A SURVEY OF FACTORS AFFECTING SYMPTOMATIC AND CLIMATIC BASED MALARIA PARASITE COUNTS

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Abstract
One of the most important things in life is health. Poor health condition affects one's life span and achievement; one of such common disease is malaria. Dynamics of Malaria parasite transmission is complex and been widely studied. Research is needed to understand the factors responsible for complexity of symptomatic malaria infection changes. Several internal and external factors are responsible for malaria transmission and severity. A survey of descriptive and experimental case study design of sampled health centers was carried out in Minna Metropolis. Also climatic data was collected from Nigerian Environmental and Climate Observation Programme (NECOP) Weather Station, Bosso Campus, Federal University of Technology, Minna, Niger state. Nigeria. The malaria cases data and climatic data served as input variables. The results indicated that symptomatic malaria infection is highly influenced externally by Temperature, Rainfall and Relative humidity. The imposed threats were headache, fever, dizziness, body pain and vomiting. This Climatic data combined with monthly malaria incidences were considered as input variables, trained and simulated using Microsoft Excel and libSVM in MATLAB 2015a. Self-Organizing Map (SOM) network was used to cluster the features. From the study after training with SMO, vomiting is the most prevalence threat followed by fever, dizziness and headache. Also the major climatic factor is the rainfall followed by temperature and relative humidity. The performance of the model was evaluated with classification accuracy(A_{cc}), sensitivity(S_e), specificity(S_p) and mean square error (mse). The results gave 85.60 A_{cc}, 100% S_e, 84.44% S_p, and 0.0776mse.

Keywords: Malaria, Classification, Severity, Prediction, Transmission, Factors, Parasite Count

Introduction
Malaria is a parasitic infectious disease being caused by *Plasmodium Species (Spp)* being transmitted by an *Anopheles mosquito.* World Health Organization Report in 2015 stated that there are 95 countries and territories with ongoing malaria transmission, and only 6 countries have eliminated malaria. An estimated 3.4 billion people are at risk of malaria globally. WHO estimates that 214 million new cases of malaria occurred globally in 2015 (range 149 -303 million) and an estimated death of 438,000, 000. Most death (90%) cases occurred in Africa, and mostly (71%) were in children under 5 years of age (WHO, 2015).

Once, the parasite invade the blood and causes adverse effect on the blood cells. Within 48 to 72 hours the parasites multiply inside the red blood cells and break open, infecting more red blood cells. The first symptoms usually occur between 10-14 days to 4 weeks after infection.

Malaria parasites can also be transmitted from a mother to her unborn baby (congenitally), by blood transfusions and by sharing needles used to inject drugs (MDHIL Network Report, 2014). In some part of the world, malaria parasites have developed resistance to insecticides and antibiotics.

Malaria transmission is site specific due to different climatic change of a region. Temperature, rainfall, relative humidity fluctuations affects the life cycle of malaria parasite (Depinay, Mbogo, Killeen, Knols, Beier, Carlson, Dushoff, Billingsley, Mwambi, Githure ..., 2004). Several non-climatic factors, such as human/behavioural factors can also affect the pattern of malaria transmission and the severity of the problem.

Literature Review

Predicting and diagnosing asymptomatic malaria transmission is not straightforward due to the obvious lack of factors responsible for the infection. And often sub-patient levels of parasites are undetectable by microscopy (Bottius, Guanzirolli, Trape, Rogier, Konate, & Druilhe, 1996). The extent of the prevalence of asymptomatic parasitemia in a given population is inversely related to the population’s susceptibility to clinical disease (Bereczky, Liljander, Rooth, Faraja, Granath, Montgomery, & Färnert, 2007). Therefore, the survey of both external and internal factors responsible for symptomatic and climatic based malaria infection is very vital in detecting its transmission dynamics

External factors

(a) Temperature: The minimum temperature for mosquito development is between 8–10°C; the optimum temperature is 25–27°C, and the maximum temperature is 40°C. The survival probability of mosquito is the proportion of by which each blood meal survive and complete each gonotrophic cycle (Bayoh, & Lindsay, 2003).

