

## **Climatic Variables and Disease Incidence in Ghana: A Study of Cerebrum Spinal Meningitis (CSM)**

**Richard Bayel Trumah<sup>1</sup>, John Ayer<sup>2</sup> and Dadson Awunyo-Vitor<sup>3\*</sup>**

<sup>1</sup>*Department of Materials Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.*

<sup>2</sup>*Department of Geomatic Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.*

<sup>3</sup>*Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.*

### **Authors' contributions**

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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### **ABSTRACT**

**Aim:** The study was undertaken to evaluate the effects of climatic factors on the outbreak of Cerebrospinal Meningitis (CSM) in the Obuasi Municipality of Ghana.

**Significance:** The project provides a validated climatic pattern and serves as reference point to: 1. Health administrators on CSM emergency preparedness which could lead to the prevention of fatalities as measures would be put in place to address an occurrence. 2. Environmentalists on the environmental factors that cause CSM outbreak. 3. Health consultants for sensitization and creations of awareness of the causes of CSM. 4. Stakeholders for planning and implementation of outbreak preparedness methods and strategy.

**Methodology:** Time series data on rainfall, temperature, and relative humidity was obtained from Ghana Meteorological Agency in Accra and AngloGold Ashanti, Obuasi. The rainfall and temperature values were taken from 1980 to 2011 while that of relative humidity was drawn from 1987 to 2011 due to the unavailability of data. Data on the reported case of CSM was obtained

\*Corresponding author: E-mail: [awunyovitor@yahoo.co.uk](mailto:awunyovitor@yahoo.co.uk); [johnnyayer@gmail.com](mailto:johnnyayer@gmail.com);

from Ghana Health Service. The data was analyzed using Cluster and correlation analysis.

**Results:** Correlation analysis indicates that the reported cases of CSM in Obuasi are positively and significantly related to temperature. However, from the cluster analysis there were no reported cases of CSM in other towns in the same cluster as Obuasi.

**Conclusion:** Climatic factors serve as catalyst for the occurrence of CSM. Without the complex interplay amongst these factors and the virus or bacterial CSM will not break out as the bacteria causing bacteria meningitis are commonly found in the nose and throat but not harmful.

*Keywords: CSM; climatic variables; obuasi; Ghana.*

## 1. INTRODUCTION

Meningitis is inflammation of the protective membranes covering the brain and spinal cord known collectively as the meninges. The inflammation may be caused by infection with viruses, bacteria, fungi or other microorganisms, and less commonly by certain drugs [1].

Most common symptoms of meningitis are headache and neck stiffness associated with fever, confusion or altered consciousness, vomiting and an inability to tolerate light (photophobia) or loud noises (phonophobia) [2].

The fatality rate of cerebrospinal meningitis in the world is not available but in Ghana it is said to have almost wiped a whole village, Tizza, in the Upper West region off from existence in the colonial days [3]. Ghana health service reports that, 21 people were reported of CSM at Obuasi in Ghana in 2010 out of which 6 people died [4].

The location of Ghana on the sub-saharan meningitis belt of Africa triggers the usual seasonal CSM epidemics that predictably occur in periodic patterns. Weather conditions during the period of the epidemic outbreak are usually harsh. The winds are often dusty, temperatures very high with the heat extending to the evenings. The night is usually very cold and the areas are usually overcrowded. These conditions leave the inhabitants susceptible to respiratory diseases. These conditions exist in the sub-saharan meningitis belt of Africa and that account for the region's high incidence of meningococcal diseases [3]. In other West African countries, people have also noted that the outbreak of the epidemic nearly always coincides with the setting in of the harmattan, a north east wind blowing from the Sahara towards the gulf of Guinea.

Using graphic representation in diseases studies have been on the ascendancy with the advent of computer technology and GIS software. Though

the practice of graphic representation of diseases in the medical field dates back to the eighteen century, it was only applied for the first time in the search to identify the source and rate of spread of communicable diseases in the ninetieth century [5]. Mapping of persistent diseases were done with the knowledge that the environment played a major role in the study of their origin. Geographical epidemiology which makes use of health and environmental data and scrutinised in geographical detail have emerged as new and important approaches [6]. The use and application of GIS tools to graphically represent occurrences in the health sector have been used in tracking and the surveillance of issues of environmental health, water-borne and vector borne diseases [7]. GIS has been used in health service research and in mapping studies of non-communicable diseases in Finland [8].

