Computational Predictive Framework towards the Control and Reduction of Malaria incidences in Africa

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Abstract

Malaria persists as a problematic disease in Africa. It is the main cause of morbidity and mortality of children and efforts are currently being pooled to increase the control measures within endemic countries. With this in mind, we developed and applied a malaria control strategy from a computational perspective, to analyze, predict and offer appropriate recommendations and control measures of malaria data obtained from WHO ten Sub Saharan countries malaria report of 2008 . The analytical tool used is based on the C# programming language embedded artificial neural network intelligence system. From the outcome obtained, the system demonstrated some level of intelligence and showed the effects and impacts of some controllable factors on future malaria occurrence. The system at 90% prediction intensity showed malaria infection course to decline sharply by 2014 in all the study countries, ranging from 15.71% in Madagascar, 35.46% in Malawi, 38.44% in Nigeria, 38.98% in Sudan , 39.05% in Ethiopia 39.09% in Zambia, 40,08% in Ghana, 42.61% in Kenya, 45.21% in Uganda and 46.63% Mozambique respectively. Therefore, more future prevention, control and management interventions are needed in Madagascar and Mozambique by 2014 as compared to the rest of the countries studied. In conclusion, the tool can be used to produce sensible and logical results which can be applied to achieve reduction of possible future malaria occurrences by governmental, NGOs and other relevant health agencies for proper public health planning.

Keywords: *Malaria incidences, control, prediction, reduction, Africa*

1. Introduction

The most fatal and prevalent form of the malaria infection is caused mainly by a blood-borne pathogen *Plasmodium falciparum*. The negative impact of the infection is huge and the socio-economic is estimated to a loss tune of US$12 billion yearly [1, 2].

The disease is common in several tropical and sub-tropical areas. It is currently endemic in over 100 countries, which are visited by more than 125 million travelers every year [3]. The spread of the disease has increased in Africa due to malaria parasite resistance to common anti-malaria drugs [4-6] and social economic status [7].Children and pregnant women are the most vulnerable endangered by the disease [8].

There are several organizational groups responsible for malaria fight in Africa: Multilateral Initiative on Malaria (MIM), WHO/TDR, African Malaria Network trust (AMANET), President's malaria Initiative (PMI), USAID, National Institute for Health (NIH), African Network on Vector Resistance (ANVR), Malaria Vaccine Initiative (PATH-MVI) just to mention a few. The efforts put forward have help to reduce the spread of the disease worldwide. Several factors responsible for the spread of malaria include, favorable climate change for the mosquitoes, lack of effective vaccines [9, 10], development of malaria parasite resistance to drugs [12, 13, and 14] and major limitations that does not allow the common usage of available chemosensory based parasite control [15]. All these factors have created an urgent need for the development and implementation of additional control strategies.

In this research, however, we focused on some "controllable" factors which could influence the spread of malaria occurrences. Ten African countries were considered in this study. They are Nigeria, Madagascar, Ghana, Kenya, Ethiopia, Zambia, Malawi, Uganda, Mozambique and Sudan. The WHO (World Health Organization data (2001-2007) of malaria occurrences for all ages from the following countries were used for the analysis in this study.

Several works with regards to malaria occurrences in these African countries have been carried out. Some of the countries in view are:

2. Materials and Methods

Nigeria: There had been several cases of malaria incidences in Nigeria. Studies carried out by Obiajunwa and colleagues [16] showed that congenital malaria is highly prevalent in Ile-Ife, Nigeria, with a paucity of its clinical manifestations in newborns. Recently, studies showed the possible risk factors for the occurrences of congenital malaria, using a tertiary healthcare hospital in the south western part of Nigeria as a case study [17]. This therefore, necessitates the need to explore the potency of computational approaches in analyzing such cases of malaria occurrence in Nigeria. This will also help to provide insight to some of the control measures against malaria incidences in the future.

Ghana: Ghana, a West African country, is not without incidences of malaria. In the reports by Fenn and colleagues [18], incidences of malaria occurrence in northern part of Ghana were confirmed mainly through laboratory analysis. Early reports in the southern part by Ahorlu and colleagues [19], also established a research infrastructure in two ecological zones, to study the variables of malaria transmissions and the possible control measures. Other studies were also investigated by Yaw and colleagues [20] when they explored the effects of irrigated urban agriculture on cases of malaria occurrences in Kumasi. It was revealed that more cases of malaria transmissions were common in irrigated urban regions than the non-irrigated regions.

Kenya: Kenya is one of the East African countries affected by malaria. Several studies have been conducted especially in the Suba District of western Kenya to characterize larval habitats of *Anopheline* mosquitoes and to analyze the spatial heterogeneity of the species. The study revealed that *An. gambiae* was relatively abundant within the Suba district. This therefore, accounted for the high cases of malaria incidences in this particular district of Kenya [21].

Ethiopia: The incidence of malaria occurrence in Ethiopia have been attributed and estimated since 1958 not to be less than three million cases. Deaths that have resulted from this incidence may have exceeded 150,000 according to Fontaine et al [22]. Another study by Tarekegn and colleagues [23] described the spatial and temporal variations in malaria epidemic risk in Ethiopia. A weather based prediction of *Plasmodium falciparum* malaria in epidemic-prone regions of Ethiopia, was recently reported by Hailay and colleagues [24].

Zambia: In Zambia, malaria is a serious illness with its adverse effects on children less than 5 years of age [25]. Studies by Chanda and colleagues[26] revealed that the use of folic acid treatment either with sulfadoxine/pyrimethamine (SP) or atovaquone/proguanil (AP); had no effect on the level of parasitemia in children and the occurrences of malaria among Zambian children with anemic malaria.

