British Journal of Environment & Climate Change

7(2): 69-82, 2017; Article no.BJECC.2017.006
ISSN: 2231–4784

Assessing the relationship between outbreaks of the African Armyworm and Climatic Factors in the Forest Transition Zone of Ghana

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Authors' contributions

This work was carried out in collaboration between both authors. Author IA designed the study, performed the statistical analysis, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Author MBM managed the analyses of the data and proof read the manuscript. Both authors approved the final manuscript.

Article Information

DOI: 10.9734/BJECC/2017/30588

Original Research Article

Received 19th November 2016
Accepted 6th May 2017
Published 3rd July 2017

ABSTRACT

The African armyworm *Spodoptera exempta* (Walker) is an important migratory pest of cereal crops and grasslands in sub-Saharan Africa. It demonstrates great variability in the extent and severity of infestation of its host crops. The African armyworm is known to cause extensive damage to maize crops and rangeland in the transition zone of Ghana. The work reported here was an investigation of the relationship between the Normalized Difference Vegetation Index (NDVI), rainfall and temperature and how they influence the outbreak of this moth species in the Ejura-Sekyeredumase district of Ghana. The temporal patterns of the variables and their interrelationships were evaluated through graphical, logistic and standardization z-score transformations. A strong similarity between temporal patterns of vegetation index and rainfall was established. On the other hand, the temporal pattern of temperature runs opposite to NDVI and rainfall patterns. Standardized NDVI anomaly revealed periods of low vegetation index with corresponding high wetness denoting damage to vegetation due to the activities of the insects during outbreaks. These revelations confirm reports gathered from local famers. NDVI therefore appears to be a good predictor of armyworm outbreaks. Indeed a relationship was established between the occurrences of the moth species and multi-temporal 10-day NDVI signals. The study confirmed that rainfall and temperature influence the occurrence of armyworms.

Keywords: Armyworm; climatic factors; cereals; outbreak; temporal pattern; relationship; NDVI; rainfall.

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1. INTRODUCTION

Insect population explosions and pest outbreaks are caused by changes in the environment and variable environmental conditions play key roles in triggering all types of outbreaks [1]. Climate change as a result of increase in carbon dioxide and temperature in the atmosphere cause a negative impact on agriculture in various parts of the world [2]. Besides impacts such as drought or flooding, dynamics of agricultural insect pests are affected [3]. The severity and frequency of insect pest outbreaks will therefore depend on the variability in environmental variables such as temperature and precipitation. This is because environmental factors play an important role in the physiological processes and distribution of insects. According to [4], plant pests are extremely dependent on climatic and environmental conditions since several phases of a pest's life cycle is influenced by the combination of two or more environmental variables including rainfall, temperature and humidity. Global climate change, therefore, is likely to affect agro-ecosystems by frequent insect pest occurrence and increased rate of development of these animals [5-7]. Ultimately, human health is also threatened by increased pesticide use due to increased pest pressures and reductions in the efficacy of pesticides [8]. Consequently, agricultural production and food security in many African countries and regions are likely to be severely compromised [4]. Climate change will also cause new patterns of pests and diseases emergence to affect plants, animals and humans [5].

The African armyworm *Spodoptera exempta* (Walker) is a migratory moth, the larvae (caterpillars) of which are important pests, particularly in sub-Saharan Africa, the Western Arabian Peninsula, Pacific Islands, south East Asia and Australia [9]. This moth species also demonstrates great variability in the extent and severity of infestation. It is a "serious outbreak pest of cereal crops and grasslands in eastern and southern Africa, devastating small-scale subsistence farms and commercial production alike" [10]. The larvae occur in large numbers when there is an outbreak hence the name "armyworm". They travel in large masses from one field to another in search of food to complete their development, devouring crops as they move. Significant yield losses have been consistently reported from eastern and southern Africa. Similar reports from West Africa have been recorded only in recent decades [11].

In Ghana, the African armyworm is reported to cause extensive damage to cereal crops and rangeland in the transition zone. The area represents the transition from semi-deciduous forest and the Guinea Savannah accounting for some 28% of Ghana's land area. The main economic activity in the area is crop and animal husbandry. According to Schmitz [12] the transition zone also referred to as the maize belt is highest in terms of maize production in Ghana. Armyworm outbreaks can have catastrophic impacts on farmer's crops, their livelihoods and food security. Armyworm out breaks is usually only periodic across the country. However the frequency of outbreaks in the transition zone is higher and is a major concern. The loss of large cropped areas affects agricultural productivity. Understanding the ecological factors that lead to armyworm outbreaks is a key step towards the development of intervention strategies.

Estimated grain losses during outbreaks in individual locations have averaged 60 per cent but, in many cases there is total crop loss [13]. The main armyworm control tool according to [11] is the application of chemical pesticides. However, due to the negative impacts of chemical pesticides, increased efforts have recently been directed at developing safe and environmentally friendly alternatives such as aqueous neem extract [13]. baculoviruses – nucleopolyhedrovirus (SpexNPV) [14]. Entomopathogenic fungi (Green Muscle) [10]. Recently in Tanzania a monitoring and prediction system based on insect trap catches of moths in relation to rainfall has been adopted with some success [11].