Cluster analysis includes a number of different algorithms, methods and catalogues for grouping objects of similar kinds into respective categories (clustering is a method of grouping where objects or occurrences are grouped together or apart based on their characteristics. Bailey and Gatrell [9] opined that grouping start in the same mode. All methods begin with the calculation of a (n\*n) matrix, D, of differences between the paired observations). Clustering techniques are used in this study to identify suitable climate condition clusters which may influence CSM occurrences [10-12].

Grischow [3] reported of the incidence of CSM in southern Ghana with changing climatic patterns. He investigated the possibility of CSM occurrence in hitherto virgin areas. The main objective of this study is to assess the role the climatic variables, temperature, rainfall and humidity play in CSM infection in Obuasi in the southern sector of Ghana.

## 2. HISTORY OF CSM AND RELATED STUDY

The first ever documentation of Meningococcal disease was in 1805 in Geneva Switzerland and it took eighty-two years (1887) before Neisseria meningitides, the causative agent was discovered. The first major outbreak recorded of the bacterial meningitis was reported in 1913 and was treated with intra theca equine meningococcal antiserum [13].

The impact of the disease has been felt across the entire world according to Whitson. In the past thirty plus years, Asia has witnessed a series of outbreaks across the region. Countries like China, Viet Nam and Saudi Arabia amongst others have experienced severe meningococcal epidemic. In Europe and in America, the only difference has been the severity of the outbreak. The sub-Saharan belt referred to as the African meningitis belt (AMB) because of the repetitive and severity of the outbreaks remains the most potent area likely to record an epidemic. This area covers an estimated 300 million people cutting across countries from Senegal in the west coast to Ethiopia in the east. Among the reasons for the high incidence of CSM across the AMB is due to a prolonged dry season and draught weather conditions. The dry season extends from late November to late June and depending on the arrival of the rainy season and location of a country the severity of an outbreak may differ. Notwithstanding the likelihood of annual outbreaks, epidemics in the AMB normally occur periodically between eight and fifteen years interval. The most recent reported pandemic of CSM was in 1996 which overwhelmed the local healthcentres and even exhausted the international supply of vaccines. Burkina Faso, Nigeria, Chad, Mali, Niger amongst other countries reported over 190,000 cases to the World Health Organisation. This prompted the World Health Organisation (WHO) to set up the International Coordinating Group (ICG) for the AMB in 1997. The group was responsible for the provisions of vaccines to countries in the AMB during epidemics. Whitson as well noted that six countries, Niger, Central African Republic, Chad, Benin, Burkina Faso and Ethiopia experienced epidemics in 2001 but the ICG was on hand to provide vaccines to the affected countries [13].

In an article published in the International Journal of Health Geographics 2008, by [14], the writers used (statistics of the annual reported cases of MCM and climatic variables in analysing and

highlighting the relationships that exist between climate MCM incidences. The study was conducted in two highly afflicted regions, Niger and Burkina Faso, in the AMB area. They established that the persistence of the disease is most likely controlled partly by the onset of the harmattan conditions in the winter. They generated a Gaussian time series which they used in establishing the relationships. The research proved that the links between MCM and climate were clearer in Niger, weak though significant in Burkina Faso. The findings of [14] were consistent with a previous study undertaken by [15]. They established a positive correlation between the harmattan conditions and the incidence of MCM in Mali, Niger and Burkina Faso.

Linear models were constructed using relevant climatic variables to forecast the intensity of MCM from year to year in a study conducted by [16,17]. The model showed that a variance of 25% of the disease can be attributed to the winter climate but could not demonstrate accurately the dynamics of the disease in Burkina Faso. Notwithstanding the statistical significance of the study, it also highlights the difficulty in ascribing climatic factors to inter annual variability in the outbreak of meningitis. There were two outstanding reasons why the researchers found it difficult to relate climate to inter annual variability in meningitis outbreak. The first was that the final size of the outbreak does not solely depend on climate giving the indication that other factors come into play. The size of the epidemic would also be aided by the affected population's immunity to the stereotype and other factors like migration and or pilgrimage [16,17]. Though there is still a raging debate on the efficiency of vaccination in the meningitis control projects [18-20] it nonetheless also affects the final size of the outbreak [21]. The second limitation was with the meningitis data itself. Underreporting as well as missing data for particular months could have introduced biases in the data that was used to run the incidence time series. As a result of the above factors affecting the final outcome of the disease incidence, it is therefore possible that the disease incidence data contained trends, strong or low incident occurrences that cannot be related to any climatic effect. This probably is what accounts for the differences in the results amongst the countries under study. The weak correlation found between climate and disease in Burkina Faso does not however confound the hypothesis of the researchers that the dry

