, Burkina Faso in the North and meets the Atlantic Ocean in the South. It covers approximately (total land area) 238,540 km^2. Ghana extends up to about 670 km northward from the Atlantic Ocean to Burkina Faso and approximately 560 km from Cote D'Ivoire (W) to Togo (E) [15]. Currently, Ghana's population stands at 32.72 million [16]. Ghana Meteorological Agency has divided Ghana into four ecological zones [17]. The methodology that was made reference to was quantitative approach.

3. Global Climate Change and Precipitation

Most of the global projections on rainfall patterns in several regions have been confirmed, but the overall constraints of Global Climate Models (GCMs) in giving explicit spatial trends of precipitation remain problematic. Nevertheless, the latest Atmosphere-Ocean (coupled) Global Climate Models (AOGCMs) is working on the interactions and feedbacks obtained among topography, elevation and albedo [3].

There is enough evidence supporting acceleration of El Nino Southern Oscillation events and the relationship between sea surface temperature (SST) and frequent cyclones occurrence, however, GCMs cannot model them thoroughly. Climate variability is also sped up by these two internal phenomena (La Nina and El Nino) in some regions such as Kenya (La Nina) and southern Africa (El Nino), and their occurrences have accounted for droughts which is negatively affecting GDP [18].

When it comes to prediction of future precipitation, there are uncertainties from a lot of the models. For instance, a recent downscaling exercises across the width and breadth of United States established that there were discrepancies with respect to evidence on precipitation from ensemble GCM modelling and 'off-line'. Regional Climate Model (RCM) modelling projected mean rises in rainfall and runoff in contrary to the earlier report from GCM and ensemble GCM-based work for at least four major river basins [19-21]. The reason might be that slight differences in scenario specification and downscaling techniques do not necessarily preserve GCM rainfall per grid cell; GCM grids tend to smear out gradients, particularly precipitation; and poor representation of an estimated shift to winter dominated precipitation in the Colorado Basin and in California - a change that would improve runoff [3].

The events of precipitation, unlike atmospheric temperature, varies from latitude to latitude or from region to region per the various simulations. Rainfall is predicted to rise over high latitudes, the Equatorial Pacific and parts of the monsoon regions, but reductions over parts of the subtropics and small portions in the tropics in SSP2-4.5, SSP3-7.0 and SSP5-8.5. The part of the land mass experiencing detectable rise or reduction in seasonal average precipitation is estimated to rise as contained in the report of AR6 [18].

A warmer climate, as being experienced recently, would amplify very wet and very dry weather and climate events and seasons, with effects of drought or floods. However, the geographical position and frequency of these phenomena depend on estimated changes in regional atmospheric circulation, comprising monsoons and mid-latitude storm tracks. There is a possibility that rainfall variability in conjunction with the El Nino Southern Oscillation is anticipated to intensify by the second half of 21st century in the SSP2-4.5, SSP3-7.0 and SSP5-8.5 scenarios [18,19].

4. Climate Change and Water Resources

Water resource is already over-appropriated in many parts of the globe. It is estimated that more than 2.4 billion people, which represents one-third of the Earth's population, will live in water-stressed regions and it is projected that by 2025, the figure is believed to increase to two-thirds [22].

As rainfall has direct impact on running and groundwater, reduction in precipitation would desiccate most water bodies on the surface of the Earth. According to Adams & Peck [23], variation in rainfall in the face of climate change will influence quantity, variability, timing, form and intensity of water resources. It is worth noting that terrestrial climate change will equally alter or cause a rise in the rate of evaporation, increase proportion of precipitation received as rain instead of snow, reduce runoff seasons, augment water temperatures and decrease the quality of water in both hinterland and coastal zones [23].

It is worth mentioning that many geographical regions will suffer from reduced water supplies. According to FAO [22], due to how man misuses water, groundwater tables and river levels are declining in several regions globally. Summer periods are projected to experience much shortfalls resulting in reduction in moisture content in the soil and more severe and regular agricultural drought [24].

Contrary, winter precipitation in the form of rain will rise as a result of increasing surface temperatures, with a deficit proportion falling as snow. Snow pack levels are equally estimated to develop later in the winter season, amass in minute quantities, and thaw earlier in the season, resulting in reduced summer flows [23,25].

A report of National Centre for Atmospheric Research [26] has it that regions classified as 'very dry' have been doubled since 1970s. Besides, areas known to be drought prone regions are also expanding in an alarming rate, and these areas comprise sub-Saharan Africa and Australia. Elsewhere in Northern Hemisphere, the flow of long-term annual rivers and natural water storage capacity have been experiencing deficit due to glacial/snow cap melting. Several Asia's largest rivers are estimated to drop off in coming years due to glacial thawing. Scientists have projected a possible dryness of Lake Mead, which serve over millions of inhabitants in the south-western United States, around 2021 [25-27].

