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Socio-Economic Determinants of the Incidence of Malaria and Correlation Between Meteorological Factors and the Occurrence of Malaria: The Case of Arsi Nagelle District, Oromia Regional State, Ethiopia

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Abstract
Climate change and variability can lead to an expansion of the areas suitable for malaria transmission, and thus increase risk of the disease. The purpose of the current study was to assess the impacts of climate variability on the incidence of malaria in Arsi Nagelle district, Oromia Regional state, Ethiopia. The study was conducted in three rural kebeles, (Haadha-Boso, Kersa-Ilala and Meraro-Hawulo) which were purposively selected as representatives of lowland, midland and highland agro-ecological zones of the district respectively. Quantitative data were collected through household questionnaire survey, while qualitative data were collected through key informant interviews and focus group discussion. Secondary data such as rainfall and temperature were collected from the National Meteorological Agency of Ethiopia; also data on the incidence of malaria cases were collected from the Health Office of the district. For the questionnaire survey, 143 rural households were randomly selected from the three rural Kebeles. The data was analyzed by using descriptive statistics, probit regression model and Pearson's correlation analysis. The result revealed that, an average of 65% of the respondents perceived that there has been an increasing temperature and decreasing rainfall in the district. However, there was significant difference between lowland and highland residents on the perception of the climatic variability. The analysis of the secondary data show that, monthly total rainfall was positively correlated with malaria incidence (i.e. the higher the rainfall amount is the higher the incidence of malaria) while mean monthly maximum and mean monthly minimum temperatures were negatively correlated with malaria incidence (i.e. the higher the maximum and minimum temperature will have the probability of being dryness (lower rainfall amount) hence, the lower the incidence of malaria. Educational status, perception and household income, as well as house quality, and accessibility of mosquito nets are the socio-economic determinants that influence the incidence and transmission of malaria in the study areas. Spraying houses with insecticides and the use of insecticide treated mosquito nets were the predominantly adopted preventive strategies against malaria infection practiced in the study area.
Keywords/Phrases: Climate variability, Socio-economic determinants, Malaria incidence, Correlation, Arsi nagelle Woreda.

Introduction

Background

Malaria is one of the most important public health problems in the world. It has been ranked as one of the top three killers among communicable diseases (Sachs and Malaney, 2002).

The estimated annual mortality attributed to malaria ranges from 700,000-2.7 million worldwide and more than 75% of them are African children and expectant mothers who have less immunity (Kumar *et al*., 2007). This disease is mainly confined to the poorer countries in the tropical and subtropical regions of the world. Sub-Saharan Africa (SSA) and South and Southeast Asia are the most malaria-affected regions. The geographical distribution and incidence of malaria are hugely influenced by the climate and ecology. Changes in climate factors such as temperature, precipitation, humidity and sea level rise affect the reproduction, development, behavior and population dynamics of Mosquito (Gage *et al*., 2008). Temperature plays a fundamental role in the rate of multiplication of the parasite in the mosquito (National Research Council, 2001). Both vector (i.e., female anopheles mosquito) and parasite of this disease are sensitive to changes in temperature, as temperatures rise the malaria parasites develop and multiple more quickly in the mosquito vectors, thereby increasing the proportion of infective vectors (Ambu *et al*., 2003). Higher temperatures increase the number of blood meals taken and the number of times mosquitoes lay eggs (Martens *et al.*, 1995). The minimum temperature for mosquitoes development is between 8-10ºC, the minimum temperature for parasite development is between 14-19ºC. The optimum temperature for mosquito development is 25-27ºC, and the maximum temperature for both vectors and parasites development is 40ºC (McMichael *et al*., 1998).

Increased rainfall leads to increase the number and quality of breeding sites (such as mud-pools, marshes and natural ponds) for malaria vectors e.g., mosquitoes increases in the humidity, which enhances survival and vector capacity and henceforth the transmission of the parasites (Ambu *et al*., 2003; Snow *et al*., 1999). Similarly, in North-East Panjub, one of the states of India, malaria epidemics increased five-folds in the year following an El-Nino event while in Sri Lanka the risk of malaria epidemics increased four-folds during the El-Nino year (Githeko *et al*., 2000). Himeidan *et al*. (2005) also found that malaria transmission depends on seasonal variation and reaches its peak during rainy season (August-October) in eastern Sudan. In fact, global malaria outbreaks have been regularly linked to temperature and/or rainfall variations brought about by El-Nino events (Bouma and Van Der Kaay, 1994; Bouma *et al*., 1994; Kovats *et al*., 2003; Berrang-Ford *et al*., 2009). Sea level rise can also play an important role in malaria transmission. Global warming leads to melt polar ice caps and consequently a rise in sea level which would cause coastal flooding in many areas. Salt-water intrusion into fresh water of coastal areas can extend breeding sites for mosquitoes and enhance transmission of the disease. For example, *Anopheles sundaicus* is a malaria vector which breeds in brackish water in the coastal areas of Peninsular Malaysia (Ambu *et al*., 2003).