northerly winds play an integral part of the reasons for the outbreak of the disease. The weak correlation could however point out that climatic conditions are not a major player in the disease dynamics. On the other hand the results gotten from the Niger model could be an indication that since the unpredictability of the disease incidence from year to year is as a result of many scenarios acting at different geographic hierarchical scales in various demographic, socio-economic and medical conditions, the results of the Niger model suggest that climatic conditions are an important factor in the triggering of the epidemic in Niger and validate the large-scale approach that was used to smoothen local data heterogeneities. This conclusion is drawn bearing in mind that the correlation and the explained variance values obtained were weak. It is most likely that changes in climate come with changes in social behaviour which is key to the determining effect. This point is made more important by the unavailability of a robust physiological mechanism to determine the role climate plays in disease occurrence. The researchers therefore concluded by indicating that the use of statistics for the study only demonstrated statistically significant association but could not demonstrate causation.

In the study of [14] which is corroborated by that of [15] the two groups of researchers agree that (the correlation between climatic conditions and meningococcal meningitis disease incidence are shown early in the meningitis epidemic period and do not persist during the epidemic season. The researchers indicated that it was not clear how atmospheric conditions in October-November-December will have an effect on an outbreak occurring 3-4 months later since the incubation period of the disease is a day to a few weeks). Thomson et al. go on to indicate that on one hand, climate could have a cumulative effect on the vulnerability of the population to the infection and or outbreak of meningitis. Long-term exposure to harmattan conditions like dry and hot air, strong dusty winds can weaken the oro-pharyngeal membranes of the human immune system through successive respiratory infections. They continue by stating that notwithstanding the influence different climate has on disease incidence, October-November-December winter conditions which marks the beginning of the harmattan period, could act with a shorter time-span by enhancing meningococcal potential distribution during the pre-epidemic season through the same mechanism explained

earlier, i.e. damage of the mucosal resistance and/or the restraint of the mucosal immune defense system. Contacts amongst households and surrounding communities increase the risk of getting infected and therefore have an effect on the size of the final total and also increase the rate at which the pathogens of the serogroup are transmitted [22].

The significance of the cases in the last size of the outbreak has been stressed by the World Health Organisation (WHO) which deems early cases in the season as a caution of large epidemic. In an online publication on Environmental changes and meningitis epidemics in Africa, [23] stated that epidemics occur throughout Africa in the dry season and it happens during periods of very low humidity and dusty conditions, and ceases in the rainy season, suggesting that these environmental factors may be responsible for the incidence of the disease. A logistic regression model was employed to identify the relationship between a district that has experienced an epidemic and a district that has never experienced an epidemic. The study concluded that humidity was the most important factor in terms of the spread of epidemics. Areas without a marked distinction between wet and dry seasons were unlikely to have had epidemics than areas with contrasting seasons. The areas without distinction between wet and dry seasons include deserts and the humid parts of coastal and central Africa, much of which are forested, and the areas with contrasting seasons made up of the semiarid savannah and grasslands of the Sahel and east and southern Africa. Surface maps of Africa showed a close link between humidity and land-cover types in these regions. The model also revealed that, having accounted for the effects of humidity, sparsely vegetated and barren regions, areas of woodland mosaic, and shrub land were unlikely than other regions to have ever had an epidemic. The Sahel, which has a prolonged dry season with low humidity, was identified as the area with the greatest risk. Peripheral regions along its southern borders, where the dry season is shorter and less extreme, carry a moderate risk. The peripheral region extends from southern Sudan and Ethiopia to the Great Lakes and Rift Valley regions and parts of southern Africa peripheral to desert areas.