5. Existing Challenge of Water Resources

One of the major problems that is threatening human survival especially in the developing countries is declining water quality. The situation is compounded by inadequate wastewater treatment due to unavailability of resources or capital. In most of less developed countries such as those found in African soil, running water (strings, streams, rivers etc.) traditionally used as sources of drinking water have been dangerously polluted by some citizens (miners) and expatriate alike who want to get rich overnight. In China, for instance, several water bodies have been polluted beyond measure. It has been estimated that due to insufficient sanitation facilities and rising water demand as a result of growing population, it is documented that globally, 900 million people lack access to safe water while up to 5 million populace die each passing year from water-related illness [24,28].

6. El Nino Southern Oscillation (ENSO) Events in Ghana

The impacts of El Nino South Oscillation is very strong on all the ecological zones in Ghana as indicated by Adiku *et al.* [29] and Sultan *et al.* [30], and it was dominant around 1972-1973, 1982-1983, 1997-1998. However, the strong influence of La Nina episodes of 1973-1974, 1975-1976 and 1988-1989 has also been felt along the coast and the forest zone. Usually, the impact of ENSO is strongest at the coast than the northern part of the country as it weakens northwards due to some dynamics from West African

Monsoon [29]. The variability of the ENSO in Ghana improves the easterlies and decreases monsoon movement. The upper easterlies are weakened giving rise to dry situations near the surface of the Inter-Tropical Discontinuity (ITD), and this happens during major rainy season and the dry season. Mawunya *et al.* [31] contend that ENSO years are characterised with late onset of rainfall while La Nina years are characterised with early onset. Various studies by Paeth & Hense [32], Owusu *et al.* [33] and Yorke & Omotosho [34] confirm that there has been a decline in the amount of annual rainfall. Recently, rainfall amount has persistently declined since 70s and it can be attributed to the strong event of ENSO, as it was also predominant around 2009-2010 [35].

7. Seasonal Trend Analysis

Generally, all the four agro-ecological zones in Ghana are experiencing reduction in rainfall with the exception of Coastal Zone which has a predominant increasing pattern (Table 1). This increasing trend that has characterised the coastal zone is nevertheless insignificant using the Mann Kendall Trend Test at the 0.01 and 0.05 significant levels (Table 1). The transitional zone persistently displays significant declining trends in all the seasons with the exception of June, July and August (JJA) as shown in Table 1. The December, January and February (DJF) season (also known as the Harmattan season) depicts a significant reduction trends at the 0.01 significant level for all but one of the agro-ecological zones signifying intensification of the dry season [15] as shown in Figure 1.

Table 1. Rainfall Trend Rate (mm per year)

Seasonal Rainfall	Coast	Forest	Transitional	Savannah
DJF	–0.1429**	–0.1273**	–0.1040**	–0.0102
MAM	0.0692	–0.0793	–0.2016**	–0.1181**
JJA	0.0510	–0.0242	0.2112*	–0.0972
SON	0.0677	–0.0512	–0.1460*	–0.1582**

DJF- December, January, February; MAM - March, April, May; JJA - June, July, August; SON - September, October, November (*Wavelet Analysis of Rainfall over the Agro-Ecology Zones of Ghana*).

Source: [15]

The rate of seasonal rainfall pattern in the four agro-ecological zones in Ghana (** and * show significant trends at 0.01 and 0.05 significant levels respectively)

The Figures shown below represent the seasonal mean rainfall over Ghana (Figure 1).

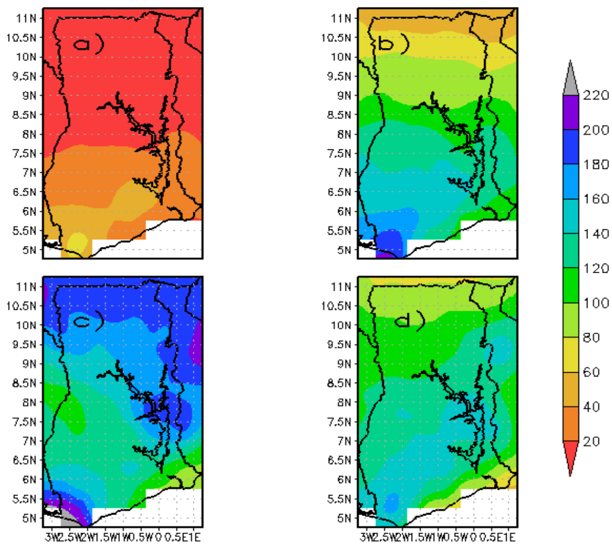


Figure 1. Seasonal mean rainfall (mm) over Ghana for a) December- January - February B) March - April - May C) June - July - August D) September - October - November During 1901 - 2010 period

Source: Baidu *et al.* (2017)