Malawi: Reported cases of malaria occurrences in Malawi have been detrimental to its populace. A model revealed the effect of malaria endemicity on spatial variations in childhood fever, diarrhoea and pneumonia. The risk of fever however, was positively associated with the high and medium malaria endemicity levels relative to the low endemicity level, while for diarrhoea and pneumonia a marginal positive association was observed [27].

Uganda: Uganda is one of the countries severely affected by malaria. In a prospective cohort study carried out discovered a combination of co-trimoxazole, antiretroviral therapy, and insecticide-treated bed nets substantially reduced the frequency of malaria in adults with HIV [28].

Sudan: Sudan is one of the most endemic malaria regions in Africa. A recent study by Hamad and colleagues [29] showed the effects of Chronic *Plasmodium falciparum* malaria infections in Sudanese villages. In another study carried out in Southern Sudan, the results provided an important missing data on anti-malarial drug efficacy in southern Sudan. It was observed that none of the drugs could be used as mono-therapy [30].

Mozambique: In the Southern region of Africa, malaria has been identified as major problem among the Mozambicans. The various control measures and burden of the malaria in Mozambique has been highlighted by Mabunda [31].

3. Computational strategy as a control and reduction factor for malaria incidences

Programming is one of the fields of computing. It thus acts as a computational strategy that finds expression and relevance in healthcare research. From the computer science perspective, it involves the design, scheduling, or planning accorded to a computer program through a sequence of instructions to enable such program accomplish a specific task. With this in view, we developed a malaria incidence predicting system using a computational programming approach. We developed and implemented a simple program to build a prototype predicting system, by using the C# programming language and embedding an artificial intelligence component into the system. The neuro-fuzzy system is a type of an artificial neural network that has been applied in several research works namely: modeling to reduce health effects [39], improvement of trypanocidal metabolites production [40], and color and shape retrieval [41]. Our predicting system, however, reasons and takes logical decisions based on the increase or decrease in corresponding controllable factors responsible for the disease. From research findings, computer programming has been applied to other areas of health research namely: the construction of expert systems for the management of pests and diseases [32], information systems in food safety management [33], an expert system for malaria environmental diagnosis [34], an online operational alert system for the early detection of shrimp epidemics [35], a computer-based expert system for malaria environmental diagnosis [36], knowledge-based data mining system for diagnosing malaria related cases [37] and secured information framework for managing malaria related cases [38].

3.1 Implementation

We developed and implemented a simple program to build a prototype predicting system, by using the C# programming language. In the development of the application, some controllable factors were put into consideration that could help offer good control measures of the malaria occurrences. These controllable factors were; improvement and distribution of malaria drugs, the effectiveness and distribution of insecticide treated nets, spray and better drainage systems, advancement in malaria research/training and the development of an effective management. Experiment was performed by feeding the annual data of each country into the predicting system and by regulating some malaria occurrence influencing factors to 30%, 60% and 90% respectively.

The first country on the list was Nigeria. The screen shots of the graphical results were obtained and displayed for Nigeria. Similarly and subsequently, the same experiment was conducted on nine other African countries with the tabular results displayed accordingly.

3.2 The Framework and components of the prototype malaria incidence predicting system.

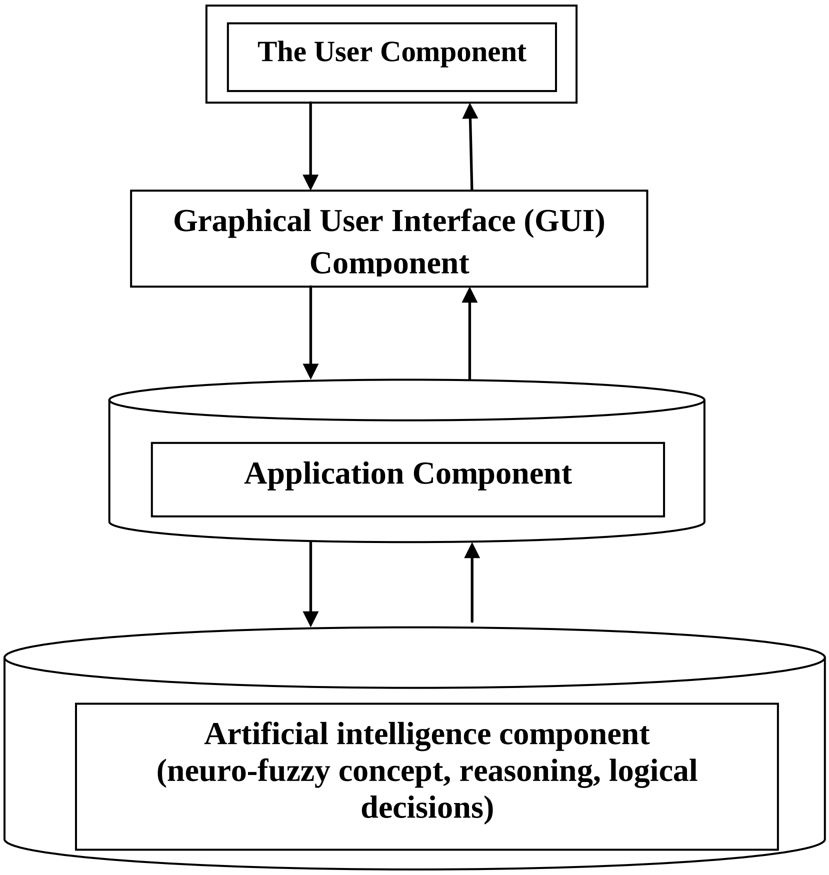

Fig. 1 Framework for the Malaria Incidence Predicting System

The framework of the malaria incidence predicting system is made up of four components, namely;

(i) The User component
(ii) The GUI component
(iii) The Application component
(iv) Artificial intelligence component

4. Data collection and management

The malaria incidence data used for this study was obtained from the World Health Organization (WHO) authorities, which was granted by permission, to make use of the Malaria incidences data from the WHO Malaria World Report of 2008. The data (2001-2007) of the malaria occurrences for all ages from the following countries: Nigeria, Madagascar, Ghana, Kenya, Ethiopia, Zambia, Malawi, Uganda Sudan and Mozambique were used as shown in Table 1.2 The data set for each country was grouped into training sets.