Many researchers have looked at the influence climatic variables have on disease incidence from other angles. A study by [24] on the effects of Climate Change on Health Risks in Nigeria is

an example. Their study stated that, the implications of climate change on human health could be direct and indirect. The direct implication of climate change in Nigeria include cerebra-spinal-meningitis, cardiovascular respiratory disorder of the elderly, skin cancer, high blood pressure, malaria and cholera. The gravity of unmanaged climatic variability is raise in morbidity rate caused by exacerbation of old and new viscera health risks like skin cancer, high blood pressure, heat stroke, influenza, psychosis and possibly neurosis. Dukic et al. [25] also looked at the influence of climatic variables from a different angle which is the domain of weather. They noted that, high temperature coupled with low humidity may favor the conversion of carriage to disease as the meningococcal bacteria in the nose and throat are better able to cross the mucosal membranes into the blood stream. Similarly, respiratory diseases such as influenza and pneumonia might weaken the immune defense and add to the mucosal damage. Although the transmission dynamics are poorly understood, outbreaks often stop with the beginning of the rainy season and may begin anew with the following dry season. Meningococcal meningitis (MCM) epidemics occur worldwide however it remains a major predicament in Africa especially in the "meningitis belt" (Fig. 1.) of sub-Saharan Africa, stretching from Senegal to Ethiopia where the highest incidence is observed [26,27]. This region according to [28] it is characterized by seasonal epidemics during the dry season which normally ceases when the rains set in and also by large epidemics which occurred every 8–12 years, culminating in a huge epidemic in which almost 200,000 cases were reported in 1996 [26,21]. Among the recognized different serotypes of *Neisseria meningitis* remote to Africa like the serogroups A, C, Y and W135, group A remains the main serogroup to blame for the continent's epidemics throughout the past 70 years [28] despite a recent occurrence of serogroup W135. These epidemics have a profound impact on health systems, economic activity and political and social life. To alleviate this pandemic countries concerned have to mobilize their already scarce resources and request for international assistances. The WHO, for its part, supports countries at risk by providing technical expertise, advocacy and fund raising activities. Health services also face major challenges in terms of means of control, vaccine, medicines, injection materials and other logistics [14].

### 3. STUDY AREA

Fig. 1 presents the map of the Obuasi Municipality which is one of the 27 administrative districts of the Ashanti Region and was created as part of the government's effort to further decentralize governance [29]. It was carved out of the erstwhile Adansi West District Assembly on the strength of executive instruments (E. I.) 15 of December, 2003 and Legislative Instrument (L. I) 1795 of 17th March, 2007. The Municipality is located at the southern part of Ashanti Region between latitude 5.35N and 5.65N and longitude 6.35N and 6.90N. It covers a land area of 162.4 sqkm. There are 53 communities in the Municipality which share 30 electoral areas.

It is bounded to the east by Adansi South, to the west by Amansie Central and to the north by Adansi North, to the south by Upper Denkyira District in the Central Region. It has Obuasi as its Administrative Capital where the famous and rich Obuasi Gold Mines, now Anglo Gold Ashanti is. The Municipality has a rather undulating topography and the climate is of the semi-equatorial type with a double rainfall regime. Mean annual rainfall ranges between 125 mm and 175 mm. Mean average annual temperature is 25.5°C and relative humidity is 75% - 80% in the wet season.