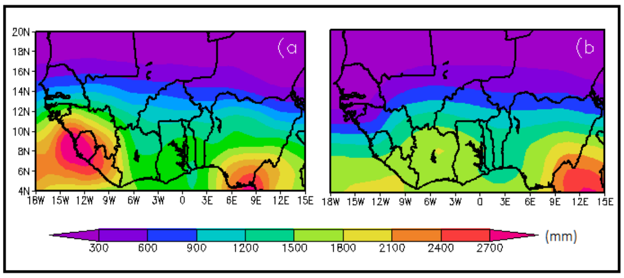
8. Inter-Tropical Discontinuity (ITD)

The nature of rainfall in West Africa, as shown in Figure 2, is characterised with variability on inter-annual and decadal time scales, and it is highly correlated with Sea Surface Temperature (SST) [36]. The positive ENSO Sea Surface Temperature anomalies of the eastern tropical Pacific has greater impact on dry conditions prevailing over Sahel and wet conditions over Guinea. The phenomenon is also correlated with SST anomalies of the Southern Hemisphere Atlantic and with negative anomalies of the Northern Hemisphere Atlantic (the Atlantic dipole) and positive SST anomalies of the tropical Indian Ocean [37-39].

Basically, the simulated pattern replicates the observed trend. Related to the observations, the broad features of rainfall experienced in West Africa such as the one that characterises Ghana-Togo gap was simulated by the model studied by Ekwezuo *et al.* (2017) as shown in Figure 2.

Figure 2 shows rainfall simulation observed in West Africa.

With regards to Representative Concentrated Pathway (RCP) 4.5 (Figure 3), around the coast of Cameroun, rainfall is projected to rise by ~35 mm, the adjacent coast by ~1 mm to 20 mm. It is anticipated that the expected changes would not benefit inland stretch where the projection will be around ~1 mm to 10 mm with the exception of north-western Nigeria, some parts of Mali, Togo and Ghana where precipitation is projected to remain comparatively unchanged.



a) GPCP-observed b) NorESM1-M- simulated

Figure 2. Mean annual rainfall trend over West Africa sub-region for the baseline period (1980-2005)

Source: Ekwezuo *et al.* (2017)

Under RCP 8.5 (Figure 3), approximately 35 mm rise in precipitation is projected around the coastal stretch of Cameroun, followed by the adjacent coast where increase of ~1 mm to 25 mm should be expected. On the other hand, rainfall reduction (~1 mm to 10 mm) is expected to characterised farther inland with an exception of north-eastern Niger and Guinea where it is anticipated to remain unchanged.

It can be inferred that under all the RCP, there is an anticipated rise in rainfall amount, with the southern part of the sub-region most especially coastal areas of Cameroun (~20 mm to 35 mm) experiencing the highest amount of precipitation. Closely followed is the south-western part of the Atlantic Ocean with a rise of ~10 mm to 30 mm. Other regions are to experience an increase of ~1 mm to 10 mm. With respect to areas where there is no noticeable change or little change, there is a considerable difference in the RCPs (Figure 3) except over the Atlantic Ocean [40].

The different rainfall regime in Ghana, the West African country, along the coastal stretch in the south to the Sahelian region in the far north [41] is defined by the northward and south-ward oscillation of the Inter-Tropical Convergence Zone [42]. This phenomenon results in African monsoon, leading to uni-modal and bi-modal distribution characteristic of the northern and southern part of the country, respectively.

The rainfall annual cycle in Ghana is characterised by bi-modal type of rainfall in the south as there is double maxima rainfall regime and uni-modal rainfall trend in the north characterised with one rainy reason followed by long dry spell popularly known as Harmattan. The rains commence in April and gets to its maximum in August-September when the moisture-bearing tropical maritime air mass gets there to induce heavy rainfall [15]. The cessation of rainy season in the north begins in October and welcomes the dry northeast trade winds. The northeast trade winds start to become dominant in November which normally lasts till March.

Under all RCP, the West African sub-region is estimated to enjoy a rise in precipitation amount. This, nevertheless, contradicts the projected change trend in the early twenty-first century. The Figure 3 below shows the current precipitation projection.

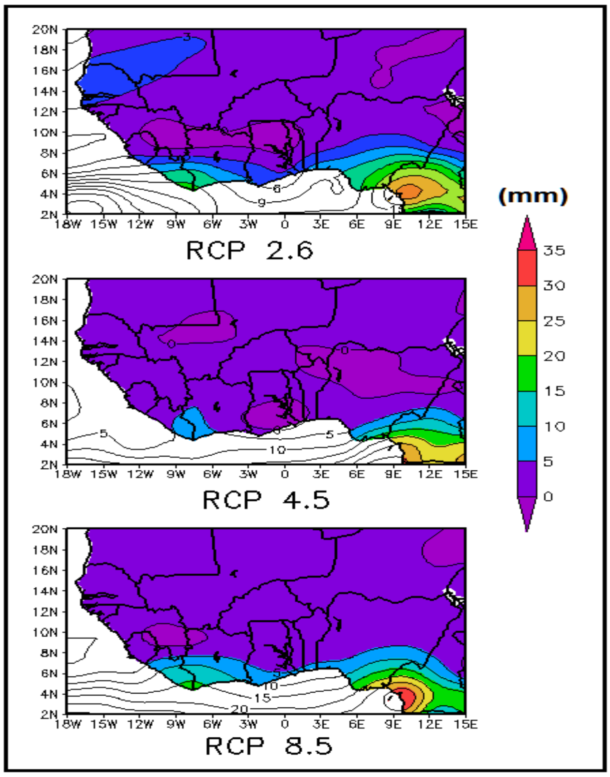


Figure 3. Projected changes in annual rainfall trend for mid twenty first century