Table 1 Reported malaria cases from different African Countries from WHO Malaria Report 2008

Years/Countries	2001 Malaria Cases, All Ages	2002 Malaria Cases, All Ages	2003 Malaria Cases, All Ages	2004 Malaria Cases, All Ages	2005 Malaria Cases, All Ages	2006 Malaria Cases, All Ages	2007 Malaria Cases, All Ages
1.Nigeria	2253519	2605381	2608479	3310229	3532108	3982372	2969950
2. Madagascar	1356520	1598818	2198035	1458428	1227632	1012639	790510
3. Ghana	3044844	3140893	3552896	3416033	3452569	3511452	3123147
4. Kenya	3262931	3319399	5090639	7545541	9181224	7958704	N/A
5. Ethiopia	2264322	2515191	3143163	5706167	3361717	3759960	1214921
6. Zambia	3838402	3760335	4346172	4078234	4121356	4731338	N/A
7. Malawi	3823796	2784001	3358960	2871098	3688389	4204468	N/A
8. Uganda	9000000	9800000	11000000	12000000	16000000	12792759	N/A
9. Sudan	4223413	3516456	3730993	2559669	2853275	2223987	2778207
10.Mozambique	3947335	4592799	4863406	5610884	5896411	6335757	6327916

Reported of malaria cases from different African Countries from WHO Malaria Report 2008 – Cited by permission and authorization

5. Results of Experiment

The computational results of the occurrences using our C# program varied among the countries studied. The system was able to produce a reliable and sensible data which can be used to estimate the future outcome of malaria infections. The malaria infection course was predicted to decline sharply by 2014 in all the study countries ranging from 15.71% in Madagascar to 45.21% in Uganda from the C# programming language prediction using the 90% intensity of malaria control prediction. Therefore, more future interventions are needed in Madagascar by 2014 than the rest of the countries in the management, control, prevention and spread of the malaria infections.

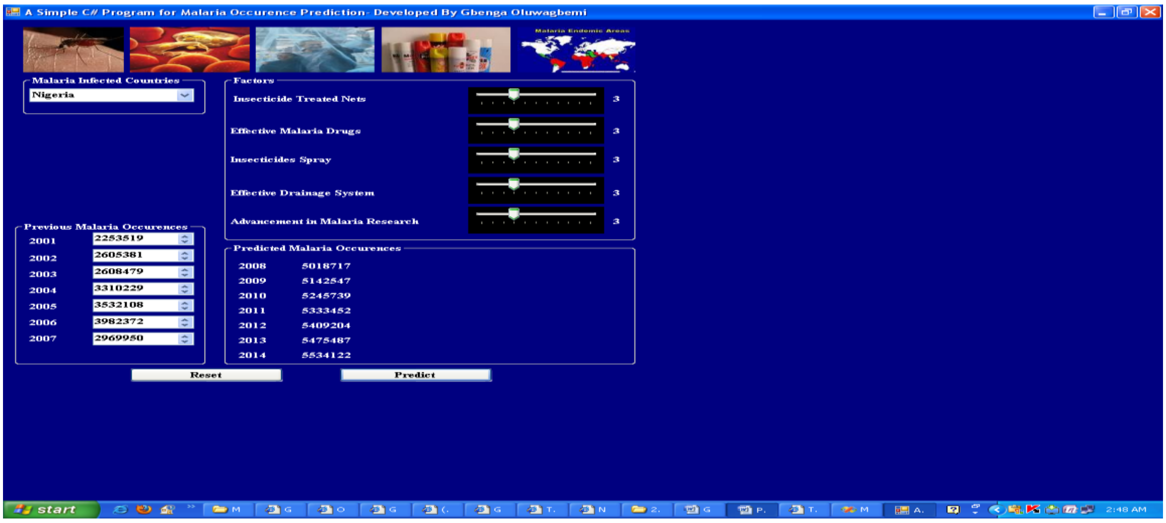

Fig.1a Results generated for Nigeria for 30% prediction from our malaria occurrences predicting system