Malaria is one of the leading public health problems in Ethiopia. Almost 75% of the landmass of Ethiopia is estimated to be affected by malaria, and about 68% of the population of Ethiopia corresponding to the human population living in areas below 2000 m elevation (approximately 52 million people in 2007) is at risk of malaria (FDRE,MOH.2007/8, Jima *et al.,* 2007 & Deressa, *et al.,* 2003).

Malaria transmission is seasonal in Ethiopia and varies across the country depending on climatic and ecological factors favorable for both the vector and parasite development, including elevation, rainfall, and temperature (FDRE, MOH.2007/8, Deressa *et al.,* 2003 & Graves *et al.,* 2009). The major malaria transmission season occurs primarily during September to December following the main rainy season, which occurs from June to September with peak precipitation in July and August (IBD).

In Arsi Nagelle district, malaria has been expanding its geographic and climatic fronts of occurrences. For instance, its incidence has become high in lowland areas such as Haadha-Boso, where it used to be of moderate occurrence; and it became of moderate occurrence in areas such as Kersa-Ilala, where it used to be of low occurrence. It is also being reported from highland areas such as Meraro-Hawulo, where its incidence was not known.

Thus, there is a pressing need to develop climate-based malaria early warning to enhance public health decision making for control and prevention of malaria epidemics in the study area.

Statement of the problem

Arsi Nagelle is a district that encompasses areas that were known to be suitable for malaria occurrence and also areas that were not known to be malaria prone. Malaria has been increasing besides the changing of the climate in all the three agro-ecological zones of the district. In the study area, the link between variability in climatic factors due to climate change and malaria transmission risk was not studied despite increased occurrence of malaria. Also, there is no climate-based epidemic early warning, prevention and response strategy in the district. This research therefore helped in assessing the impacts of climate variability on the incidence of malaria in the area, so that appropriate copying strategies could be designed and integrated within the health sector.

Significance of the study

The study will play prominent role in examining the influences of climatic variability on malaria distribution in Arsi Nagelle district. Study patterns of correlation between meteorological factors and malaria case occurrence over the last decade. The research will assess socio-economic determinants of malaria incidence in the study area. Generally, the research will contribute to the efforts being made to address the challenges of climate related malaria outbreaks in the district. Therefore, the study could be used as an input for policy makers at local as well as national level and lay foundation for other related studies.

Operational definitions of terms

Climate: Climate is usually defined as the “average weather” or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO, 2007).

Weather: Is a short-term phenomenon, describing atmosphere, daily air temperature, pressure, humidity, wind speed, and participation. (IPCC, 2007).

Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. (UNFCCC, 2007).

Adaptation: The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNFCCC, 2007).

Climate variability: Refers to variations in the mean state of climate on all time and spatial scales more than that of individual weather events (United State Agency for International Development, 2007).

Climate change: “A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use" (IPCC, 2007).

Materials and Methods
Description of the Study Area
Location

Arsi-Negele district is located in West Arsi zone of the Oromia Regional State. The district capital is about 225 km south of the capital Addis Ababa. Geographically, it is situated in the Ethiopian central rift valley system at 7^0 09'-7^0 41' N and 38^0 25'-$38^0$54' E. It is bordered in the South by Shashamene district, in the southwest by Bulbula woreda which separates it from Seraro, on the west from the Southern Nations, Nationalities and Peoples Regional state, on the North by Adami Tullu and Jido Kombolcha districts with which it shares the shores of Lakes Abijatta and Langano. On the East, it is bordered by the Arsi Zone (ORS, 2004). The altitude of the district ranges from 1500-2300 masl. Lakes Langano, Abijata and Shala partly lie in the Arsi Nagelle district. Most of the malaria transmission occurs between September and December, after the main rainy season from June to August (MOP, 2013).