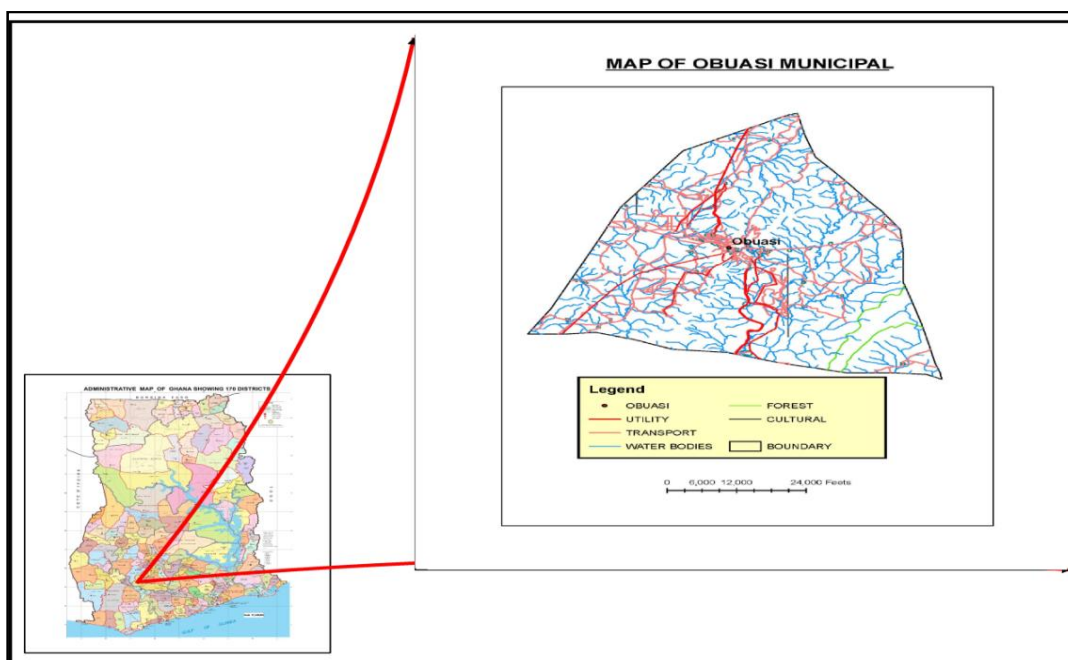
The population of the Municipality is estimated at 205,000 using the 2000 Housing and Population Census as a base and applying a 4% annual growth rate. The vegetation is predominantly a degraded and semi-deciduous forest. The forest consists of limited species of hard wood which are harvested as lumber. The Municipality has nice scenery due to the hilly nature of the environment [29].

### 4. METHODOLOGY

#### 4.1 Data Sources

The data on the twenty-one (21) cases recorded and the six (6) fatal cases was obtained from the Ghana Health Service (GHS).

Climatic data was obtained from the Ghana Meteorological Agency in Accra and AngloGold Ashanti, Obuasi mine. The rainfall and temperature values were taken from 1980 to 2011 while that of relative humidity was drawn from 1987 to 2011 due to the unavailability of data.



**Fig. 1. Map of Obuasi Municipal**

Temperature, relative humidity and rainfall data values were arranged in monthly and yearly values where the monthly values of rainfall were aggregated from daily values for that particular month and the temperature and relative humidity figures were the mean of the daily values for the month. The data was from 1980- 2011.

Monthly Rainfall, Temperature and Relative Humidity data covering 54, 18 and 8 towns with rain gauge, thermometer and barometer stations respectively distributed evenly across the entire country were obtained for use in this research (Table 1). The data set covered the period between 1980- 2011. The stations and their locations of the rainfall, temperature and relative humidity are listed in the tables below.

#### **4.2 Data Handling and Analysis**

The raw data was entered into Microsoft Access 2007 version. The data was then imported ArcGIS suit version 10 which was used for mapping and spatially analyzing the effect of the climatic parameters in the outbreak of CSM in the Obuasi Metropolis and possible areas of outbreak using the case of Obuasi as the bench mark. ArcGIS is a Geographic Information Systems software program developed by Environmental Systems Research Institute, Inc (ESRI).

ArcMap component of ArcGIS 9.3 software was used for the construction of the maps and presentation of the climatic variable stations on the map. Unscramble X10.2: Multivariate statistical software for solving statistical problems including cluster analysis was also employed in the analysis of data.

### **5. RESULTS AND DISCUSSION**

#### **5.1 Results of Correlation Analysis**

The correlation analysis carried out here was to establish correlation between the climatic variables and the disease incidence as recorded in the Obuasi municipality and also the level of significance and if that significance could trigger an outbreak of the disease in the other areas which are in the same cluster as Obuasi. The outcome of the statistical analysis (Table 2.) shows that climatic parameters have influence on the outbreak of CSM. However, the analysis shows that the various climatic parameters of rainfall and temperature have varied degree of impact on the outbreak of cerebrospinal meningitis.