(b) Rainfall: Mainly malaria vectors breed in stagnant water collections, rarely in slightly moving waters and never in rapidly flowing streams and rivers. Too much rainfall flushes away breeding habitats temporarily, but mosquitoes start breeding as soon as the rain stops (Yusuf, 2013).

(c) Relative Humidity: Relative humidity is the amount of moisture in the air, expressed as a percentage. Relative humidity affects malaria transmission through its effect on the activity and survival of mosquitoes. The parasites also become more active when humidity rises [7].

(d) Vegetation: Vegetation cover increases after rainfall, which in turn increases the relative humidity of the environment (Yusuf, 2013).

(e) Altitude: Altitude influences the distribution and transmission of malaria indirectly, through its effect on temperature. As altitude increases, temperature decreases, so highlands are colder and lowlands are warmer. In the Ethiopian highlands, with altitudes between 2,000 and 2,400 metres, malaria transmission occurs for short periods only when temperatures rise unusually high (Yusuf, 2013; Tesi, 2011).

(f) Human/behavioural factors: Several non-climatic factors, such as human/behavioural factors can also affect the pattern of malaria transmission and the severity. Travelers from non-endemic areas may choose not to use insect repellant or medicines to prevent malaria. Reasons may include cost, inconvenience, or a lack of knowledge. Poor rural populations in malaria-endemic areas often cannot afford the housing and bed nets that would protect them from exposure to mosquitoes. Human activities can create breeding sites for larvae (standing water in irrigation ditches, burrow pits). Agricultural work such as harvesting (also influenced by climate) may force increased nighttime exposure to mosquito bites. Raising domestic animals near the household may provide alternate sources of blood meals for *Anopheles* mosquitoes and thus decrease human exposure (CDC, 2015). Malaria-endemic countries governments often lack financial resources. As a consequence, health workers in the public sector are often underpaid and overworked. They lack equipment, drugs, training, and supervision.

(g) Environmental changes: Environmental changes such as increased global mobility and increased drug resistance, global warming, civil disturbances, are also considered among the causes of the severity of malaria cases worldwide (Greenwood, 1916).

Internal Factors

Five critical internal factors responsible for Malaria transmission are identified:

(i) Frequency of Human Blood Index (HBI): This is the proportion of blood meals derived from humans by mosquito vectors. It is dependent on the host and the temperature condition. It determines the likelihood of malaria infection and transmission of the infection back to a human (Molineaux, Wernsdorfer, & McGregor, 1988).

(ii) Duration of Sporogony: Time taken from infection to sporozoite development as determined by temperature and parasite genetic (Molineaux, Wernsdorfer, & McGregor, 1988)

(ii) Vector Density: Influential for transmission because human hosts are sporadically infected (Molineaux, Wernsdorfer, & McGregor, 1988).

(iii) Vector susceptibility: Varies with capacity of species and geographical strains of anopheles to transmit different parasites (Molineaux, Wernsdorfer, & McGregor, 1988).

(iv) Demography: Resistance to malaria infection can be acquired with age, therefore the age structure of a population may have consequences for the rate and distribution of malarial transmission (Sallares, 2002).

Clinical symptomatic threat of malaria

All the clinical symptomatic threats associated with malaria are caused by the asexual erythrocytes or blood stage parasites. When the parasite develops in the erythrocyte, numerous known and unknown waste substances such as hemozoin pigment and other toxic factors accumulate in the infected red blood cell. These are dumped into the bloodstream when the infected cells lyse and release invasive merozoites. The hemozoin and other toxic factors such as glucose phosphate isomerase (GPI) stimulate macrophages and other cells to produce cytokines and other soluble factors which act to produce fever and rigors and probably influence other severe pathophysiology associated with malaria. The clinical symptomatic threats of malaria are:

(a) Headache: Headache is a common symptom of malaria, either cerebral type or not. The cytokine is believed to be an important factor leading to headache in acute malaria. In addition, headache is one of the symptoms of post malaria neurologic syndrome. Headache usually lasts for the whole duration of illness (Wiwanitkit, 2009).