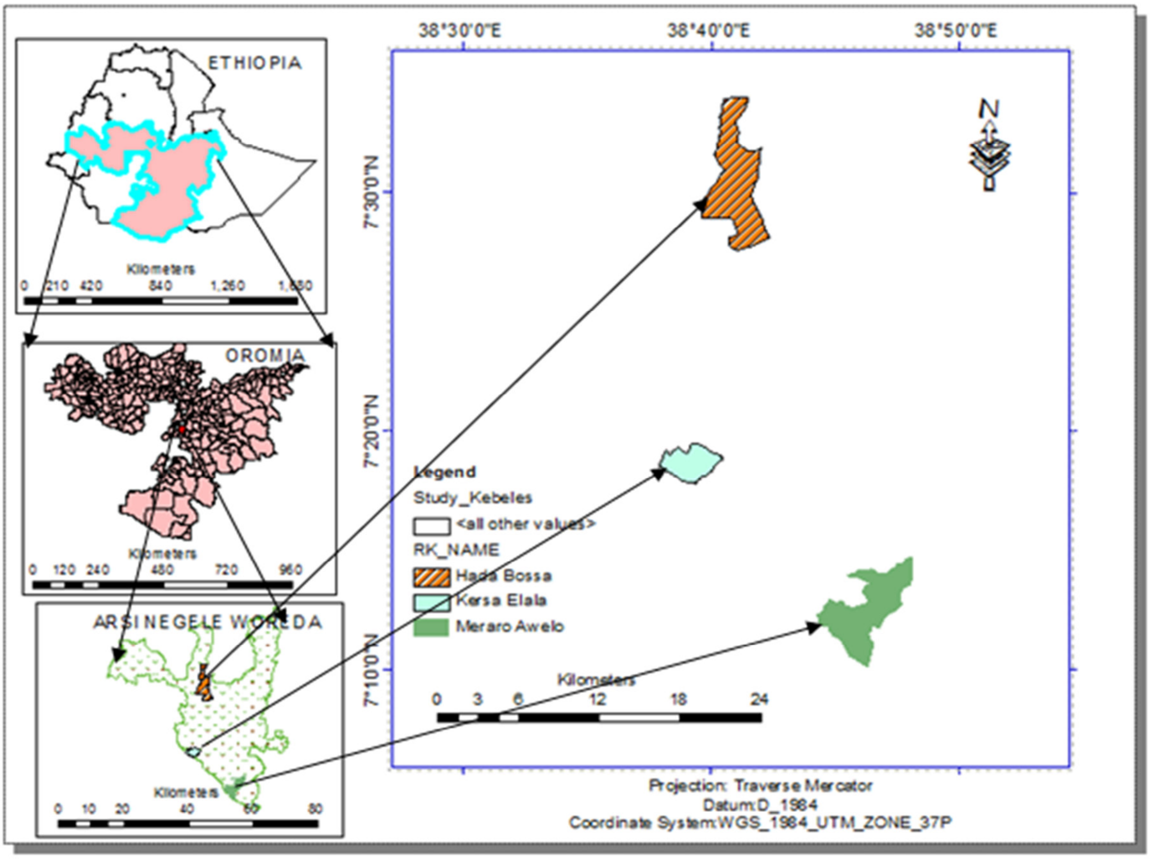

Figure 1 Map of the study area

Climate and Agro-ecology

The study area covers three agro-ecological zones (low, mid and high land) based on temperature, rainfall, altitude and vegetation and that ranges from 1500-2300 masl (ICRA, 2002). The high altitude zone occupies the largest area followed by mid and low altitude climatic zones, respectively. Average annual temperature varies from 10-25 C^o while annual rainfall varies between 500-1000mm (ORS, 2004). About 80% of the district is sub-tropical, while 20% belongs to the temperate agro-climatic zone.

Topography

The topography of the study area is slightly undulating, especially in the highlands and is almost flat in the lowlands. The area has relatively fairly good agricultural potential, which is reflected in the diversity of crops and its animal resources. Some parts of the highlands in the study area are still covered by natural forest, bush lands and shrub lands. Large water bodies from the three inland Lakes: Abijata, Shalla and Langano cover large part of the study area (ORS, 2004).

Population and Farming System

The district has 43 rural and 4 urban peasant associations/kebeles. The total population of the district is estimated to be 260,129 of which 80.2% is rural with an average density of 105.4 persons per km^2 (CSA, 2007). Rain-fed agriculture mainly cereal cropping along with livestock raring are the major sources of food and income for maintaining the livelihoods. The traditional farming system, integrating crop production and animal rearing is common practice in the area. The cattle provide labor service in their farming activities like drought and threshing power. There is interaction between animals and crop production. Animals improve the soil quality through manure and slurry provision, and the crop residue is provided for animals as fodder, thereby increase the productivity per unit area and supports household economy. Grazing is mainly carried out in communal land and under plantations. The major annual crops produced include different varieties of barley (*Hordeum vulgare*), wheat (*Triticum sp.*), millet (*Eleusine coracana*), maize (*Zea mays*), teff (*Eragrostis tef*), sorghum (*Sorghum vulgare*), onion (*Allium cepa*), potato (*Solanum tuberosum*), and perennial crops includes sugarcane (*Saccharum officinarum*), *Coffea arabica* and Enset (*Ensete ventricosum)* (Asferachew, 2004).