The correlation only established relationship between the climatic variables and the CSM cases. The analysis here indicates clearly that there is correlation between the climatic variables

and the occurrence of the disease. What the correlation does not establish is that, the relationship between the climatic variables and the disease incidence is solely responsible for the disease outbreak as recorded in the Obuasi municipality.

From Table 2 it can be seen that the Pearson's correlation coefficient between rainfall, temperature and relative humidity and the incidence of CSM is at 0.814, 0.775 and 0.730 respectively which are very high considering that the highest correlation level is at 1. However, the level at which this correlation becomes significant is given as 0.186, 0.225, and 0.270 respectively which are far below a statistical significance level of 0.05. These make these correlations rather weak. In a nutshell, though there is a high positive correlation between the climatic variables and CSM, they were however not significant. This led to rejection of the null hypothesis, that, selected climatic variables solely influence the incidence of CSM. Other factors acting in association with the climatic variables may be responsible for the occurrence of CSM so in this respect, it would be concluded that the occurrence of CSM in Obuasi in August 2010 was accidental and did not have anything to do with the prevailing climate at Obuasi. In order to validate this result, clustering was done to investigate other towns with similar climatic conditions as Obuasi.

## 5.2 Clustering Results

Individual clusters were generated for monthly rainfall, mean monthly temperature and mean monthly relative humidity across the country from 1980-2011, 1980-2011 and 1987-2011 respectively.

The results of the clustering for monthly rainfall for fifty four (54) rainfall stations across the country showed that Akrokerri, Barekese, Fumso, Kwadaso, Goaso and Owabi are in the same class with Obuasi. Similarly clustering the mean monthly temperature from eighteen (18) stations showed Accra, Ada and Wenchi in the same class with Obuasi. For the mean relative humidity, Obuasi appear to be in its class alone.

Different clustering approaches performed for climate variables produced results given by the dendrogram and the results summarized in Table 3.

The three algorithms use in the cluster analysis all placed Obuasi alone in its cluster class for

relative humidity. This could probably be due to the limited number of stations available with relative humidity data (eight stations) for long enough periods to be used in the clustering.

In order to determine stations with similar climatic conditions as that of Obuasi based on the three climate variables, the stations within the class 5 of the monthly rainfall cluster were superimposed on the annual temperature map of Ghana to determine those with similar rainfall and temperature conditions as that of Obuasi. It was found that Kwadaso, Fumso, Akrokerri, Barekese and Owabi had similar rainfall and temperature conditions as that of Obuasi. Though Goaso had similar rainfall condition as Obuasi, it was discovered that its temperature was dissimilar to Obuasi.

Fig. 2 presents a temperature cluster map on which is superimposed a rainfall cluster to produce the temperature-rainfall cluster map.

Table 4 shows the stations in the various clusters as seen on the map. The first cluster containing only Brekum indicates that in terms of the combined effect of rainfall and temperature the Brekum station has no similarity with any other station. If this station were to be a closed society and recorded an outbreak of cerebrospinal meningitis, the other stations nearby need not be alarmed if climatic conditions of temperature and rainfall were the only contributory causative and/or propagative factors. It would on the other hand inform health administrators to educate the people of that station to be cautious.

The second cluster containing Goaso, Mampong, Sunyani and Nkwakaw means if there were a reported case in any of these stations, the other stations must instantly take precautionary measures to contain an eminent outbreak provided conditions depend solely on temperature and rainfall.

It is of interest to note that Goaso has similar rainfall characteristics as Obuasi but showed marked dissimilarities when the rainfall map was superimposed on the temperature map. The Obuasi cluster of both temperature and rainfall includes Akrokerri, Barekese, Fumso, Kwadaso and Owabi. These stations had similar rainfall and temperature characteristics as those of Obuasi. This means that should any of those stations record an outbreak, the other stations would also have recorded an outbreak if climate has a causative effect on CSM.