A reliable method of forecasting outbreaks will greatly enhance the application of management strategies [13]. The common approach for analyzing the relationship between population dynamics and climatic variables according to Stenseth et al. [15] is by means of simple correlation or using the climate as an additive covariable in statistical models. This involves techniques such as remote sensing (RS), geographic information system (GIS) and ecological models which have the advantage of mapping the distribution of the insects and offer the most efficient and effective means to inform about their spatial and temporal distribution [16].

The economy of Ghana is agricultural dependent. Agriculture provides over 37.3% of the country's gross domestic product (GDP) [17]. More than 60% of the population is engaged in the agricultural sector. The sector is dominated by smallholder farmers. Over 70 % of the farmers cultivate on holdings less than three hectares [12]. About 80% of the farming population is resource-poor practicing subsistence agriculture. Eighty-nine percent (89%) of the farming population cultivate maize [18]. Maize is both the main staple and is also the primary feed ingredient for the countries booming poultry industry. According to official statistics, the area planted to maize in Ghana currently averages about 650,000 ha per year. Crop destruction by insect pest constitutes one of the most important constraints farmers face in their effort to produce food to feed the ever increasing population. The nation's aim to attain food self-sufficiency by 2020 would be illusive unless strategies are developed to curtail the frequent outbreaks of pests such as the African armyworm. In October 2006 and again in October 2009 nine districts and three farming communities in the Brong Ahafo region were hit by armyworm outbreaks which devastated a total of 3,600 hectares of maize [19]. In such situations, the livelihood of these resource poor farmers and their families as well as the food security status of the country is threatened.

It is therefore important to determine the environmental factors that influence their occurrences. The Food and Agriculture Ministry in Ghana lacks the resources for armyworm surveillance (Dr. J. Vespa Suglo Director PPRSD of MOFA, Pers. Comm.) since no such study has ever been carried out in Ghana. Preventive control of these pests before they become a serious problem is a major management technique. It is thus important to know the trend and scale of infestation. Environmental factors which influence insect behaviour can be monitored to deduce their relationship to outbreaks.

The outcome of this research therefore should fill the information gap and provide an early warning guide to alert the Ministry and farmers about possible outbreaks. The study therefore sought to ascertain whether armyworm occurrence can be related to a multi-temporal 10-daily NDVI signals as derived from SPOT Vegetation. It was also to establish the relationship between the occurrence of past outbreaks and climatic factors for the district.

2. MATERIALS AND METHODS

2.1 Site Selection

The Ejura-Sekyedumase district was chosen for the study because of the dominance of maize cultivation in the country. The district is located within longitudes 1˚5W and 1˚39' W and latitudes 7˚9' N and 7˚36'N. The district lies within the transitional zone of the semi-deciduous forest and Guinea Savannah zones. The vegetation characteristics in the district are to a large extent dictated by the topography, climatic condition and patterns. The northern part is covered with sparse derived deciduous forest vegetation. The climatic conditions of the district together with the topographical layout are favourable for the cultivation of food crops. The Ministry of food and Agriculture records indicates that the district is prone to army worm outbreaks, experiencing four armyworm outbreaks since 1989.

2.2 Data Collection

2.2.1 Presence and distribution data

The field work was carried out between September 16th and October 14th 2009. The district was stratified into outbreak and none outbreak locations. Stratification was based on armyworm outbreak data showing communities and years of attack provided by the Plant Protection and Regulatory Service Directorate (PPRSD) of the Ministry of Food and Agriculture (MoFA). In each stratum, 35 farms each of outbreak and no outbreak communities were randomly selected. Field data consisted of crop calendar information and geographical locations of farms under maize cultivation during past outbreaks. The data was obtained by conducting farmer interviews using a structured questionnaire. The interview sought information on cropping history, experience of armyworm outbreaks and the methods of control employed under the circumstances. With the use of a global positioning system (GPS), precise geographical locations of fields reported to have suffered outbreaks were recorded. Choice of outbreak locations was however based on farmers' response. In all, seventy farmers were interviewed and geolocations of farms with or without experience of outbreaks was recorded.

2.2.2 Precipitation data

Daily rainfall records for the study area over the period 2005-2009 was obtained from the Tropical Rainfall Measuring Mission (TRMM) web data base. It consisted of precipitation time-series (TS) datasets that is daily variation in precipitation on low spatial resolution grids (0.25 x 0.25 degree resolution). The data was extracted in ASCII format for three individual pixels covering the study area and transferred into excel. (http://disc2.nascom.nasa.gov/Giovanni/tovas/). The 10-day accumulated rainfall data was derived by summing the values for day 1 to day 10, 11 to 20 and 21 to 31 for each month. This was done in order to put the daily rainfall data into similar format as the NDVI 10-day product for fair comparison. Additionally, the establishment of a relationship between rainfall and insect behaviour according to [17,20,21] could predict outbreaks.

2.2.3 Temperature data

The temperature data is also in daily recorded format and was downloaded from Atmospheric Data Access for the Geospatial User Community (ADAGUC) surface temperature web portal. http://geoservices.knmi.nl/adaguc_portal/index.html. This dataset provides daily temporal global land surface temperature with a spatial resolution of 0.25 degree. The data was extracted similarly as described above and averaged into 10-day decadal products for consistency. In other words, ten daily temperature values were averaged into one value. The gridded datasets allowed for comparison of temporal variation in climate with the occurrence of outbreaks in the different years [22].