Livelihoods

The livelihood of the people in the study area is dominated by mixed farming like most part of Ethiopia**.** Land is an important asset of households for production of crops and rearing of livestock. Livestock serves as a source of manure and fuel, pay land tax, fertilizers and as a saving to buffer bleak seasons of food/seed shortage (Abate, 2009). Oxen are the major ploughing engines. Donkeys, horses and mules play a significant role in transportation of people, water, and goods. Though mixed farming is the dominant livelihood system there are arid and semiarid predominantly pastoralist in some mid and lowlands, and highland pastoralist-perennial crop livelihood systems. Crop production decreases with increasing altitude with the exception of some vegetables and enset (*Ensete ventricosum*), and animal husbandry takes the ranking. The most commonly produced crops in the zone are annual crops such as barley, wheat, teff, maize, haricot beans, horse bean, field peas and linseeds, and perennial crops like potato. The wealth classification criteria for some districts were not clearly set. As in all other rural parts of Ethiopia, livestock ownership and land holding are the two most important criteria for one's wealth and status measure in the society. The household size is also included in wealth ranking criteria; large family households are considered as better-offs. The number of eucalyptus tree and beehives are also considered in the classification. However, the agricultural production is predominantly subsistent and it is difficult to estimate the household yearly income. Nevertheless, it is clear that most of the produced crops and livestock or livestock products are used for household consumption. The remaining used to cover seed and sold to pay credits, taxes, purchase of fertilizer, household financial expenses and others (CSA2, 2008).

Vegetation

The farm lands are endowed with scattered remnant trees from the natural forest which gives the agricultural landscape a parkland Agro-forestry structure. Coniferous forests of podocarpus variety, woodland, and broadleaf forests prevail in the district. At the Rift Valley plain, open *Acacia* woodland dominates, and this gradually turns into dry open deciduous woodland of a transitional vegetation type (Eriksson *et al*., 2003). At mid and high altitude i.e. between 2000-2300 m above sea level tropical dry evergreen montane forest dominates. Different plant communities comprise this section. At the lower sub-humid part a *Podocarpus falcatus - Croton macrostachyus* mixed forest exists, which gradually converts into the humid zone dominated by *Podocarpus falcatus* forest. These vegetation communities are all referred to as 'Montane forests' in many classification systems (Brown and Cocheme, 1969).

The vegetation of the woodland at lowland part can be classified mainly as Acacia-Balanites with some thorny shrub lands occurring around the lakes. The characteristics species of woody plants include various types of trees, shrub, sub-shrub and climbers with different distribution and abundance. Small area of woodland surrounding the head quarter of the National Park (which is protected from human interference) exhibits the initial complex of plant species diversity in the study area (Pichi-Sermolli, 1975).

Besides, there are also plantation species, which are exotic. The main species include *Cupressus lustanica, Pinus patula, Eucalyptus globules (E.globules), E. grandis, and E. viminalis.*

Methods of data collection and analysis

Study site selection

In the first stage, the District was classified into three strata of Lowland (kola) hot, Midland (woyna-dega) medium and Highland (dega) colder agro-ecological zones based on their altitudinal difference. From each agro-ecology one target kebele was purposively selected. These kebeles represent the type of living conditions of people about their socio-economic conditions, perceptions on the impacts of climate variability on malaria distribution and the existences of malaria prevention strategies.

Sampling design and sample size determination

Haadha-Boso, Kersa-Ilala and Meraro-Hawulo kebeles were purposively selected from the three Agro-ecological zones respectively. The number of households in each target kebeles was identified and sample size was determined for the random sampling. Accordingly, Haadha-Bosso kebele consisted of 556 households, Kersa-Ilala kebele consisted of 514 households and Meralo-hawlio kebele consisted of 616 households making a total of 1,686 target households. Among several approaches to determine a sample size this study applied a simplified formula provided by Yamane (Yamane, 1967 cited in: Israel, 1992) to determine the required sample size at 95% confidence level, degree of variability=0.05 and level of precision= 8%

$$n = \frac{N}{1 + N(\mathrm{e})^2}$$

Where'' n'' is the sample size, ''N'' is the population size (total household heads size), and ''e'' is the level of precision.

Accordingly, a total of 143 sample households were studied. Proportionately distributing the sample size to the three kebeles; 47 households from the Hada-Bosso, 44 households from the Kersa-ilala and 52 households from the Meralo-hawlio was sampled. Finally, the respective sample households from each kebele were identified and contacted for the studies of socio-economic and perception on the malaria incidence beside climate variability.

Data Collection Methods

Primary data collection

In order to collect the robust data needed to achieve the objectives of the research, a multi-source data collection method through stratified random sampling (SRS) was employed. The primary data collection involved household survey, 6 key informants interview and 3 focus group discussions.