**Table 1. Rain gauge stations and their locations**

<b>Id</b>	<b>Station_names</b>	<b>Latitude_DD</b>	<b>Longitude_DD</b>	<b>Id</b>	<b>Station_Names</b>	<b>Latitude_DD</b>	<b>Longitude_DD</b>
1	Tumu	10.87154	-1.870227	24	Ejura	7.382326	-1.347705
2	Navrongo	10.87154	-0.997064	25	Sunyani	7.3617	-2.303371
3	Bolgatanga	10.771848	-0.773617	26	Kumasi	6.694796	-1.605528
4	Bawku	11.029671	-0.182342	27	Berekum	7.468267	-2.554319
5	Wulugu	10.452146	-0.728928	28	Goaso	6.832302	-2.516505
6	Wa	10.070567	-2.39275	29	Bibiani	6.461036	-2.310246
7	Sawla	9.269595	-2.344623	30	Awaso	6.223838	-2.265557
8	Tamale	9.3796	-0.787368	36	Obuasi	6.196337	-1.663968
9	Yendi	9.427727	0.017041	31	Kade	6.086333	-0.849245
10	Bole	9.04271	-2.399625	32	Koforidua	6.07602	-0.264845
11	Bimbila	8.850202	0.075481	33	Keta	5.893824	0.986458
12	Salaga	8.56144	-0.488292	34	Nsawam	5.794132	-0.357662
13	Bamboi	8.183298	-1.993982	37	Tema	5.646313	-0.000146
14	Kintampo	8.056105	-1.694907	35	Accra	5.553497	-0.19953
15	Yeji	8.210799	-0.649862	38	Oda	5.900699	-1.000502
16	Wenchi	7.753592	-2.073048	39	Swedru	5.525996	-0.715177
17	Techiman	7.592023	-1.883978	40	Cape Coast	5.09629	-1.289264
18	Hohoe	7.134815	0.474248	41	Sekondi	4.938158	-1.760222
19	Kpandu	6.986997	0.28174	42	Axim	4.848779	-2.27587
20	Ho	6.595105	0.477686	43	Tarkwa	5.309424	-2.031797
21	Nkawkaw	6.553853	-0.766742	44	Dunkwa	5.955702	-1.798036
22	Konongo	6.622606	-1.203323	45	Prestea	5.429742	-2.169303
23	Mampong	7.059187	-1.399269				

Source, Ghana Meteorological Services Agency, 2013



**Table 2. Correlation analysis between the climatic variables and CSM**

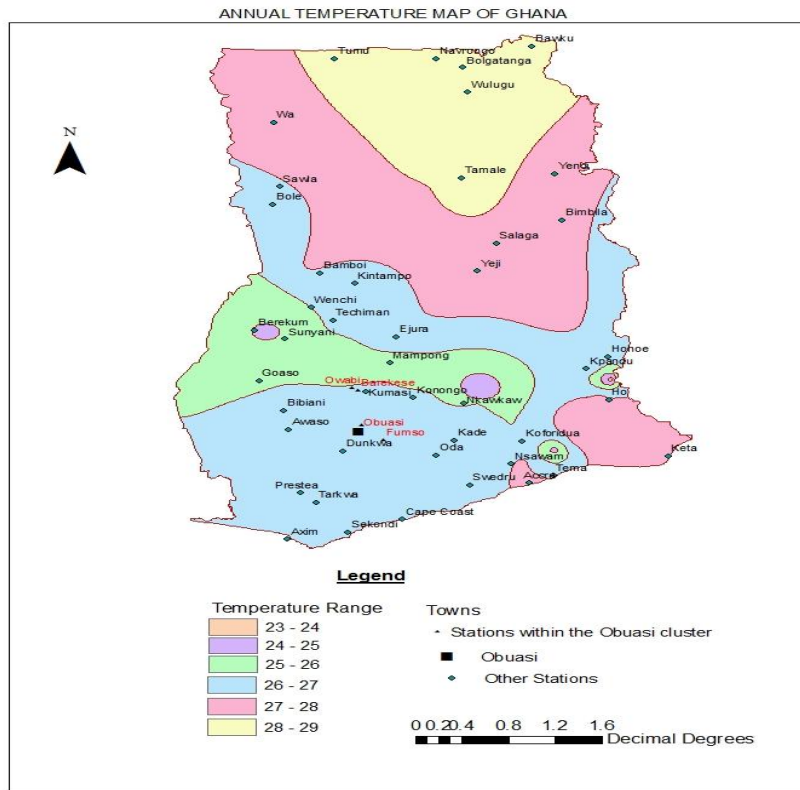
	Csm	Rainfall	Temperature	Humidity	Csm
Csm	1				
Rainfall	0.814	1			
Temperature	0.775	0.871	1		
Humidity	0.730	0.793	0.990***	1	