Source: Ekwezuo *et al.* (2017)

9. Evidence of Climate Change in Ghana

According to IPCC forth assessment report [43], currently, Ghana is undergoing four physical impacts of climate change, and these include temperature rising, changing regime of rainfall towards a longer dry season and vanishing rainy season. Climate change is impacting on rainfall trend in all ecological zones but has hit hard in the far north where rainfall regime is single maxima. Recent sea level rise coupled with floods being experienced in southeast (Keta) of the coast of Ghana is a clear indication that climate change is at work.

A projected trend of atmospheric temperatures from 2010 to 2050 by World Bank as cited by Asante & Amuakwa-Mensah [44] for Ghana shows warming over the entire West African country with the highest temperatures occurring in the northern part of Ghana with the lowest being experienced in the transitional belt (formerly Brong Ahafo).

The current mean annual temperature ranges between 25 °C to 30 °C. However, occasionally, the air temperatures can be as low as 18 °C (minimum) and as high as 40 °C (maximum) in the northern part of Ghana [44].

An average annual precipitation of 2000 mm/year, 950 mm/year and 800 mm/year occur in the South West, Northern and South Eastern parts respectively. According to a study by Adjei & Kyerematen [13] and Owusu, *et al.* [45], the transitional ecological zone of Ghana (a region separating forest from Savanna belt) has undergone late onset of rainfall (from early March to late March) and early cessation of it (from November to late October). This has compelled farmers to shift planting date from March to April [46] while others (farmers) too have turned their attention from their main occupation (maize) to cashew farming [47]. A long-term data analysis by Dietz *et al.* [48] shows that places in the northern part of Ghana around Upper East Region has equally experienced below average rainfall conditions for over 18 years (1972-1990). In the same vein, it is reported that drought years have risen in several parts of Ghana. According to a study by Adiku *et al.* [49], manifestation of drought year has reached 3 to 4 out of every 10 years in the late 1980s as compared to 1 to 2 years in the preceding years. The paper further argued that rainfall irregularity analysis substantiate the swing from drought to flood years have become pervasive posing great threats to most smallholder farmers in Ghana.

The climate change in Ghana is having a negative impact on vital water resources, energy supplies, crop production and food security. The three northern regions of Ghana are the most vulnerable with the experience of extremely high temperatures and severe flooding [50]. According to Akudugu and Alhassan [51], the northern part of Ghana has repeatedly experienced incidences of droughts and floods with several communities and families losing their farms as a source of their livelihood in the past years which is attributed to a change in climatic conditions. Furthermore, in 2007, floods in the northern part of the country, proceeded a long period of dryness which affected more than 325,000 people (Global Facility for Disaster Reduction and Recovery) [52]. The capital city of the country (Accra) in 2015, also experienced days of torrential rainfall which resulted in severe flooding leaving 159 Ghanaians losing their lives [53]. However, Ghana as a whole is also experiencing increased extreme weather conditions [54] such as a rise in sea level causing flooding and displacing some communities in the coastal belt. Ghanaian farmers have identified erratic rainfall patterns, longer periods of dry season and desertification as the main current consequences of climate change [55]. Prolonged period of drought coupled with high temperatures is also experienced, changing rainfall pattern making it difficult for farmers to plan their planting season due to their inability to predict rainfall pattern [13]. This has affected food production and poor yield by farmers causing food insecurity in Ghana (especially in the northern part). Farmers are therefore forced to grow crops that are resilient to extreme weather conditions such as cassava, cocoa and cashew [46]. Furthermore, prolonged drought has caused drying up of major water bodies that serve as source of raw water to the Ghana Water Company Ltd (GWCL). This has caused water shortage in several communities, villages, towns and cities in the country [56].

There is also a current tension between Ghana and Burkina Faso over a decision to withdraw water from the River Volta which would lead to a reduction in the volume of water needed for the production of electricity in Ghana from a study carried out by USDA [57]. This however could lead to trans-boundary conflict. In addition to the above evidence of climate change in Ghana is where nomadic herdsmen in search of water and grass to feed their cattle cause destruction to farmers in the southern part of the country. This has led to a number of conflicts between the Fulani herdsmen and the farmers [58,51]. The decrease in the volume of water in the Akosombo dam has also had a negative impact on generation of hydroelectric power in that the country experienced severe power outages consistently as a result of drought [59]. Due to an increase in air temperatures, the countries inland fisheries in Lake Volta also experience a reduction in stock [60].