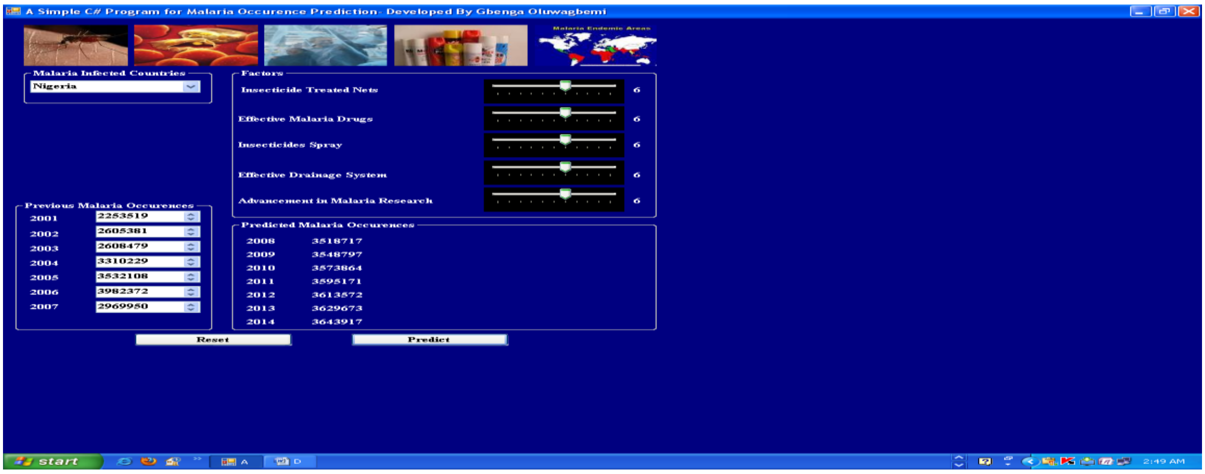

Fig.1b Results generated for Nigeria for 60% prediction from our malaria occurrences predicting system.

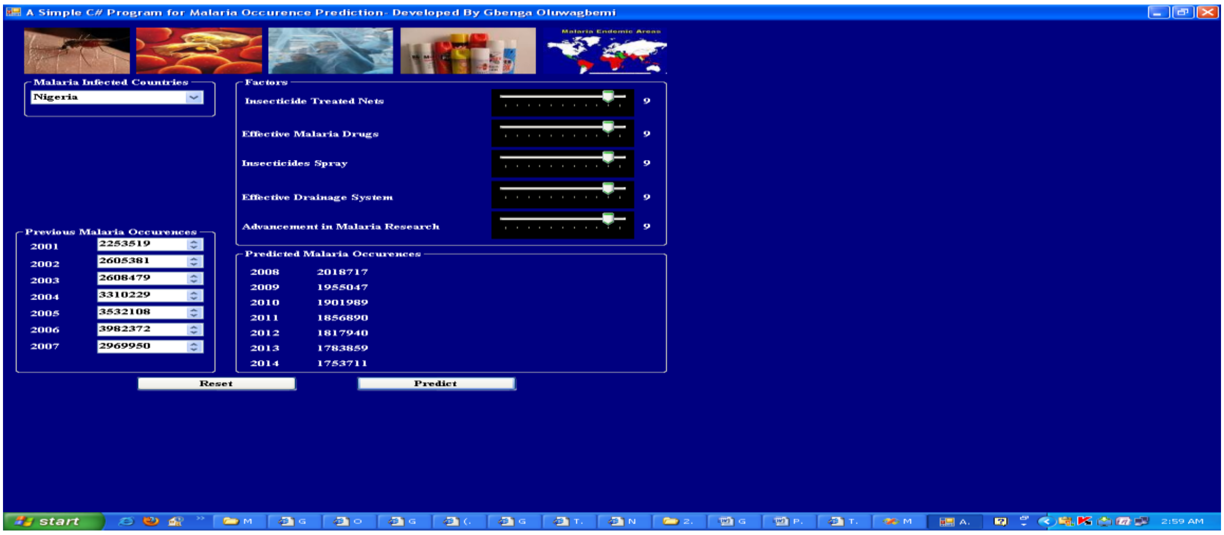

Fig.1c Results generated for Nigeria for 90% prediction from our malaria occurrences predicting system

The results from **Nigeria** with a 90% intensity of malaria control measure prediction showed that about 2018717, 1955047, 1901989, 1856890, 1817940, 1783859, and 1753711 cases of malaria occurrences was predicted for 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 38.44% as shown in Figure 2.

The analysis for **Madagascar** using the 90% intensity of malaria control measure, the result from Madagascar showed that about 1188756, 1176959, 1167128, 1158771, 1151554, and 1145240 cases of malaria occurrences was predicted for the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases to about 15.71% (Figure 3).

The reduction was also observed for **Ghana** using the 90% intensity of malaria control measure: 2160131, 2087623, 2027199, 1975839, 1931483, 1892671 and 1858338 predictions for the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 40.08% (Figure 4).

The same trend was observed for **Kenya** were the 90% intensity of malaria control measurement showed that about 3320113, 3175106, 3054267, 2951554, 2862847, 2785228, and 2716565 was predicted for the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 42.61%. This was depicted in Figure 5.

The reduction at 90% intensity of malaria control measurement for **Ethiopia** was about 2068960, 2002150, 1946475, 1899151, 1858281, 1822519 and 1790884 predictions from 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 39.05 % as shown in Figure 6.

The trend for **Zambia** at 90% intensity of malaria control measurement was 2363626, 2278399, 2207377, 2147008, 2094871, 2049252 and 2008896 predictions from 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 39.09% (Figure 7).

For **Malawi** at 90% intensity of malaria control measurement were 2067545, 2000824, 1945222, 1897961, 1857145, 1821430, and 1789837 predictions for the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 35.46% (Figure 8).

The experimental analysis was carried out, with a 90% intensity of malaria control measure and the predicted result for **Uganda** showed that about 6129120, 5871050, 5655992, 5473192, 5315320, 5177181 and 5054982 was predicted for the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 45.21% as shown in Figure 9.

The trend for **Sudan** at 90% intensity of malaria control measurement read 2063286, 1996830, 1941451, 1894378, 1853725, 1818153 and 1786686 predictions level corresponding to the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 38.98%. This was depicted in Figure 10.

Mozambique had the following experimental analysis at 90% intensity of malaria control measurement: 3183893, 3047400, 2933656, 2836973, 2753474, 2680413, and 2615781 predictions for the years 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. This represents an estimated overall reduction of malaria predicted cases of about 46.63 % (Figure 11).