\*\*\* Significant at 1%

**Table 3. Summarized clustering results showing towns in same cluster as Obuasi**

Clustering method	Climate variable	Cluster towns with Obuasi
Single linkage clustering		Ho, Wenchi, Tema, AkimOda, Ada, Takoradi, Accra, Saltpond
Complete linkage clustering	Temperature	Ho, AkimOda, Ada, Accra Wenchi
Wards method		Accra, Ada, Wenchi
Single linkage clustering		Akrokerri, Barekese, Goaso, Fumso, Owabi ,Kwadaso .
Complete linkage clustering	Rainfall	Akrokerri and Fumso
wards method		Akrokerri, Barekese, Goaso, Fumso, Owabi, Kwadaso.
Single linkage clustering		None
Complete Linkage clustering	Relative humidity	None
Wards method		None

Source: Fieldwork 2012



**Fig. 2. Annual temperature map of Ghana after clustering**

Source: Fieldwork 2013

**Table 4. Results after using temperature to cluster stations**

Cluster group	Name of station
23-24	-
24-25	Brekum
25-26	Goaso, Mampong, Sunyani, Nkwakaw,
26-27	Bole, Bamboi, Sawla, Kintampo, Wenchi, Techiman, Ejura, Kpandu, Hohoe, Cape Coast, Sekondi, Bibiani, Awaso, Dunkwa, Takwa, Axim, Swedru, Prestea, Kumasi, Barekese, Owabi, Obuasi, Fumso, Oda, Kade, Nsawam, Konongo, Koforidua, Tema
27-28	Ho, Keta, Wa, Yeji, Salaga, Bimbila, Yendi, Accra
28-29	Tumu, Navrongo, Wulugu, Bolgatanga, Bawku

Source: Fieldwork 2012

In line with the third objective of this study, an attempt was made to either confirm the results occurrence of the outbreak in these towns. Information made available from the regional disease control office in Kumasi, however, did not contain evidence of a reported case of CSM much more an outbreak. This information therefore goes further to indicate that climate is not the only factor responsible for an outbreak of CSM.

The study went further to validate the findings by checking with the disease control office located in the premises of the Komfo Anokye Teaching Hospital (KATH) polyclinic in Kumasi. The information gathered there indicated that there have been no recorded case(s) of CSM in the other five stations in the same cluster as Obuasi i.e. Akrokerri, Barekese, Fumso, Kwadaso and Owabi. This information disproves the second hypothesis which postulated that areas with similar climatic conditions as those in Obuasi would have also recorded an occurrence of CSM. The cluster analysis brings into perspective areas that are prone to CSM.

## 6. CONCLUSION AND RECOMMENDATIONS

The results show a correlation between the locations that recorded the outbreak of the disease in the Obuasi municipality and the frequency of occurrence in those locations. There is a correlation between the local climatic variables and the incidence of CSM. It therefore means that the incidence of CSM was not necessarily accidental and if the climatic variables in other stations with same characteristics as Obuasi existed in the sub-station level, then, CSM can occur in those stations.

The stations (Obuasi, Akrokerri, Barekese, Fumso, Kwadaso and Owabi) were within the Obuasi cluster when all the three climatic factors were used together for the clustering.

There were no reported cases of CSM occurrence in other towns with the same climatic conditions as Obuasi so climatic variables were not the sole risk factors in CSM outbreak in Obuasi. Climatic factors serve as catalyst for the occurrence of CSM. Without the complex interplay amongst these factors and the virus or bacterial, CSM will not break out as the bacteria causing the bacteria meningitis are commonly found in the nose and throat but are not harmful.

## 7. RECOMMENDATIONS FOR FURTHER STUDIES

As earlier noted in the literature review, the generally held view about CSM occurring during the dry season and ending when the rains set in is thrown in doubt here as the disease incidence was recorded in August which is within the rainy season [13]. As seen from the study, CSM is not caused exclusively by climate but by a multiplicity of factors including climate, therefore it is recommended that other variables can be included in addition to the climatic variables used separately to determine the cause of CSM in Ghana.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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