10. Nature of Water Resources in Ghana

Basically, water resources in Ghana can be categorised into surface and underground sources. The known major water bodies (rivers) classifying under surface water in Ghana include River Volta and its tributaries (Oti, Black and White Volta), Pra, Bia, Tano, Todzie, Aka, Densu, Ayensu, Ankobra, Ofin and Och-Nakwa (Figure 4). Apart from the tributaries of River Volta, almost major rivers in Ghana drain the southern sector of the country [61,62] (Figure 4). The largest river, which is River Volta, is shared among five other countries which include Cote d' Ivoire, Mali, Burkina Faso, Togo and Benin. It drains about 70% of the total land of the country (Ghana) and the other rivers take over the 30% remaining [61].

About 41% of the population of Ghana depends on groundwater for their livelihood. Nevertheless, this rate is higher in the small communities in the hinterland (59%) as compared to urban areas (16%). The dependency ratio of the populace on groundwater is highest in the northern part of Ghana due to low seasonal availability of surface water [63,64]. Unlike precipitation where the projection is full of uncertainty, higher atmospheric temperatures are expected to be dominant hence will speed up evaporation and result in water losses and this will consequently affect water resources in most parts of the country [44].

The surface water sources are made use by industries, home, transport services and tourist whereas the groundwater sources are mainly used among both urban and rural folks for domestic purposes [62].

A study conducted on River Offin [65] suggests that climate change has a great gravity on water resources. The study argued that several tributaries that feed the River Offin are drying up with some ceasing to exist. The dryness of the tributaries of River Offin has made the volume of the River small. So when dry season prolongs, the River reduces to pocket of stagnant water bodies. In 2013 for instance, the report maintained that the River Offin dried up and became dry land. Hand-dug wells were produced around the banks of the river to provide alternative source of water to the communities at the catchment area. Other rivers which have also been affected by this phenomenon are River Anyinam in the Eastern Region closed to Anyinamso and River Goa near Goaso. A research has established that the entire river, which the community (Anyinamso) was named after, has vanished (dried up) leaving behind its huge channel due to scanty rainfall and dissipation of streams that supply constant water to the river [65].

Apart from River Volta and its tributaries, most of the water bodies (rivers) found in Ghana can be located in the southern part of the country as depicted in Figure 4. The Figure 4 also shows that Ghana does not experience water stress or scarcity (if the country gives priority to its water resources).

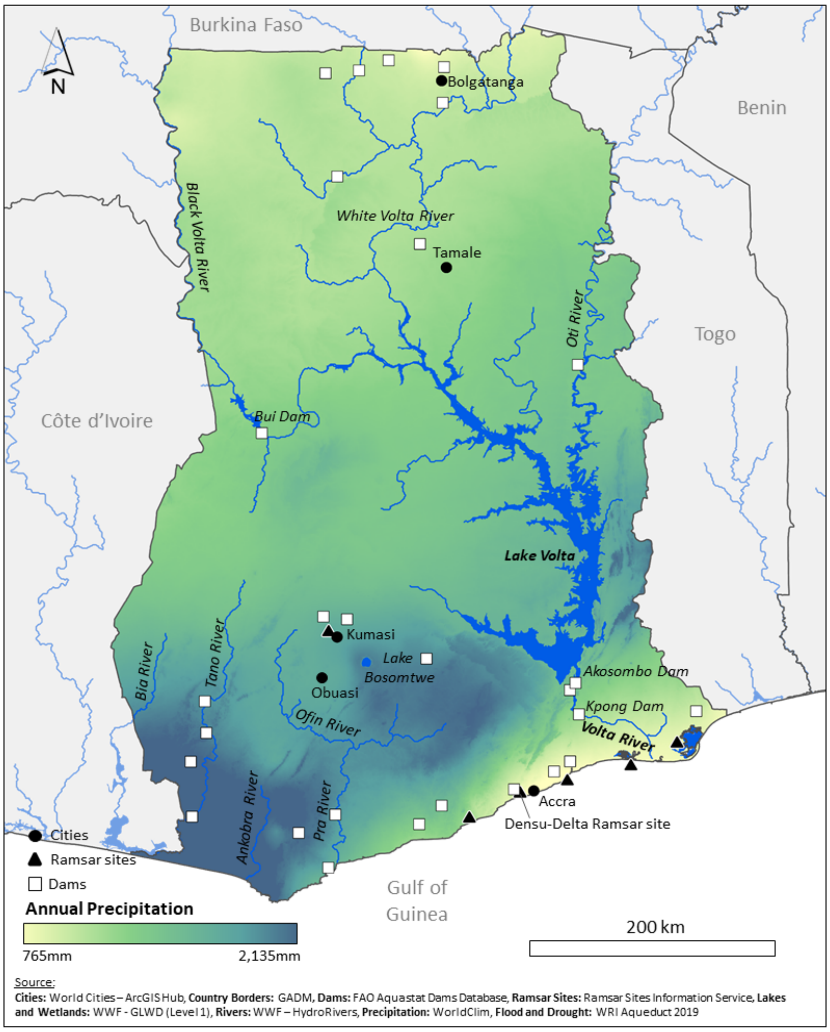


Figure 4. Annual rainfall and major water bodies in Ghana

Source: USAID (n.d)