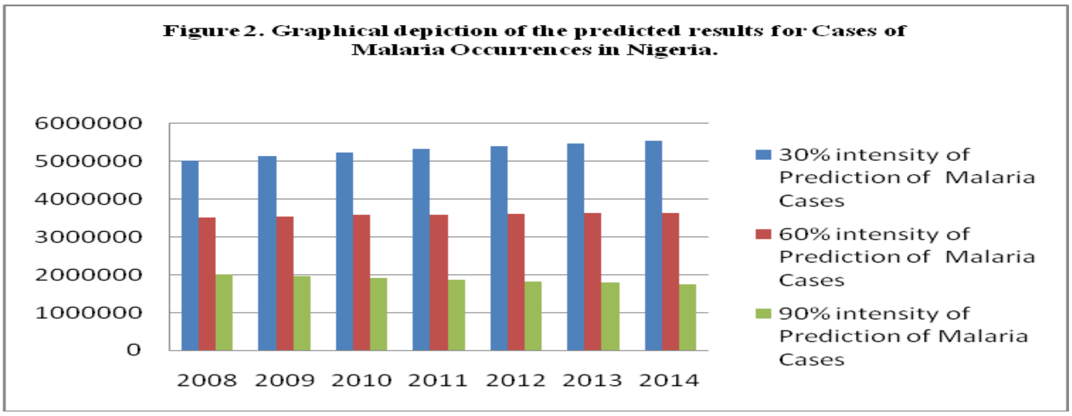

Figure 2. Graphical depiction of the predicted results for Cases of Malaria Occurrences in Nigeria.