***(b) Fever*:** Fever is a high temperature which comes and goes. The patterns of fever vary according to the species of malaria. However, malaria does not have a specific pattern. Initially, malaria feels like the flu with high fever, fatigue, and body aches, with high body temperature and cold stages. Signs and symptoms in children may be non-specific, leading to delays in diagnosis (Cox, Kum, Tavul, Narara, Raiko, Baisor, ... & Day, 1994).

***(c) Dizziness*:** Some patients may present with dizziness or vertigo, with or without fever. Associated with Dizziness may also be vomiting and/or diarrhea (WHO, 1997).

***(d) Body pain*:** is a feeling of general discomfort, uneasiness or pain, of being "out of sorts", often the first indication of an infection or other disease (Cullen, & Arguin, 2013).

***(e) Vomiting*:** Vomiting is the involuntary, forceful expulsion of the contents of one's stomach through the mouth .Vomiting can be caused by a specific response to ailments like gastritis or poisoning or malaria (Glass & White, 2007).

Methodology

This research adopts descriptive and experimental case study design method. The first step undergone was the qualitative research of patients' observations (symptoms) and Laboratory test results documented and get report analysis to identify malaria threats and attacks on human health. Monthly surveys of malarial incidences were collected from sampled health centers in Minna Metropolis, Niger State. Climatic data were collected from Nigerian Environmental and Climate Observation Programme (NECOP) Weather Station, Bosso Campus, Federal University of Technology, Minna, Niger state. Each patient has a set of symptoms and MP count known as Patients' malaria data symptoms and lab test results.

Given a number of features, wrapper method and Support Vector Machine were used to select subset of features that have the greatest predictive power and still carry their class discriminatory properties. This research features is thus restricted to five(5) predominant malarial symptomatic features Headache (H_d), Fever (F_v), Dizziness (D_z), Body Pain (B_p), Vomiting (V_m) and two (3) significant climatic factors that contributes to having malaria; Temperature (T_{emp}), Relative humidity (R_h) and Rainfall (R_f). Self-Organizing Map (SOM) network was used to cluster the features as shown in Figure 3.2 and later trained and simulated using Microsoft Excel and libSVM in MATLAB 2015a.

Results and Discussion

Each patient has a set of symptoms and MP (Malaria Parasite) counts. The dataset consists of 1,200 malaria cases between January, 2012 and December 2015. The dataset has these prevalent features: Headache (Hd), Fever(F), Dizziness(D), Body Pain(Bp) and Vomiting. The climatic factor; temperature, relative humidity and rainfall contributing factors to being having malaria were identified. The features are presented in Table 1.

Table 1: Malaria Model Features Description

Input Variable	Description (Malaria Demographic)	
Age	Adult (1)	
		Children(2)
Gender	Male(1)	
		Female(2)
Headache(H_d)	+ve(1)	
		-ve(0)
Fever(F_v)	+ve(1)	
		-ve(0)
Dizziness(D_z)	+ve(1)	
		-ve(0)
Body Pain(B_p)	+ve(1)	
		-ve(0)
Vomitting(V_m)	+ve(1)	
		-ve(0)
Temperature(T_{emp})	$\{0 \leq T_{emp} \leq 32.83\}$	
Relative Humidity(R_h)	$\{0 \leq R_h \leq 83.74\}$	
Rainfall(R_f)	$\{0 \leq R_f \leq 0.034\}$	
Output Variable	MP Count	- (Class 0)
		+ (Class 1)
		≥++ (Class2)

Findings

Temperature: Fig. 1 shows the Variations of Temperature in the Study Time which shows that mosquito saterted breeding at an optimum (25-27)^{0}C. The sporogonic cycle has a complex relationship with is completely dependent on mosquito survival and temperature. The measurement of sporogonic cycle is degree days, which are calculated by adding the heat from each day, which comes from the temperature. Higher temperatures increase the number of blood meals taken and the number of eggs laid by the mosquitoes, which increases the number of mosquitoes in a given area.