11. Mining Operations in Ghana

11.1 Nature of Illegal Mining (Galamsey) Activities in Ghana

Ghana, a West African country formerly called Gold Coast, is blessed with enormous mineral deposits (Figure 5); the major ones being gold, diamonds, manganese and bauxite. Gold is principally the largest mineral produced in the West African country, accounting for over 90% of all mineral revenues accrued from minerals for the past two or more decades [66]. The sector is made up of large and small scale industries. The small scale also comprises legal and illegal mining sectors. The small scale sector absorbs about one million unemployed indigenous people [67]. The unregulated or illegal mining sector which is commonly known as *galamsey,* is the chief polluter of water bodies as its activities are not monitored by any legal instrument. According to Baah-Ennumh [68], illegal mining in Ghana depicts all mining activities done without obtaining proper license from regulatory bodies that govern practices of miners, hence such activities flout most of the mining laws, and fail to observe appropriate buffer restrictions. They make use of rudimentary tools and techniques such as pick ass, chisels, sluices and pans for the exploitation of mineral reserves [69,70].

In Ghana, and many other countries in sub-Saharan Africa, predominant environmental challenges associated with small-scale mining activities consist of destruction of farmlands, pollution of water bodies, destruction of vegetation and habitats of wildlife [71,72].

According to a study by Yeleliere *et al.* [73], about 60% of surface water bodies in Ghana are polluted, and the menace is worse in the southern part of the country where mining activities are ubiquitous. High turbidity in the River Pra for instance has substantially increased water treatment cost and left some plants inoperable for couple of years [74]. A study has shown that River Volta basin contains high level of chromium that might have come from industrial or municipal pollution [65].

Ghana is blessed with gold. However, most of the rocks containing this mineral are found in the western part of the country running from north to south (Gulf of Guinea) as shown in Figure 5.

11.2 Impacts of Illegal Mining (Galamsey) on Drainage Systems

There are countless of environmental problems and challenges linked to mining activities which evolve from competition for surface water [76]. The danger posed by illegal mining to water quality and water resources in Ghana has led to public outcry due to the closure of several treatment plants and how it has left several water bodies unusable [77]. Contamination, which is very deadly to both aquatic and living creatures, results from the discharge of effluents making up the various toxic chemicals such as cyanide, mercury and other organic chemicals used in the processing of mineral ores. These chemicals (with high percentage of acid) of effluent can either percolate into the soil affecting underground water or cause havoc to water bodies on the surface of the earth posing threat to humankind, domestic animals and even wildlife which depend on the water bodies in the catchment area [78-80]. "Once in the natural environment, mercury undergoes a change in speciation from an inorganic to a stable methylated state (MeHg) by non-ezymically and microbial action, and when ingested, ecotoxicological effects result" [82].

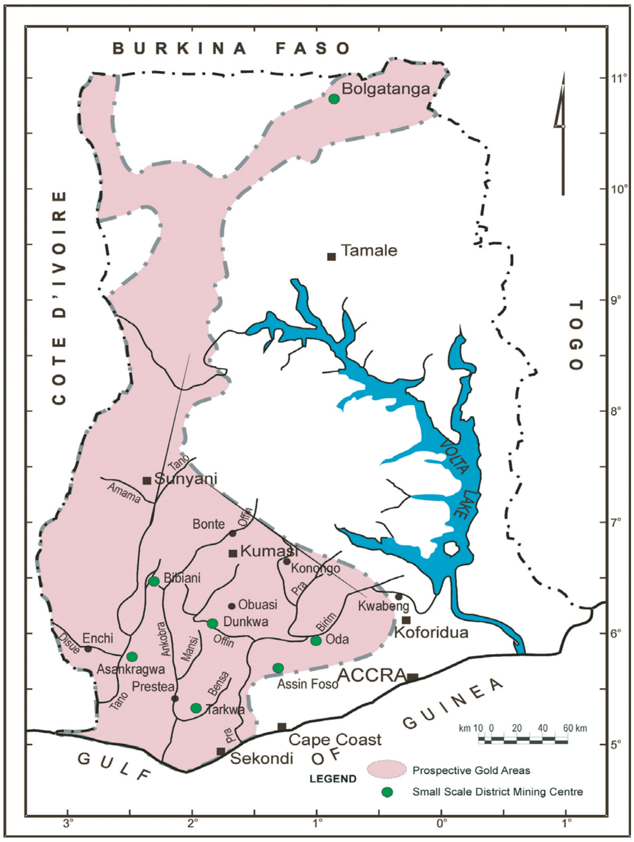


Figure 5. Prospective Gold Mining Areas in Ghana

Source: Hilson (2002)

Another concern of worry is the leaching of heavy metal oxides which comprises lead and zinc. Sometimes, these aforementioned metals spread throughout the environment following down pour causing mayhem to aquatic life, fauna, fora and the micro-organisms [78]. It is very hard, in recent years, to notice water resources such as crabs, fish, shrimps, snails etc. in the water bodies found in Ghana especially where mineral is mined due to the presence of hazardous chemicals in most water bodies [83].