Rainfall and temperature offer immense contribution to the ecological characteristics of *Spodoptera exempta* and therefore exploring their effects is likely to enhance the establishment of relationships to armyworm outbreaks [23,24].

2.2.4 Normalized difference vegetation index (NDVI) vegetation time series data

The NDVI data used consisted of geo-referenced and cloud free SPOT-5 vegetation 10-day composite NDVI images at a resolution of 1 km^2 from April 1998 to October 2010 obtained from http://www.vgt.vito.be and the NDVI data was derived from the red and near-infrared bands as follows: NDVI = (near infrared - red)/(near infrared + red) [25]. NDVI composition involved pixel-by-pixel processing to determine the maximum value during each 10-day period. An iterative Savitzky-Golay filter was applied as in [26]. Further processing including subsetting and made available by Dr. Anton Vrieling, ITC. For the purpose of this study data covering 2005 – 2009 (180 decadal images) for which the African armyworm outbreaks had occurred in the district was used. The NDVI time series were extracted per pixel based on the field data locations. Three 10-day composite available for each month were averaged to account for the mean monthly NDVI particularly for the outbreak month as well as inter annual comparison [27]. The NDVI dataset provided temporal coverage for every ten days and was used to measure temporal variability of vegetation disturbance for the five year period. This was premised on the assumption that areas with healthy vegetation will record high NDVI values, while disturbed vegetation or unhealthy areas show lower values.

2.2.5 Spatial pattern of outbreaks

Using Erdas Imagine Classic 10.0 software, the attributes of the Landsat image was processed to cover the study area by masking the attributes to the district outline. Geographical locations of field data collected were overlaid to show the spatial extent of outbreak coverage of the study area. This was further processed into a false composite (RGB: 452) of the image which reflects the vegetation characteristics of the district after the outbreak. Field locations of presence/absence of armyworm outbreak overlaid on the false composite image could identify armyworm occurrence in the area.

2.2.6 NDVI data analysis procedure to monitor vegetation conditions and its variation with time

Geographical locations of field data collected were overlaid onto the NDVI vegetation time series image. Temporal profiles were then extracted for the pixels covering locations where field data were collected [28]. Using the available NDVI profiles, analysis focused on the 10-day, monthly and annual periods from 2005 to 2009. NDVI profiles were studied visually by exploring the pattern over time. In comparison to crop calendar information, it showed good temporal representation of vegetation disturbance. This was determined by associating low NDVI values in mean stacked NDVI images of 10-day composite. The resultant NDVI graphical output exhibited some variability suggesting a relationship to the damage caused by the African armyworm outbreaks. Using the Predictive Analytics Software (PASW 18) [29] and the Scientific Package for the Social Scientist (SPSS 17), differences emanating were considered statistically significant when $P<0.05$.

2.3 Statistical Analysis

Statistical analyses were performed to confirm the relationships observed using graphical visualization. In view of the binary nature of the dependent variable with or without outbreak experience logistic regression [30] best fit for the analysis for the elucidation of the effect of the predictor environmental variables was employed. A stepwise regression technique, which automatically selects the most statistically significant predictors among the input potential predictors, was used to establish a relationship [31]. The field locations on presence/absence of armyworm outbreak were regressed with the 10-day NDVI for August, September and October 2006 and 2009.

2.3.1 Meteorological data analysis procedure

Rainfall and temperature time series were extracted for each of the three pixels covering the study area. Time series plots of both climatic variables were used to identify whether clearly different climatic conditions occurred during outbreak years as compared to non-outbreak years. The assessments were based on visual interpretation of 10-day, monthly and yearly profiles variation and trends. As the climate data only covered three pixels, regression analyses that investigate spatial relations between climate and outbreak occurrence could not be performed.

2.3.2 Profile analysis and interpretation

To ascertain a clear relationship between NDVI and climatic factors, the generated profiles were also compared by graphical visualization for possible clues to determine a response by the insects. Profile analysis is a useful tool for interpreting the pattern of tests or scores and may be used across groups or scores for an individual variable. In addition, to observe differences in the patterns, relationships were explored between anomalies in the vegetation indices and the climatic information. The NDVI standardized anomalies which is the departure of NDVI from the long-period average, normalized by the long-period variability was employed. It indicates whether the vegetation greenness at a particular location is typical for a particular averaging period of the year. Ten-day anomalies are generated from the 10-day NDVI and climatic datasets. The transformation used in this study was the 10-day Z-score, which involved taking the set of values for a given month for example all Januarys and computing their Z-score value. This is achieved by subtracting the mean and dividing by the long-period standard deviation for that decade of the year, for each grid cell. The reference period is 2005 to 2009. The standardized seasonal anomalies were calculated with the use of z-score transformation equation:

$$z_{tj} = \frac{x_{tj} - \overline{x_j}}{s_j} \tag{1}$$

where $\bar{x}$j and sj denote the long-term means and standard deviations, respectively, for month j, and t is a time index [32]. To test the correlation between precipitation and NDVI, graphical comparison of the temporal sequences of NDVI and rainfall was used as an explorative test of a relationship [33]. To further determine relationships between armyworm outbreaks and variation in climatic factors descriptive statistics and visual comparisons were employed.