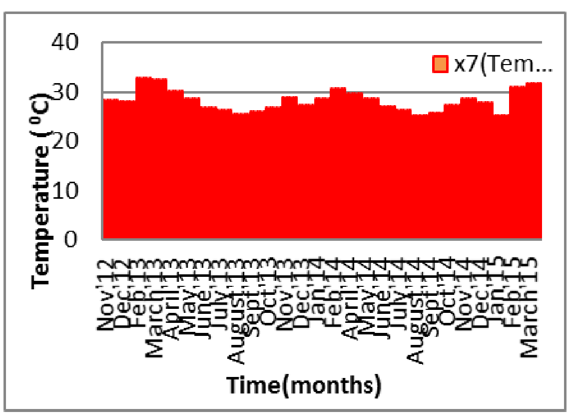

Fig. 1: Variations of Temperature

A certain amount of energy needed to complete the cycle is added up. The required amount of heat must be reached within the mosquito's lifetime, unless the sporogonic cycle will not occur. It's been measured also in degree days and the gonotrophic threshold is the minimum temperature required for mosquito reproduction.

Rainfall

Fig. 2 depicts the Variations of Rainfall in the Study Time. From the study, there is prevalence of mosquitoe between March and April. When temperature subsides by the effects of rainfall between May - August , the breeding decreseses. The breeding also took off November and December. Flushing occurs frequently in highlands and hilly areas than in the lowland plains, so a bigger impact on vector breeding habitats. Not all water collections are suitable for the mosquito life cycle. In dry areas, rainfall affects malaria transmission indirectly through its effect on humidity.

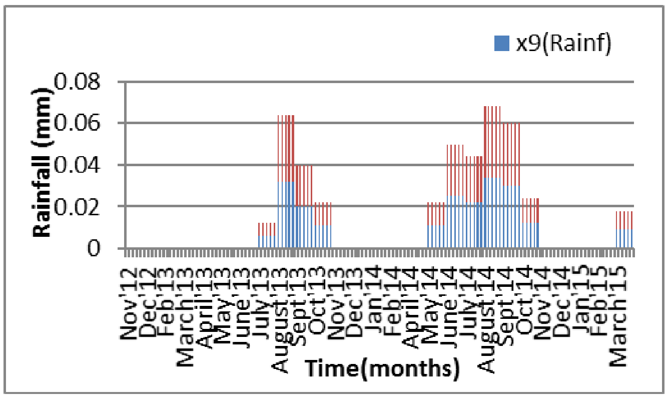

Fig. 2: Variations of Rainfall

(a) Relative Humidity

Relative humidity is the amount of moisture in the air, expressed as a percentage. Relative humidity affects malaria transmission through its effect on the activity and survival of mosquitoes. Fig. 3 shows the Variations of Relative Humidity in the Study Time so there is prevalence of mosquitoe between April - October .Mosquitoes need to live at least 8–10 days to be able to transmit malaria thus mosquitoes survive better under conditions of high humidity. The parasites also become more active when humidity rises (Bayoh, & Lindsay, 2003).