Household survey-The necessary data required for the study was gathered through administering questionnaire to selected household respondents. The questionnaire was pre- tested on randomly selected household heads before the formal survey is conducted, and modified slightly for clarity. The questionnaire was used to collect qualitative and quantitative data from the household heads having both structured and non-structured forms. The generated data from the survey included the living conditions of people beside malaria incidences, about their socio-economic conditions, disease history and perception of peoples on malaria incidence in relation to climate variability, impacts of climate variability on variation of malaria transmission and age groups which are mostly infected by malaria.

Focus group Discussion: One focus group was organized in each of the selected kebeles, and the discussion was guided by the researcher using a checklist of issues on which in-depth information is needed.

Participants were identified purposively from inhabitants of the each kebele in consultation with the enumerators. The purpose of the focus group discussion was to generate in-depth information on some of the survey findings and other issues that may not have been adequately captured by the structured questionnaire survey. Discussions were facilitated by the researcher assisted by note-takers.

Secondary data collection

For this study, monthly data on the incidence of malaria for the period of ten (10) years (2006-2015) was obtained from Arsi Negelle district health offices which were reported from health centers, clinics and hospitals. The previous 30 years (1985-2015) monthly minimum, maximum and mean temperature and total rainfall of the district was obtained from national meteorology agency of Ethiopia. The impact of climate change on the incidence of malaria was estimated with a focus on the period of five years variations of climatic trends in the study area

Data Analysis

In this study, descriptive statistics was used to explain socio-demographic characteristics of sampled household. These include mean, percentage and frequency of the dependent and independent variables was analyzed. The statistical significance of the variables was tested for both dummy and continuous variables using probit regression model and correlation analysis. Statistical software such as STATA11, Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 20.0 was used to analyse the data from the household socio-economic survey in order to understand the impact of the underlying socio-economic variables determining the perception and traditional knowledge of the local communities on the association between climate variability and malaria incidence.

To observe the correlation between meteorological variables and incidence of malaria, the monthly malaria cases were regarded as the dependent variables, while meteorological variables such as monthly mean maximum, mean minimum and total monthly rainfall were independent variables. Pearson's correlation analysis was conducted to examine the type and strength of relationship between meteorological variables and malaria cases. Then, to assess the effect of each independent variable on the outcome, variable linear regression model was fitted. Since there might be auto-correlation among independent variables over time, autocorrelation analysis was conducted. When the correlation coefficient for the association between these independent variables was larger than 0.5, these variables were analyzed in different regression models to reduce multi- collinearity. The distribution of malaria and meteorological data was examined and all were approximately normally distributed. Finally, the results were summarized and presented as Tables or graphs.

Description of variables

Malaria incidence (MI): malaria incidence in the study area is treated as a dichotomous dependent variable, i.e. it takes the value of 1 if there is an incidence in the area & zero otherwise.

Independent Variables

The independent variables of the study are those which are expected (hypothesized) to have association with the incidence of malaria on the basis of past research studies and prior knowledge of the study area. Thus the relationship between them is hypothesized in this study as follows.

1. Sex of the household head (SEX): This is a dummy variable, which takes a value of 1 if the household head is male & 0 if female. It is hypothesized that males are more exposed to malaria caused by the effects of climate variability, compared to women. This is because men are farmers and usually they keep working for a long time outside, be it on rainy or sunny days. At the time of morning and evening the mosquitoes are so active that the men end up being bitten. By the time they go to bed, they will have already been bitten besides the more other mosquitoes in the house that bites them when they go to bed early. Men also don't care for environmental sanitation compared to women. Therefore, it is expected that there is a positive association between male household and malaria incidence. i.e. the more the male household the more exposed people to malaria in the area.

2. Educational status of the household head (EDU): Education is supposed to have negative impact on malaria incidence resulted from the impacts of climate variability. This is because people with higher education may get more awareness on malaria incidence and make possible coping strategies to reduce malaria outbreaks. It is categorical variable, and takes values 0 for those that have no formal education, 1 for those only read and writes, 2 for those have Primary education, 3 for those have Secondary education and 4 for those have higher education. Hence, in this study, it is hypothesized that a household's educational level is negatively related with malaria incidence. Accordingly, the study in Indonesia found that lower education levels were significantly associated with malaria incidence Dale *et al.,* (2005).

3. Age of Respondents (AGE): it is a categorical variable which takes values 1 (18-25), 2(26-35), 3(36-45), 4(46-55) and 5(above 56). It is expected to affect the rate of malaria incidence positively. It is noted that elderly people and children are so prone to malaria.This is because elder people and children under the age of five years have low immune system comparing to younger people. The more aged people the more vulnerable to malaria. So, there is positive association between age households and incidence of malaria. I.e.the more children and elder people, the more malaria incidence (World Health Organisation news, 2010).