It has been reported that [81] the south-western basin of River Tano contains heavy metal from gold mining, but the situation is worse in the River Pra Basin where haphazard illegal mining is intensified. Again, arsenic levels near Prestea (River Pra Basin) have also been detected nearly 800 times the World Health Organisation (WHO) guideline limit for human consumption, most likely from unregulated gold mining in the country [61,74,73,84].

Total metal concentrations in mg/kg dry weight (ppm) and organic matter content determined as loss on ignition (LOI) on river sediments done by Donkor *et al.* [85] from the River Pra basin during the rainy season (summer season) are displayed below. The Table 2 shows the mean values of physicochemical parameters and the maximum and minimum values of heavy metal concentration in River Pra. The various contaminants in the river make it unwholesome for human and animal utilisation or consumption.

Furthermore, a study by Duncan [77] in River Pra established that excessive pollution of the River (Figure 6) poses health threat to the riparian communities around which rely on the River for their livelihood as most fisher men too had lost their jobs due to the death of fishes in the water body.

High or low pH can cause the death of aquatic organisms. pH also influences the solubility of certain toxic compound such as heavy metals in a river (Table 3).

Total metal concentrations in mg/kg dry weight (ppm) and organic matter content determined as loss on ignition (LOI) on river sediments done by Donkor *et al.* [85] from the River Pra basin during the dry season (winter season) are shown in Table 3. BDL = Below Detection Limit (i.e. 0.003 ppm for Pb and o.00075 ppm for Co). The Table 3 shows the mean values of physicochemical parameters and the maximum and minimum values of heavy metal concentration in River Pra. The various pollutants in the river make it unwholesome for human and animal utilisation or consumption.

Natural courses of several water bodies are either diverted or blocked to provide successful operations of small scale mining activities (most especially the illegal ones), and sample is given below in Figure 6. While large scale mining takes into account the health of the ecosystem, the small scale mining does not as the miners tend to float over environmental laws.

Table 2. Water quality parameters of River Pra in dry season (winter)

River Section	Site #	Hg	Al	Fe	As	Pb	Cu	Mn	Co	Ni	V	Cr	Zn	%OM
Lower	1	0.066	278.1	301. 2	0.414	0.238	0.263	6.790	0.053	0.439	0.777	0.905	1.418	2.08
Pra	2	0.076	267.5	328.1	0.411	0.043	0.226	8.955	0.134	0.370	0.791	0.819	1.531	5.55
	3	2.917	236.9	168.7	0.213	0.179	0.252	2.387	0.130	0.271	0.706	0.724	1.553	9.98
	4	0.018	146.2	134.8	0.184	0.064	0.127	3.516	0.063	0.308	0.392	0.47	0.742	11.50
	5	0.046	174.7	225.3	0.360	0.096	0.221	6.518	0.188	0.362	0.758	0.825	1.214	1.30
	6	0.103	195.1	155.6	0.384	0.041	0.158	4.384	0.078	0.318	0.518	0.586	0.754	4.92
	7	0.022	223.6	220.7	0.488	0.022	0.221	6.297	0.166	0.348	0.652	0.744	1.072	1.67
	8	0.31 0	348.9	370.4	0.691	0.078	0.333	8.595	0.272	0.493	1.098	1.321	1.285	7.61
Upper	9	0.079	226.8	432.9	0.180	0.060	0.386	4.88 3	0.112	0.356	3.378	1.176	1.526	1.91
Pra	10	0.678	158.1	166.2	0.079	0.214	0.169	2.658	0.023	0.300	0.594	0.620	0.802	2.89
	11	0.071	273.7	376.1	0.115	0.014	0.323	5.002	0.249	0.441	1.252	1.273	1.201	1.56
	12	0.180	736.9	1266.3	0.133	0.160	1.010	10.704	0.517	0.874	0.861	2.401	1.603	7.91
	13	0.070	236.8	290.2	0.165	2.441	0.299	3.546	0.138	0.342	0.834	1.100	1.286	3.47

Source: Donkor *et al.* (2005)

The low and stable temperature recorded, as shown in Table 4, do not favour the growth and survival of aquatic species; this would explain why fishes are scarce in rivers where mining is done. Apart from the temperatures menace, there are other factors such as presence of heavy metals that have resulted in disappearance of fishes.