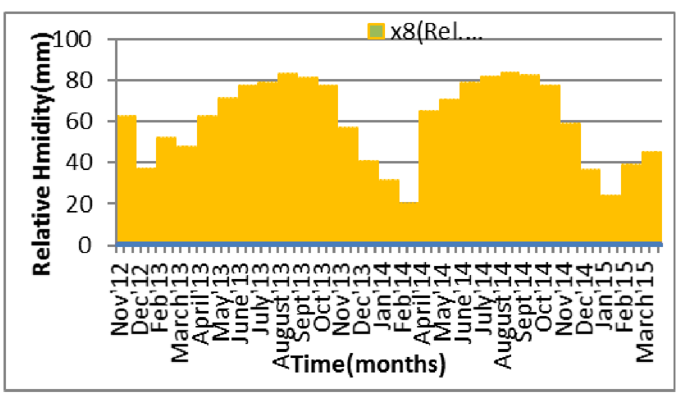

Fig. 3: Variations of Relative Humidity

Weights from different inputs

Before training rands function a symmetric random weight/bias initialization function was used to initialize the weights to random values. Weights are initialize to small random valued to prevent saturation. A network training function 'traingscg' was also used to update weight and bias values according to scaled conjugate gradient method. The network topology used for this study is 8-10-1 structure as shown in Fig. 3.1. While weights from different inputs H_d(Headache), F_v(Fever), D_z (Dizziness), B_p (Body pain), $V_{m.}$ (Vomiting), T_{emp} (Temperature), R_h (Relative humidity) and R_f (Rainfall) are depicted in Fig 3.2.