4. Perception of the respondents on the impacts of climate variability influencing malaria incidence (PERSCEP): It is a dummy variable which takes a value 1 for those who have the perception that the climate variability is affecting malaria distribution and 0 otherwise. Those who have good understanding about the impacts of climate variability on malaria incidence are hypothesized to make possible coping strategies in the communities. Therefore, the expected sign of this variable is negative. Similar study was done in Uganda found that perception level of households on the climate variability influencing the spread of malaria was negatively correlated with the propagation of malaria (Caroline, 2012).

5. Yearly Income of the Household (INCOME): This variable refers to the yearly cash income of the household in terms of birr. It is continuous variable which includes the income of household from all sources. Accordingly, a study in Indonesia found that low-middle income is significantly associated with malaria incidence Dale *et al.,* (2005). When other things remaining constant, the lower the respondent's income the higher the malaria incidence in the study area. Thus the expected sign of this variable is negative.

6. House Quality. It is a dummy variable which takes a value 1 for house which are constructed in a qualified manner(constructed with cemented/blocked wall and galvanized roof) and 0 for poorly constructed houses(grass thatched and made of mud). A poorly constructed house enhances or causes malaria incidence by making suitability for its distribution, and vice versa. Housing type and quality can directly influence malaria incidence (Gaunawardena *et al.,* 1998). In our study, it is hypothesized that house quality could negatively impact malaria incidence. I.e. the more qualified houses could reduce malaria incidence.

7. Availability of mosquito net: It is a dummy variable which takes a value 1 for the presence of mosquito net and 0 other wise. Utilization of mosquito net could decrease malaria incidence, and vice versa. Here, in our study availability of mosquito net could influence malaria incidence negatively. This study is consistent with the previous study done in Bioko Island, of Equatorial Guinea found that prevention of malaria incidence were associated to household ITN (insecticide treated nets) ownership García-Basteiro *et al., (*2011).

Model Specification

In a situation when dependent variables is not modeled using OLS, the application of linear regression is limited. But in linear model the dependent variables is represented as linear function and hence OLS works. In binary choice, the basic assumption is that the individuals express the choice between two alternatives i.e. there exist probability of choice one alternative over the other. Because of this, inconsistency and bias will occur on estimation used by OLS parameter. In this regard, linear probability model, logistic and probit regression model are suggested as best alternatives to overcome the limitation (Worldridge, 2005).

The result of OLS in LPM is plagued by several problems. The limitations of LPM are: it assumes the predicted value lie outside the region of probability range which violets rule of probability. The other problem of LPM is that, the variance of disturbance term is not constant it fluctuates with value of explanatory variable. Thirdly lower value of computed coefficient of determination (R^2) and non-normality of disturbance term. There for non-linear probability model is developed to reduce this limitation (Gujarati, 2004).

The non-linear probability model (NLPM) is preferred over the LPM due to (i) as the value of the explanatory variable increase, response probability increases without stepping 0-1 outside the interval level. (ii) The other advantage of NLPM over LPM is non-linear relationship between the response probability and the explanatory variables i.e. as the probability of the event approaches zero at slower and slower rate, the explanatory variables gets small and approaches to one as value of explanatory variable gets larger and larger (Maddala, 1992).

Logit and probit models specification are comparable while their differences are; in the probit model, the error term of equation is normally distributed with mean zero and standard deviation of one. But in logistic regression, the error term is assumed to be normal distribution while standard deviation is different from one. Besides, the probit model assumes weak multi-collinearity between explanatory variables (Gujarati, 2004). Because of this nature, probit model is selected for the current study.

Probit Model specification

As it is indicated, the purpose of this study is to analyze the impact of climate variability on malaria incidence. The dependent variable in this case is dummy variable, which takes the value of one or zero. The explanatory variables are either continuous or dummy variables.

Suppose response variable Y is binary, that is, it can have only two possible outcomes which are denoted as 1 and 0. For example, *Y* may represent presence/absence of a certain condition, increment/decrement of some device, answers yes/no on a survey, etc., there are also a vector of repressors *X*, which were assumed to influence the outcome *Y*. Specifically; it is assumed that the outcome model

$\mathbf{Y}_{\boldsymbol{i}} = \boldsymbol{\beta}^{\mathbf{1}}\boldsymbol{X}_{\boldsymbol{i}} + \boldsymbol{\varepsilon}_{\mathbf{i}}$, **$\mathbf{Y_i}$ is observed**

$(\boldsymbol{\varepsilon}_{\mathbf{i}}) \sim$ **normal** $(\ \mathbf{0}\ , \boldsymbol{\sigma}_{\boldsymbol{\varepsilon}}\ \boldsymbol{\sigma})$

Where, $\boldsymbol{Y_i}$ is a dummy variable that takes a value of 1 if the incidence of malaria is increasing in the area and 0, otherwise.