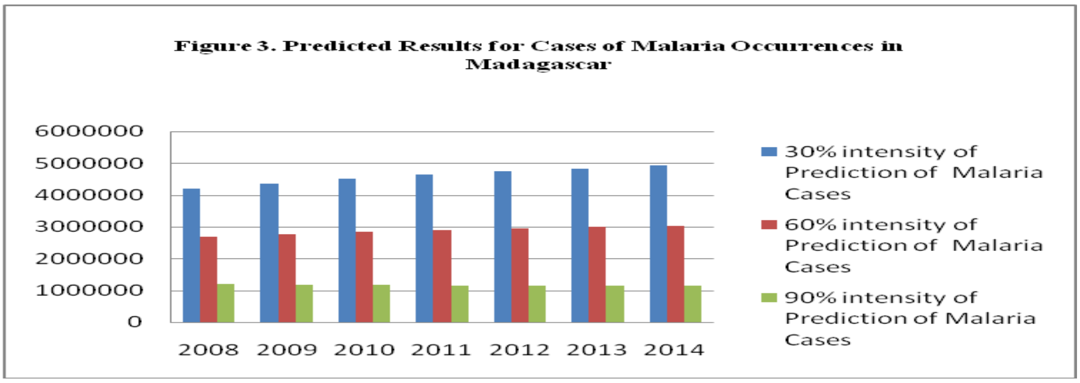

Figure 3. Predicted Results for Cases of Malaria Occurrences in Madagascar

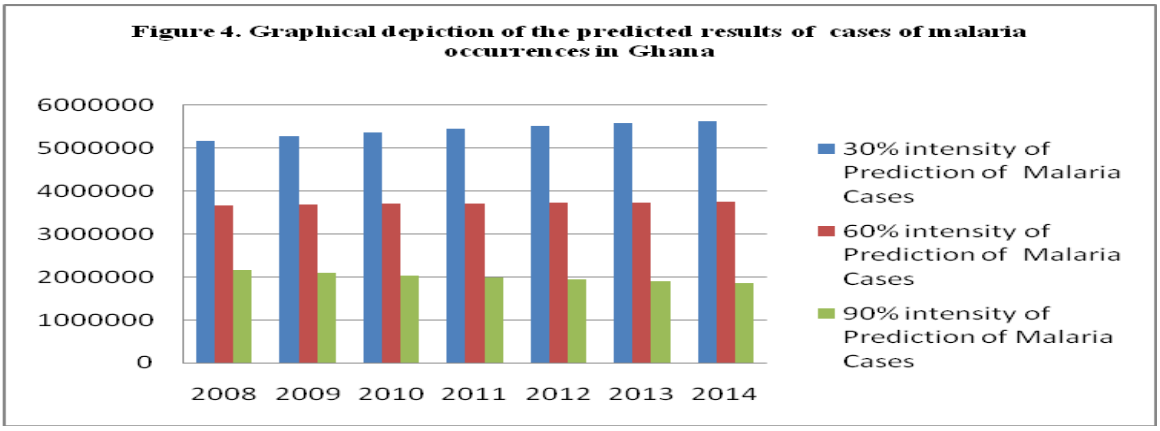

Figure 4. Predicted Results for Cases of Malaria Occurrences in Ghana

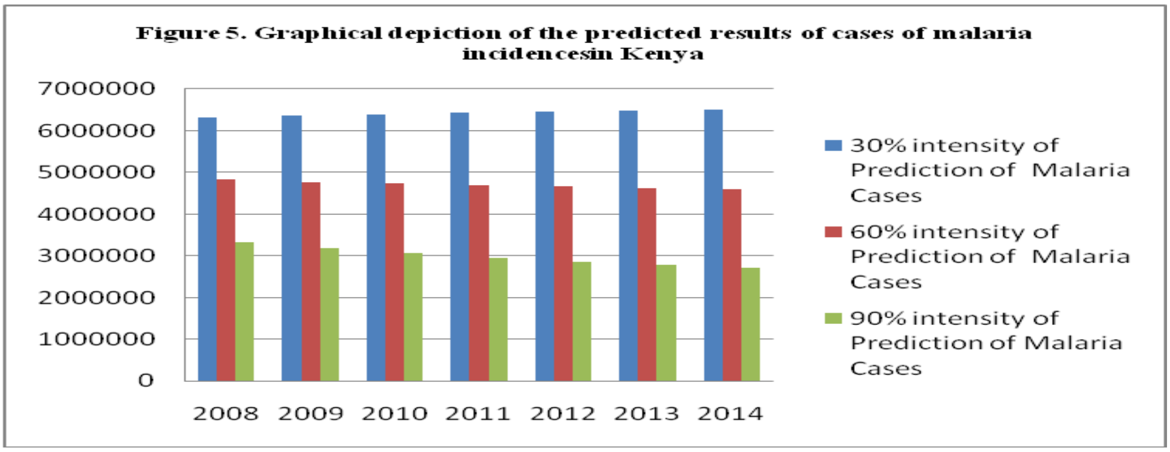

Figure 5. Predicted Results for Cases of Malaria Occurrences in Kenya

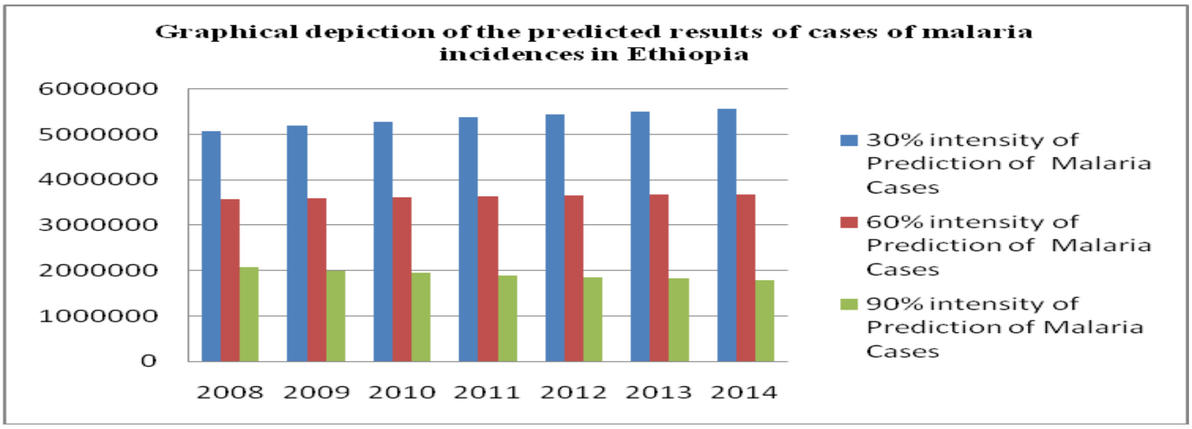

Figure 6. Predicted Results for Cases of Malaria Occurrences in Ethiopia

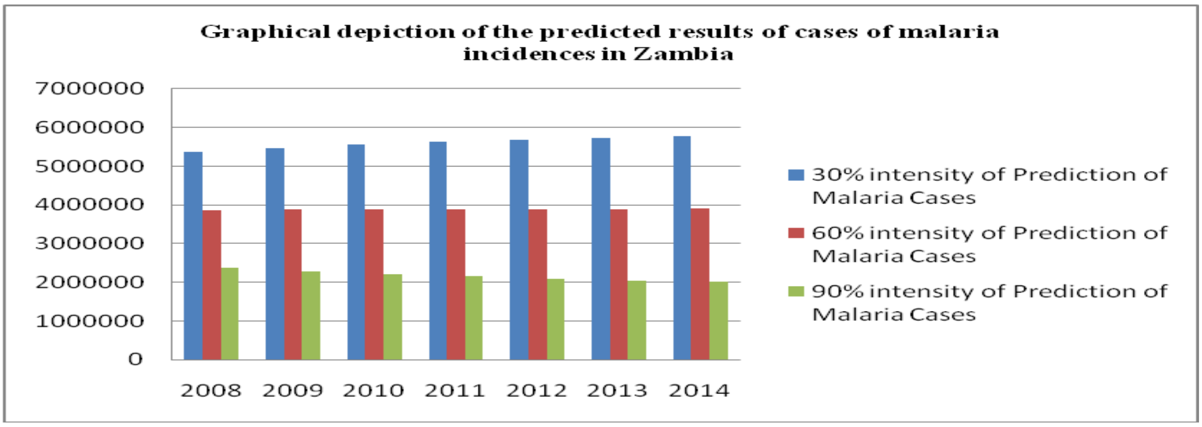

Figure 7. Predicted Results for Cases of Malaria Occurrences in Zambia

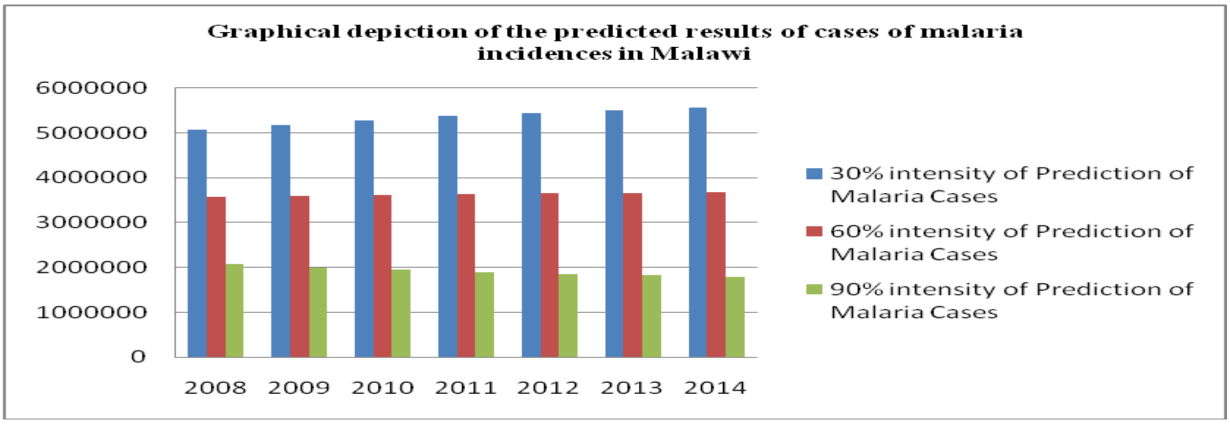

Figure 8. Predicted Results for Cases of Malaria Occurrences in Malawi

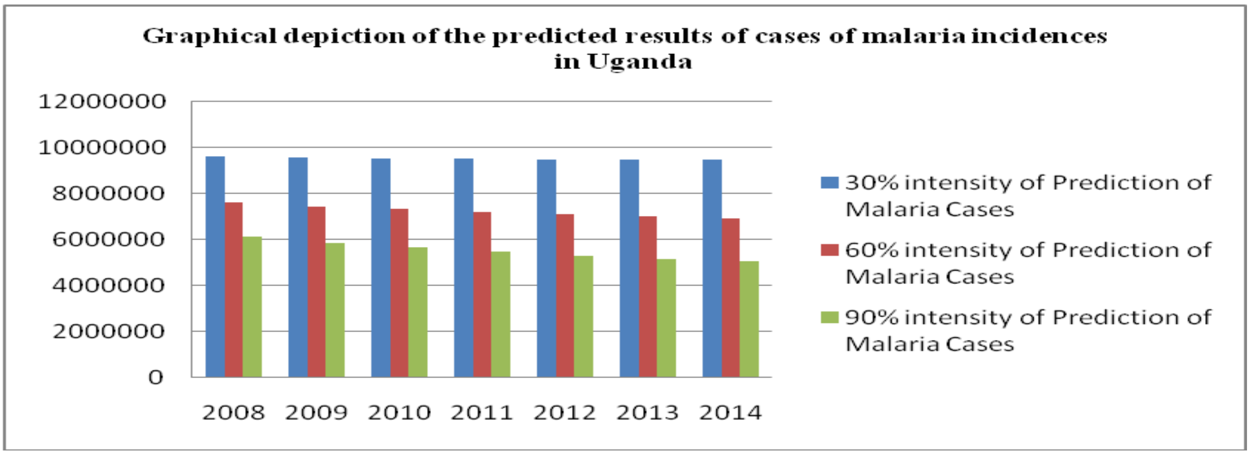

Figure 9. Predicted Results for Cases of Malaria Occurrences in Uganda

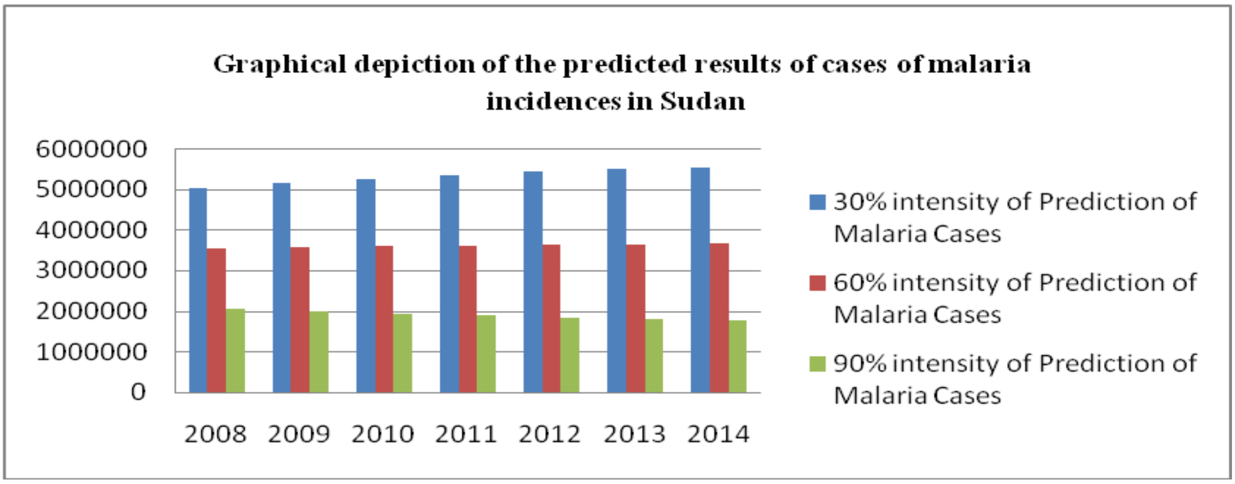

Figure 10. Predicted Results for Cases of Malaria Occurrences in Sudan

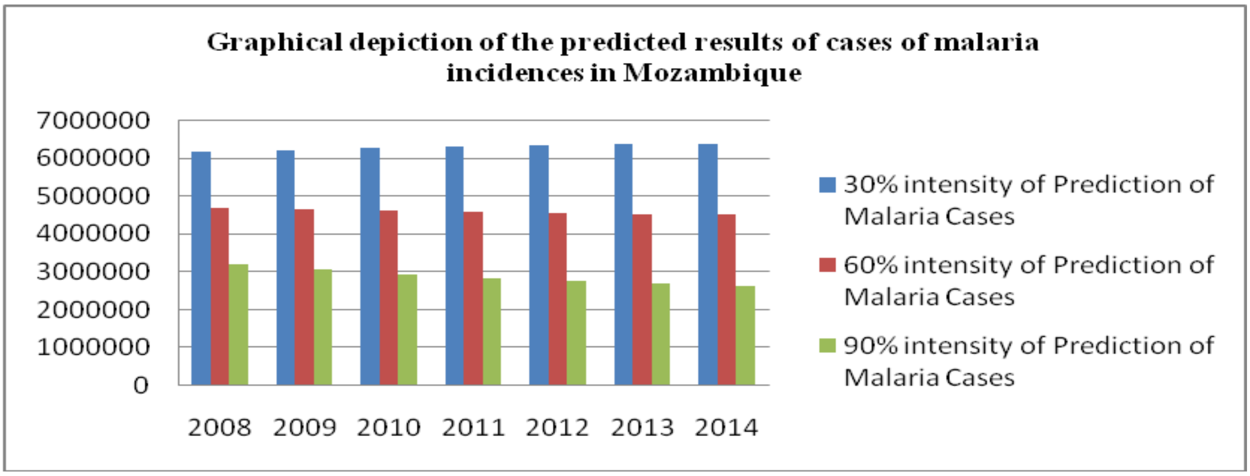

Figure 11. Predicted Results for Cases of Malaria Occurrences in Mozambique

6. Discussion

From Fig.1a, 1b, 1c, and Table 2, it can be observed that the combined factors of different malaria control measures helped to greatly reduce the incidences of malaria occurrence countries studied. This can be observed for countries like Madagascar, Ghana, Kenya, Ethiopia, Zambia, Malawi, Uganda Sudan and Mozambique. Figure 2 to Figure 11 shows the result generated by our predicting system for 30%, 60% and 90% combination respectively. This shows that an effective combined effort of the use of controllable factors such as insecticide treated nets, effective malaria drugs, effective insecticides spray, effective drainage system, advancement in malaria research and the discovery of effective drugs can help drastically to reduce the malaria incidences.

Based on the results, the following recommendations were proposed for each country:

Discussions and Recommendations