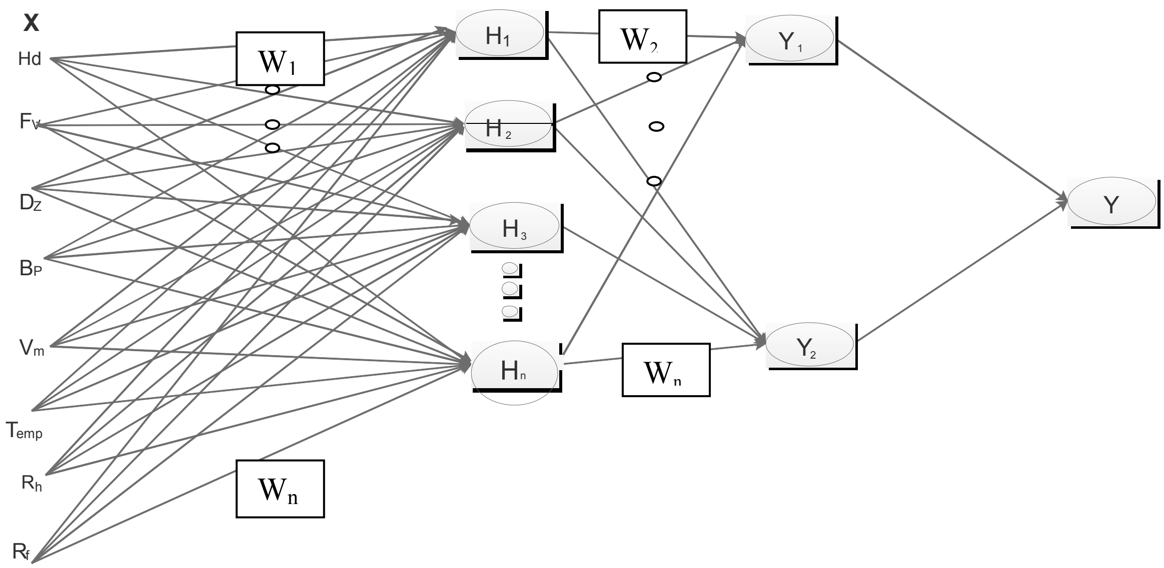

Figure 3.1 : A Schematic Description of ANN Malaria Model

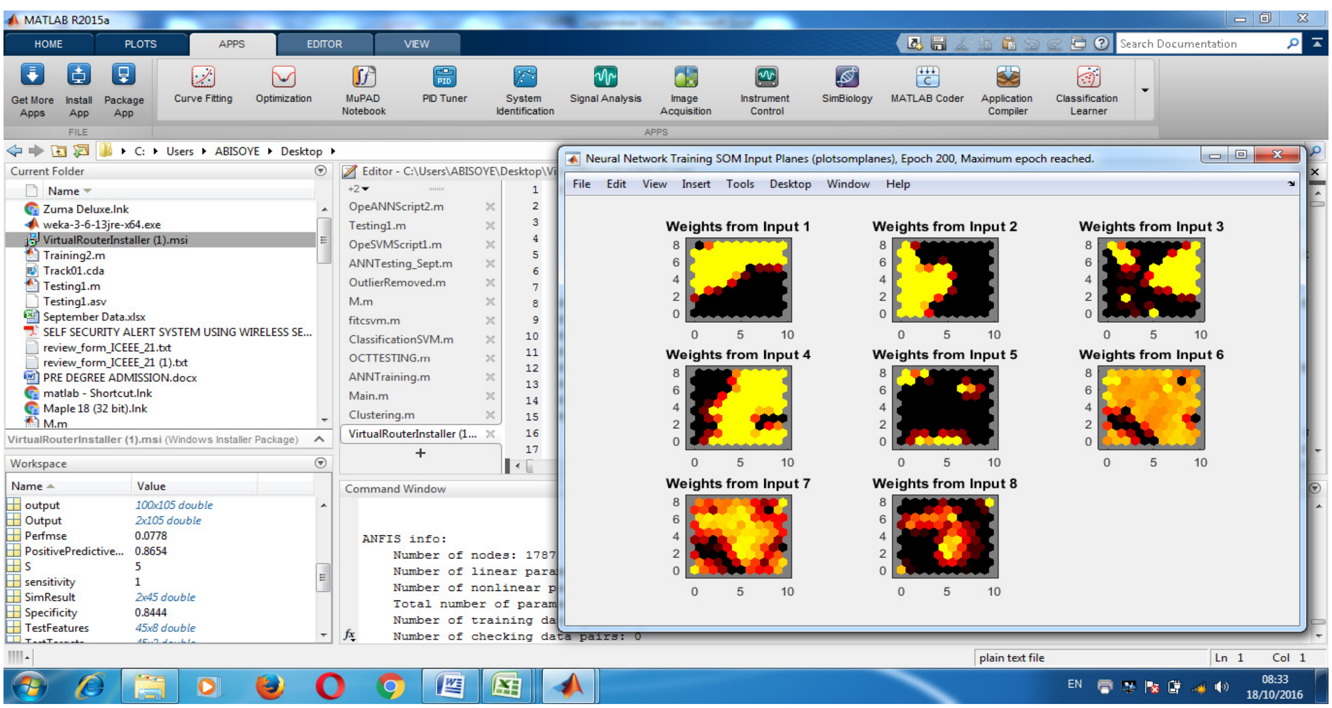

Fig. 3.2: Weights from different inputs

SOM training shows the visualization of the weights that connect each input to each of the neuron. From Fig 3.2 SOM training identified the weight vector associated with each neuron and moves to become the center of cluster of input vector. Darker colours reveals larger weights. Inputs are highly correlated if if connections of two inputs were very similar. It was revealed that the sampled data set at the study time has prevalence of vomiting feature has a great determinant on severity of malaria infection. Rainfall is also the next determinant followed by fever, dizziness and headache. Temperature and relative humidity has lesser effect on the severity of malaria parasite counts.

Conclusion

Malaria has been a major public threat to human health. Existing studies focused on the binary nature of malaria cases and influences of climatic factors were not considered. But Malaria diagnosis may be asymptomatically or symptomatically low, mild and high. So the need to study the effects of the climatic factors on re-occurrence symptomatic malaria parasite count and take appropriate measures so that its devastating impact will be reduced is of great importance especially to the affected immense society. In this paper, we have identified the major external and internal factors that makes an individual susceptible to malaria infection, the threats of the infection and proposed a malaria predicting model. This will help individuals, World Health Organizations and Government Agencies to take appropriate actions.

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