3. RESULTS AND DISCUSSION

3.1 Spatial Pattern and Potential Factors to Explain Differences in Outbreaks

The spatial distribution of armyworm outbreaks follow ecological gradient as per Fig. 1. The general pattern of outbreak is evident in the eastern part of the district which is characterized by savannah type vegetation with predominantly grassland and maize cultivation. The western portion on the other hand has more forest cover and records varied cropping patterns with no records of armyworm outbreaks. The difference in vegetation patterns within the district is a possible reason for the differences in outbreak levels. According to Rainey [34] air temperature and certain crops attract insects to outbreak destinations. With no outbreaks occurring in the forest area create natural barrier which disrupt the convergence of the insects.

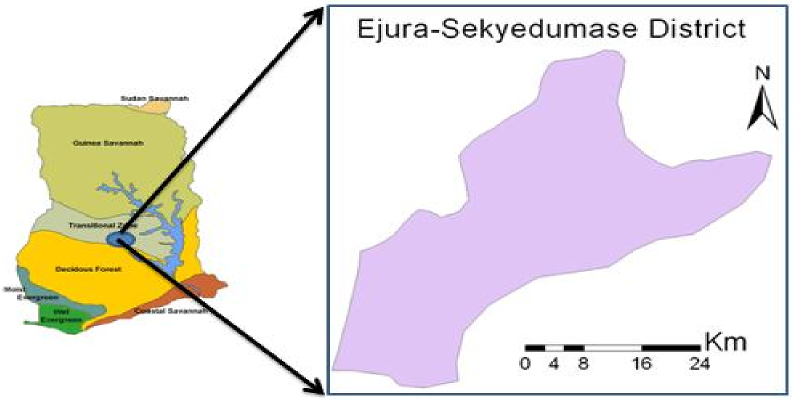

Fig. 1. Ecological zones map of Ghana, showing the study area
Source: https://www.uni-hohenheim.de/respta/pics/agriczones.jpg

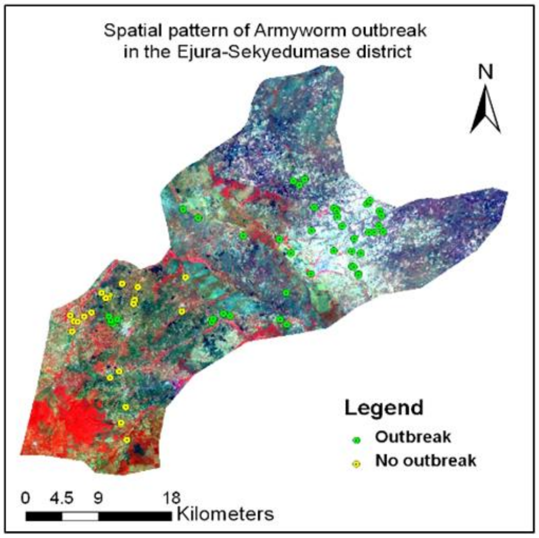

Fig. 2. Spatial distribution of outbreak and no outbreak of armyworm on a false composite image map of the district

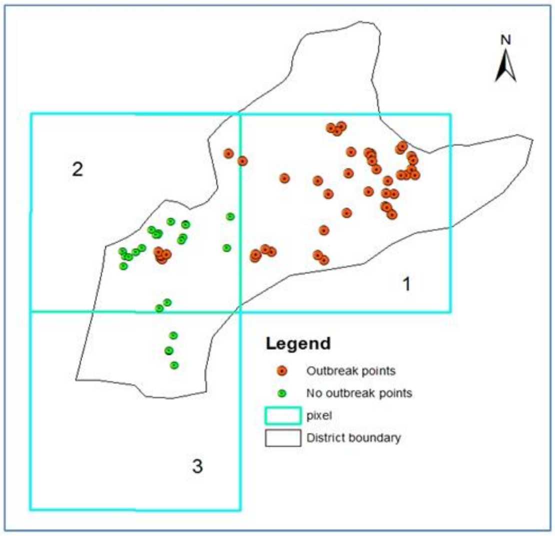

Fig. 3. Grid cell for climatic data extraction

Spatially, more outbreaks occurred in the north-eastern part of the district. There were more locations with no experience of any armyworm outbreaks to the south-western part of the district. The spatial distribution of armyworm outbreak in the Ejura-Sekyedumase district showed that 67 % of the locations are situated in the north-eastern part of the district which is dominated by grasslands and mono-culture maize cultivation. [35] confirm that risk of insect pest outbreak is higher in monocultures and that monocultures may provide favorable conditions for population growth. The south-western part of the district with some forested vegetation and varied cropping pattern recorded mostly no outbreaks. This is probably due to the aggregated vegetation serving as wind break. Wind flow is impeded and affects moth transport to the area. Equally, ecosystems of varied vegetation balance enhance the activities of herbivorous natural enemies [35]. Large populations of insect pests, especially polyphagous species migrate en masse to newly establish vulnerable crop monocultures [36]. The few outbreak locations within the area could probably be as a result of opening the area to extensive maize cultivation since transforming natural habitats into monocultures also leads to reduced biodiversity and increased risk of insect outbreaks [37]. The spatial distribution of armyworm outbreak in the Ejura-Sekyedumase district shows the concentration of outbreak locations in the predominantly savannah area.