The majority of aquatic creatures prefer a pH range of 6.5-9.0 even though some can live outside that pH range. The pH of water can equally be influenced by the acidity of the catchment area. Fen 1 has a pH value within World Health Organisation's permissible value as recorded above. Again, heavy metals can be dissolved into water by low pH; due to the continuous usage of rivers by farmers for irrigation purpose, this phenomenon has a public health concern [77].

Temperature positively impacts aquatic life. It accelerates the activity of photosynthesis, reaction of pollutants and parasites, and influences solubility of dissolved oxygen in water [86].

The concentration of pollutants (metals) shown above were far higher than required limit is an indication that the river was polluted, and these metal concentration has been aggravated by the intensity of the mining carried out in the water body. The results show poor and marginal quality of River Fena, and this possesses threat to domestic activities and aquatic life.

Table 3. Water quality parameters of River Pra in dry season (winter)

River Section	Site #	Hg	Al	Fe	As	Pb	Cu	Mn	Co	Ni	V	Cr	Zn	% OM
Lower	1	0.003	90.0	141.0	0.216	BDL	0.018	3.031	*BDL	0.252	0.204	0.203	0.569	0.46
Pra	2	0.008	308.0	214.0	0.146	BDL	0.089	2.828	BDL	0.400	0.484	0.523	1.199	3.15
	3	0.002	406.0	236.0	0.281	BDL	0.153	5.102	BDL	0.457	0.645	0.732	0.704	1.68
	4	0.017	570.0	283.0	0.355	BDL	0.207	4.461	BDL	0.457	0.878	0.985	1.280	4.74
	5	0.005	117.0	68.0	0.218	BDL	0.029	1.470	BDL	0.301	0.145	0.267	0.746	0.25
	6	0.043	198.0	271.0	0.370	BDL	0.192	7.890	BDL	0.453	0.619	0.579	1.152	0.96
	7	0.009	287.0	135.0	0.158	BDL	0.091	2.573	BDL	0.343	0.475	0.575	0.557	0.00
	8	0.002	245.0	247.0	0.458	BDL	0.133	8.221	BDL	0.574	0.548	0.537	0.756	3.01
Upper	9	0.002	407.0	497.0	0.125	BDL	0.150	5.016	BDL	0.437	0.867	1.030	1.027	1.74
Pra	10	0.002	318.0	116.0	0.088	BDL	0.072	2.195	BDL	0.429	0.461	0.522	0.728	0.52
	11	0.005	509.0	356.0	0.124	BDL	0.196	9.781	BDL	0.568	0.885	1.031	1.171	0.39
	12	0.030	288.0	378.0	0.103	BDL	0.261	4.480	BDL	0.429	1.219	1.755	0.666	0.84
	13	0.043	247.0	243.0	0.369	BDL	0.049	2.495	BDL	0.569	0.349	0.333	0.881	2.91

Source: Donkor *et al.* (2005)

Figure 6. Illegal activity in Ghana.

Source: Fatawu, & Allan (2014)

Table 4. The quality of River Fena in a mining area

	Fen 1			Fen 2			
Parameters	Mean and std	Max	Min	Mean and std	Max	Min	WHO standard
pH	6.17 ± 0.27	6.63	5.82	5.81 ± 0.41	6.33	5.21	6.5-9
Temp.	23.58 ± 0.17	23.85	23.31	23.45 ± 0.17	23.73	23.08	25-30°C
Turb.	182.25 ± 20.49	213	148	194.33 ± 16.34	231	169	75NTU
TSS	2415.67 ± 440.1	3314	2560	2971.67±	3354	2830	500 mg/L
TDS	3165.33 ± 207.83	3314	2560	3180.50 ± 142 .11	3334	2730	500 mg/L
Conductivity	1236.75 ± 59.38	1311	1103	1268 ± 19.44	1300	1238	1000 mg/L
Pb	0.192 ± 0.23	0.81	BDL	0.72 ± 0.29	1.04	0.23	0.01 mg/L
Cd	0.14 ± 0.19	0.7	BDL	0.02 ± 0.01	0.04	0.01	0.003 mg/L
Cu	0.09 ± 0.03	0.14	0.03	0.09 ± 0.06	0.24	0.01	2 mg/L
Fe	12.94 ± 1.57	16.43	11.03	13.01 ± 0.71	14.09	11.63	2 mg/L
Zn	0.81 ± 0.14	0.91	0.46	0.84 ± 0.09	1.02	0.71	5 mg/L

Source: Duncan (2020)

12. Conclusions and Recommendation

Ghana has enough water bodies that can protect the country from water stress. There is also enough groundwater to shield the West African country from water scarcity. However, climate change and variability are currently impacting on these water bodies drying up most tributaries which feed up such streams and rivers. In recent years, most rivers are either reducing volumes drastically or completely drying up. The presence of illegal mining in water bodies is compounding the situation which might lead the country to experience water stress if measures are not put in place to contain mining in river banks and beds. Politicisation of sensitive issues in Ghana has made the fight against illegal mining in water bodies extremely difficult for the various ruling governments.

Conflict of Interest

There is no conflict of interest.

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