$\mathbf{X_i}$ and $\boldsymbol{\beta}^{\boldsymbol{i}}$ are parameters of the models and $\boldsymbol{\varepsilon_i}$ is error terms of the regression

$\mathbf{Pr(Y = 1|X) = \Phi\ (X'} \boldsymbol{\beta})$

Where Pr denotes probability, and $\mathbf{\Phi}$ is the Cumulative Distribution Function (CDF) of the standard normal distribution. The parameters $\boldsymbol{\beta}$ are typically estimated by maximum likelihood. It is also possible to motivate the probit model as a latent variable model. Suppose there exists an auxiliary random variable

Where $\boldsymbol{\varepsilon} \sim \boldsymbol{N}\mathbf{(0, 1)}$. Then $\boldsymbol{Y}$ can be viewed as an indicator for whether this latent variable is positive:

$$\mathbf{Y = 1_{\{Y* > 0\}}} = \begin{cases} \textbf{if Y} *> 0\ i.e. -\ \varepsilon \mathbf{X'} \boldsymbol{\beta}, \\ \quad \mathbf{0\ otherwise} \end{cases}$$

The use of the standard normal distribution causes no loss of generality compared with using an arbitrary mean and standard deviation because adding a fixed amount to the mean can be compensated by subtracting the same amount from the intercept, and multiplying the standard deviation by a fixed amount can be compensated by multiplying the weights by the same amount.

To see that the two models are equivalent, note that

$$\begin{aligned} \mathbf{Pr(Y = 1|X)} &= \mathbf{Pr(Y^* > 0)} = \mathbf{Pr(X^*} \boldsymbol{\beta} + > \boldsymbol{0}) \\ &= \mathbf{Pr(}\boldsymbol{\varepsilon} > \mathbf{-X'} \boldsymbol{\beta}) \\ &= \mathbf{Pr(}\boldsymbol{\varepsilon} < \mathbf{X'} \boldsymbol{\beta}) \quad \text{(by symmetry of the normal distribution)} \\ &= \mathbf{\Phi\ (X'} \boldsymbol{\beta}) \end{aligned}$$

The probability of malaria incidence (probit) selection model is given by:

$$y_i = \beta' x_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

$$\boldsymbol{I = 1} \qquad \boldsymbol{if\ Y_i \geq t_i}$$

$$I = 0 \qquad \text{if } Yi < t_i$$

Where

$Y_i = i^{th}$ respondent's true unobserved point valuation on the impacts of climate variability influencing malaria incidence in question.

$\beta = a$ coefficient for X

$t_i =$ the offered threshold, assigned arbitrarily to the i^{th} respondent

I = discrete response of a respondent on the impacts of climate variability on malaria incidence question (1=Yes or 0= No)

εi = unobservable random component distributed **N(0,)**

X_i= observable attributes of the respondent

The empirical probit model for this study is as follows:

PMALINC(Y) = ß$_0$+ ß$_1$ EDULHH + ß$_2$ SEX + ß$_3$AGE + ß$_4$PERSCEP + ß$_5$TINCOME + ß$_6$ HOUSEQ + ß$_7$ MOSQNET+ ………………………………………………………2

Where: ***PMALINC***: **Probability of malaria incidence in the study area(Y)**

EDULHH: **Educational status of the household head**

SEXHH: **Sex of the household**

AGEHH: **Age of the household**

PERSCEP: **Perception of the household on the impacts of Climate variability on malaria incidence**

TINCOME **Total Yearly Income of the Household**

HOUSEQ **House quality of the Household**

MOSQNET **Mosquito net availability in the Household**

Where Y is the dependent variable and measures whether malaria incidence exists or no. The number 1 records a yes vote, and 0 records a no vote.

Results and Discussion

Demographic and socio-economic characteristics of households

The demographic characteristics of respondents are summarized and presented in Table 1, a total of 143 respondents were included in this study, of which 114 (79.72%) were males and the rest 29 (20.3%) were females.

About 11% of the respondents were 18-25 years old, 37.067% were 26-35 years old, 25.2% were 36-45 years old,16.8% were 46-55 years old, 9.8% were 56 and above years old. The mean age of the participants was 28 years. All the participants were the residents of the area.

About 64 (44.75%) of the respondents had no formal education; whereas, 79 (55.25%) had Attended formal education.