3.2 Monitoring Temporal Patterns of Vegetation Condition

Fig. 4 illustrates a comparison of 10-day NDVI and rainfall amounts during the observation period for pixel 1 in the outbreak area. Monitoring vegetation conditions with variation in time was based on the analysis of decadal NDVI imagery. Majority of farmers in the district reported that they experienced armyworm outbreaks in October of 2006 and 2009 and the graphical representation show clear negative NDVI anomalies for October 2006 (arrowed) with a corresponding positive wetness within the period. The high rainfall recorded during the period rules out the possibility of drought and therefore suggests there was vegetation disturbance during that time. It will be too early to say however that the poor vegetation condition was due to damage caused by this moth species. The situation in 2009 is completely different from observation by the farmers. A positive NDVI is shown with a matching negative precipitation. The NDVI for October 2009 even though positive was very low. The low vegetation index gives some signal to vegetation disturbance which is difficult to explain form this study. Nonetheless, in 2006 a period of dryness was observed with high vegetation cover i.e. July-August. This probably could have been a dry period with moderate precipitation likely to create a congenial atmosphere for moth concentration [9, 38,39] to attract the insects to breed. On the contrary no such signal can be observed in 2009 Fig. 4.

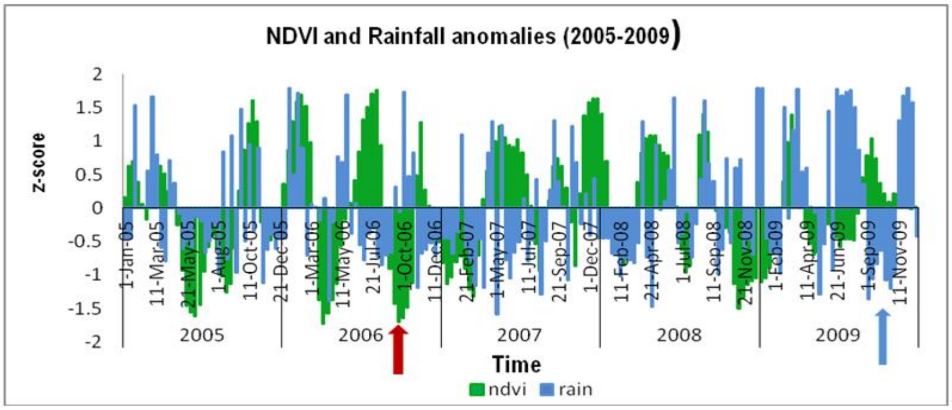

Fig. 4. Time series analysis of standardized NDVI and rainfall anomalies of a selected location for Ejura-Sekyedumase district. Red arrow shows negative NDVI anomaly (Oct, 2006) and blue positive NDVI (Oct, 2009)

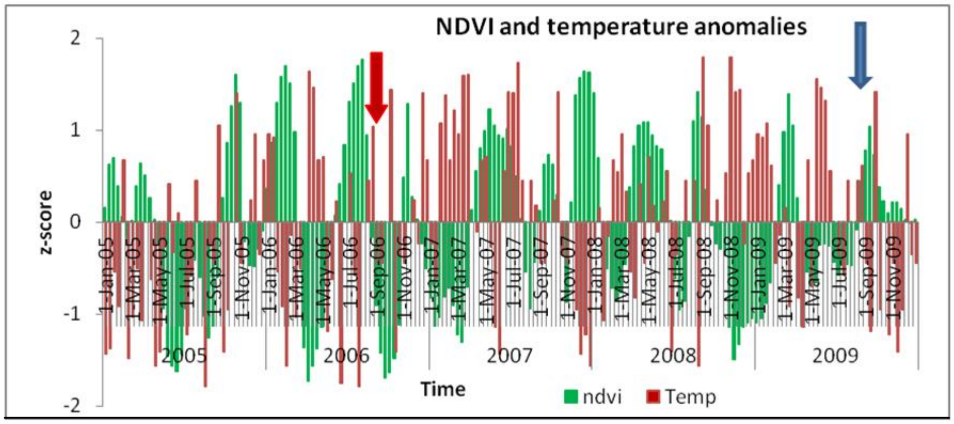

Fig. 5. NDVI and temperature anomalies, Red arrow shows negative NDVI, high temp and blue arrow positive NDVI high temp