Nigeria: The result obtained for Nigeria thus shows that NGOs will help to achieve a drastic reduction in malaria occurrences in Nigeria in the next seven years with a good combination of the use of insecticide treated nets, advancement in scientific research in the development of new malaria drugs and effective drug combination strategy to combat *Plasmodium falciparum* resistance mechanisms, and the construction of better drainage system to discourage breeding sites for mosquitoes.

Madagascar: Based on the result obtained from our predicting system, malaria reduction in Madagascar can be achieved by Government investing more in malaria research by providing funding for Malaria research institutes in that country. NGOs can also help to supply insecticide treated nets in rural areas, especially villages where mosquitoes are common. Government can also help by clearing swamps in such villages.

Ghana: The predicted result obtained from Ghana shows that with the combined effort malaria occurrences in the next seven years will be drastically reduced in Ghana due to advancement in scientific research in the development of new malaria drugs and effective drug combination strategy to combat *Plasmodium falciparum* resistance mechanisms. Also the re-construction of better drainage system to discourage breeding sites of mosquitoes will be of help.

Kenya: The result obtained from Kenya shows that the malaria occurrences can be reduced in the country by the use of more insecticide treated nets in rural areas, the provision of good and clean environment in rural areas. Government agencies should also invest more in advancing research in the development of new malaria drugs that will be more effective in combating malaria.

Ethiopia: Government and Non-Governmental agencies can help reduce cases of malaria incidences in Ethiopia by providing more community hospitals where malaria drugs can be readily available with competent Pharmacists to correctly prescribe drugs to patients instead of relying on self-medication and self-treatment. Furthermore, Government should also provide effective and adequate drainage systems in hot districts of Ethiopia, so as to truncate the developmental phases of mosquitoes in swampy areas. Investment in malaria drug research will be of good help.