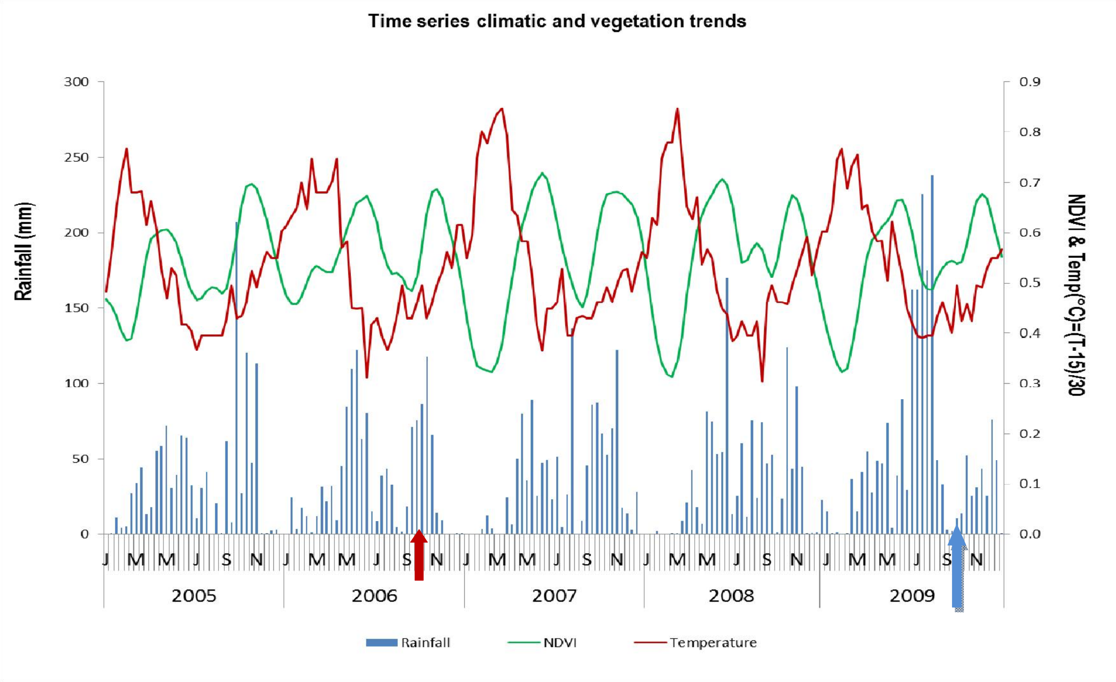

Fig. 6. Annual variation patterns of average vegetation, rainfall and temperature within the period (2005-2009) Red arrow shows October 2006 while the blue arrow points to October 2009

Unlike rainfall, temperature anomaly (Fig. 4) saw a sharp drop in October 2006 during which a negative NDVI anomaly was registered. A similar trend occurred in 2009 for temperature even though a positive NDVI anomaly was observed. It is evident that during the period of high wetness amidst very low NDVI, high temperatures were observed but drop suddenly.

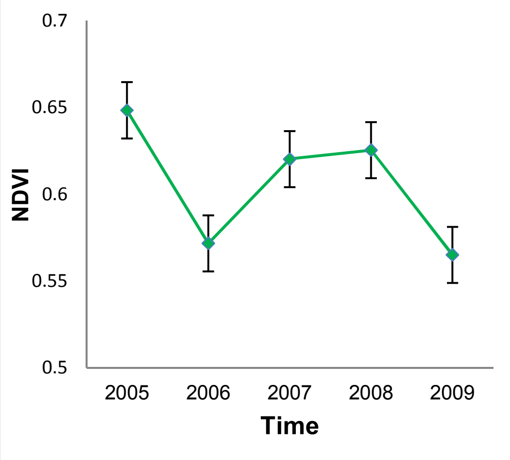

Fig. 7. Average monthly (October) NDVI performance of fields during outbreak with time

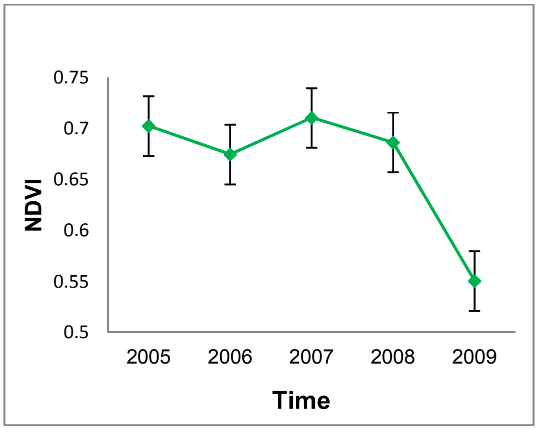

Fig. 8. Average monthly (October) NDVI performance of fields which never experienced outbreak with time

The positive NDVI anomaly in October 2006 was quite low which suggest some vegetation disturbances but difficult to explain at this point. The probability of outbreaks increased with increasing ability to respond to increased temperature [40]. [41] found a consistent relationship between temperature and Larch budmoth (LBM, *Zeiraphera diniana* Gn.) outbreaks. Björkman et al. [40] again hinted that the frequency of favourable years of outbreaks is directly linked to the temperature variations.

Generally, rainfall and NDVI followed a similar pattern whereas temperature on the other hand showed a contrasting one. As can be observed in Fig. 4 temporal variation of NDVI is directly influenced by precipitation. In other words, high NDVI correspond with high precipitation and vice versa. This result corroborates with that of [42, 43] who established that rainfall is positively associated with NDVI.

Temporal analysis of monthly mean NDVI across the period of consideration showed an interesting pattern. A sudden dip in greenness for 2006 picking up gradually in 2007 and 2008 but dipped again in 2009 (Fig. 6). This observation occurred in areas claimed to have suffered outbreaks in 2006 and 2009 by farmers interviewed. The temporal NDVI analysis revealed low vegetation indices in October 2006 and 2009 and the result confirm reports by farmers on the period of outbreaks.The time series mean monthly NDVI plots for a selected outbreak site illustrate that the October 2006 time periods showed the most pronounced anomalous vegetation greenness associated with the minor cropping seasons between 2005 and 2009. Statistically, the dip for 2006 outbreak locations was significant ($p<0.05$) as compared to no outbreak locations. A look at areas where there was no report of outbreak also showed a similar trend (Fig. 7) but the reduction in greenness in 2009 is not significantly different from the outbreak locations in that year. This is difficult to explain because level of wetness at the time was fairly good. Possibly, something might have happened for which its explanation is beyond the scope of this study.