Zambia: In Zambia, investment on advance research in the production of effective malaria drugs will yield encouraging results. Secondly, in order to reduce child mortality due to malaria, Government and Non-Governmental organizations should endeavor to invest in the production of more effective insecticide spray, construction of good road networks, introduction and enforcement of environmental sanitation programs.

Malawi: The predicted result for Malawi shows that Governmental and Non-Governmental agencies will help achieve a drastic reduction in malaria occurrences by promoting and supporting scientific research in the development of new malaria drugs. The use of effective insecticides, the effective drug combination therapy against Plasmodium falciparum resistance and the re-construction of better drainage system will help to discourage breeding sites of mosquitoes.

Sudan: The predicted result obtained for Sudan shows that Governmental and Non-Governmental agencies will help achieve a reduction in malaria incidences by investing in quality research in malaria drug combination to effectively tackle malaria in the region. Furthermore, funding should be provided for research in the development of insecticides that can truncate the malaria parasites development within mosquitoes. Environmental sanitation will help to reduce the multiplicity of mosquitoes thus reducing the spread of malaria.

Mozambique: The predicting system showed malaria reduction in Mozambique can be achieved by Government investing more in malaria research by providing funding for Malaria research institutes in that country. NGOs can also help supply insecticide treated nets to rural areas, especially villages where mosquitoes are many. Government can also help by clearing swamps in such villages and establishing a weekly environmental sanitation program. Research into the development of insecticides that can truncate malaria parasites should also be funded by Government agencies in Mozambique.

7. Conclusion

In conclusion, we agree to the fact that the application of computational approaches to malaria research is a good development which can help offer probable solutions to the control of malaria.

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