The temporal pattern of rainfall contrasted with temperature as depicted in the Fig. 8. In other words high rainfall amounts corresponded with low temperatures. This trend of affairs however is considered normal as it agrees with results of several other studies including [44]. It is important to note that climatic variability is referred to variations in the mean states of weather in each temporal scale [45]. In 2006, there was rainfall and temperature variability particularly in the month of August in which the amount of rainfall recorded was quite moderate accumulated rainfall of 45mm with fairly low temperatures and moderate NDVI probably suitable for moth aggregation and subsequent breeding. According to [46], concentration of adult moths resulting from climatic factors is judged to be the most likely mechanism for outbreaks. As shown in Fig. 7 such moderate accumulated amounts of precipitation and corresponding NDVI and temperature could be a contributing factor for that year's outbreak. In contrast to 2009 the month of August witnessed heavy precipitation. The pattern of rainfall with regard to the onset of the minor season was varied. The pattern seems different for all years. Temperature has been fairly consistent at the beginning of the minor growing season for the five year period.

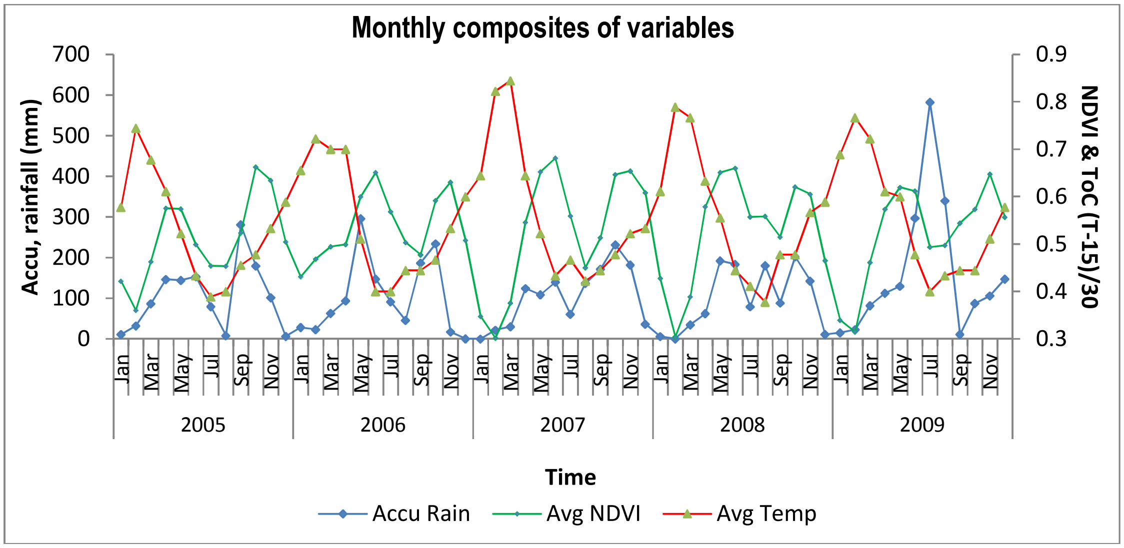

Fig. 9. Time series of monthly composites of NDVI, rainfall and temperature

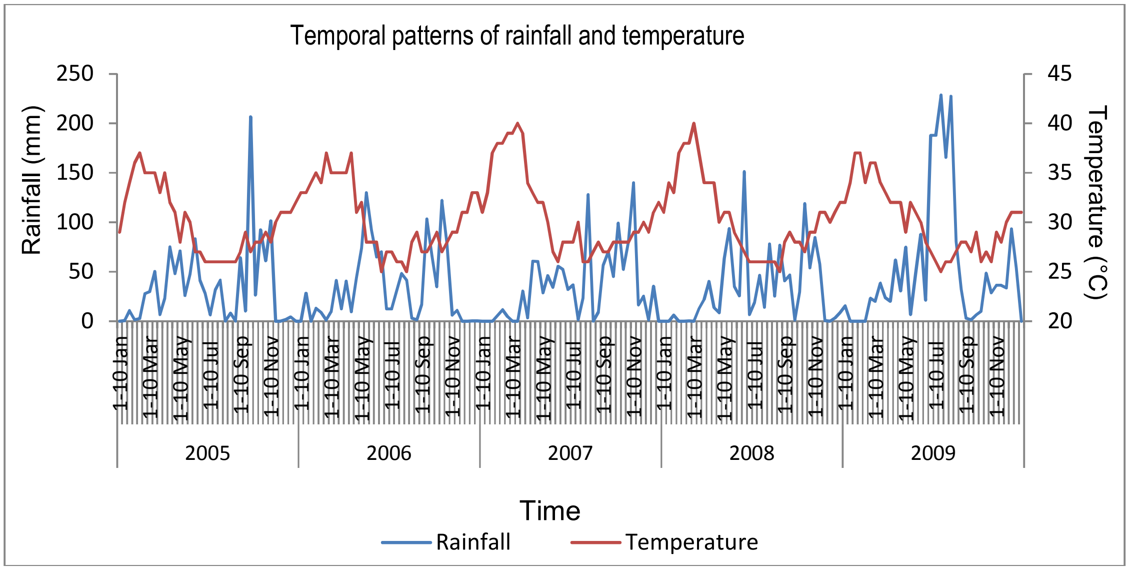

Fig. 10. Temporal patterns of rainfall and temperature

Table 1. Summary output of stepwise logistic regression (Forward LR)

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1[a]	@2131Oct06	-.156	.040	15.557	1	.000	.855	.792	.924
	Constant	32.463	8.250	15.482	1	.000	1.255E14		
Step 2[b]	@2131Oct06	-.288	.094	9.308	1	.002	.750	.623	.902
	@2130Sep09	-.092	.040	5.432	1	.020	.912	.844	.985
	Constant	74.289	24.901	8.900	1	.003	1.833E32		

a. Variable(s) entered on step 1: @2131Oct06.
b. Variable(s) entered on step 2: @2130Sep09.
$P \leq 0.05$

Stepwise logistic regression was calculated and the result is shown in the table above. Out of the 18 temporal 10-day NDVI decades regressed across the minor season for 2006 and 2009, October 06 and September, 09 are significant at $p < 0.05$ and the final model is depicted below:

$$\text{Log }(p/1-p) = 74.289 - 0.288*21\_31Oct06 - 0.092*21\_30Sep09$$

This indicates that the last dekad of the months of October and September in 2006 and 2009 respectively registered some disturbance in the vegetation composition of the district during the period; hence offer the most ideal conditions and therefore vulnerable months for outbreaks. This result could therefore be interpreted as possible outbreaks of the African armyworm as reported by the farmers interviewed.

NDVI values of a whole growing season were constructed into trace profiles of crop growing conditions. These profiles indicate monthly variation of NDVI for the five year period. In this study the interpretation phase was mainly based on a qualitative analysis of NDVI temporal profiles calculated for observation points. For each observation, average NDVI value was calculated for each dekad and plotted on a graph (Fig. 8). Shapes and relative positions of each profile describe the development pattern of vegetation during the period. Also, accumulated monthly rainfall and mean temperature were extracted for same observation points. The temporal pattern of low NDVI for the months of October and September in 2006 and 2009 respectively are an indication of vegetation disturbance. This situation could not be due to drought since rainfall was fairly heavy during the period and therefore thought to be the effect of armyworm outbreak. This finding corroborate with [47] who reported lower NDVI values in remotely sensed data that represented zones of open and/or stressed canopy as a result of activities of the beet armyworm (*Spodoptera exigua*), indication that beet armyworm infestations were associated with lower NDVI values. In another study, exceptionally high rainfall was related with decreased NDVI as a result of flooding [48]. The time series mean monthly NDVI plots as well as the z-score transformation results confirm the graphical visualization of temporal variability in the pattern of NDVI across the five year period investigated. This result is strange in that the z-score transformation analysis albeit depict a low positive NDVI anomaly at the same time, it does not show a likely outbreak in September 2009 For 2006 enough clues gathered point to the fact the highly negative NDVI anomaly and positive anomaly in precipitation was as a result of activity by this moth species.

Although temperature and rainfall are essential to the development of the African armyworm, it is difficult to measure their risk to outbreaks [49]. The rainfall and temperature variability particularly at the onset of the minor growing season for 2006 suggest reasons which could probably have influenced attraction of the moth to the area. This assertion is based on the claim by Shank [49] that changes in the climatic condition at the onset of the rainy season can give cause to outbreaks. Clearly, 2006 offer peculiar conditions for instance temperature was quite low coupled with moderate rainfall. Average temperatures close to 25°C at the beginning of the season enhanced mating, oviposition and hatchability of eggs [50,51]. In contrast however, the pattern and variability of these climatic factors do not seem to follow a trend that suggest clues to associate with the low NDVI values recorded in September 2009. Wen and Zhang [30] found a close relationship between the wide-area temperature, rainfall factors and the beet armyworm outbreak trend. A good spell of hot weather is conducive for armyworm survival [52].

4. CONCLUSION

In conclusion, it is gratifying to note that this study is a preliminary investigation and that some findings will be difficult to relate to previous studies since the study happens to be the initial attempt to unravel the problem in the transitional zone of Ghana. An attempt has been made to find a relationship between NDVI and armyworm outbreak. Variation in climatic patterns has also been suggested to account for the suitable condition required by the adult moth to establish a colony and subsequent reproduction and destruction of crops. This study has been able to establish a link between NDVI and outbreak of the African armyworm. The transition zone covers about a third of the land area of the country and the problem abounds in the entire zone. This study therefore should be antecedent to holistically investigate the problem of armyworm outbreaks in Ghana. it is recommended that further studies be conducted this time with inclusion of climatic factors such as humidity, evapotranspirarion wind speed and wind direction and also cover a substantial portion of the zone if not all. Because of the difficulty to access gridded products of the above mentioned climatic factors, emphasis should be placed on direct field measurements.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of Mr. Eric Tsikata during primary data collection and the Dutch government under the Netherland Fellowship Programme (NFP) for financial support to carry out the study.

COMPETING INTERESTS

Authors make the declaration that no competing interest exist for the work carried out and publication.

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