The mean annual income of respondents is found to be birr 7208.68, however it ranges between 1540 to 17620 birr. Agricultural production, off-farm activities like petty trade were important income sources for sample households. Agriculture is the main source of income and it constitutes 85.4% of total income per annum. Livestock availability is the second generating income for the households and it accounts 10.28% of the total income. Non-farm activities such as petty trade rank third in generating income for the households and it accounts 3.09% of the total income. Tourism related activities were also another income generating structure and it covers 1.21% of the total income of households in the study area. The result shows that among the household's income sources, it is the farm income that stands first whereas; the income from non-farm activities is very low.

Table 1 Demographic and Socio-economic characteristics of studied households (N=143)

Variables	Type	Number	Per cent
Sex of HH	male	114	79.7%
	Female	29	20.3%
Age of HH	18-25	16	11.2%
	26-35	53	37%
	36-45	36	25.2%
	46-55	24	16.8%
	Above 56	14	9.8%
Educational status of HH	Attended formal education	79	55.2%
	Didn't attend formal education	64	44.7%
Occupational status of HH	farmers	108	75.5%
	Petty trader and farmer	6	4.2%
	Farmer and Gov. Employer	15	10.5%
	Causal workers	2	1.4%
	Had no job	12	8.4%
Annual income sources of HH	Crop	122	85.4%
	Livestock	15	10.3%
	Non-farm income	4	3%
	Tourism Income	2	1.2%

Analysis of time series climate data and the incidence of malaria in Arsi Nagelle district

Climate is one of the major factors that influence the distribution and occurrence of malaria epidemics in Arsi Nagelle. Rainfall and temperature affect the breeding and survival of the mosquitoes. In most parts of the district, temperature and rainfall allow intense, perennial malaria transmission.

Mean monthly maximum temperature distribution

The statistical analysis of the mean monthly maximum temperature of the district for the period from 1985 - 2015 clearly indicated that there were fluctuations in mean maximum temperature during the specified period (figure 2). During that period, the highest mean maximum temperature in the district was recorded in 2005, while the lowest was recorded in 1995. The rise of temperature across a year may have had impact on the reproduction of mosquitoes, which in turn influences the transmission of malaria. The highest mean monthly temperature was recorded in the months of January, February, March, November and December between the years 1985-2015, and it gradually decreased from April through October.

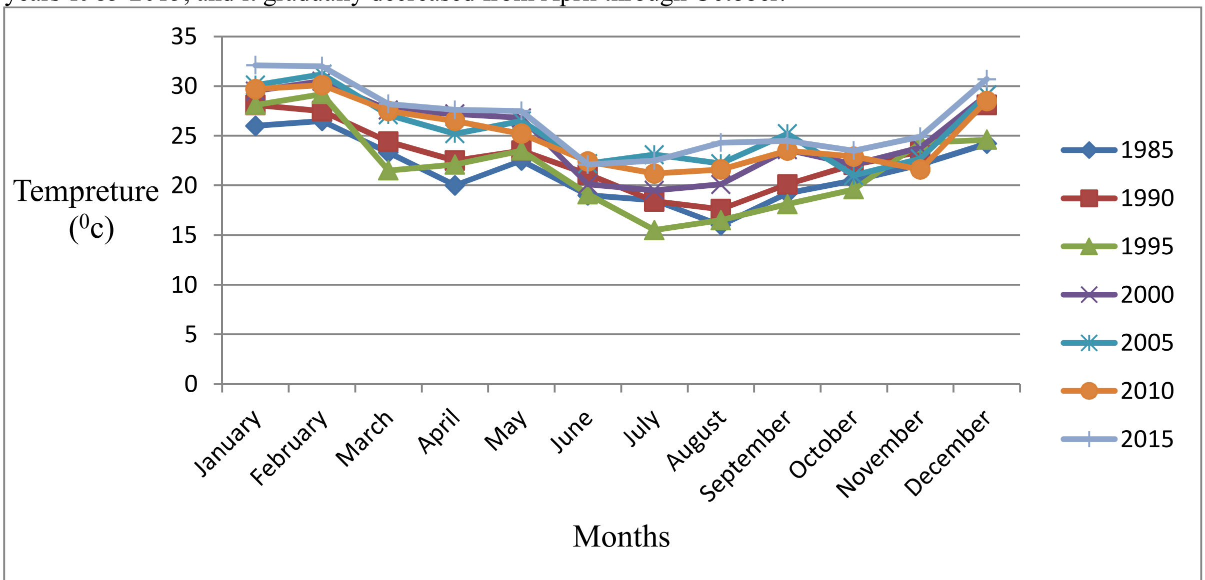

Figure 2 Mean monthly maximum temperature ^{0}c (1985-2015) in Arsi Negele district (data source NMA, 2015)

Mean monthly minimum temperature distribution

The trend (figure 3) demonstrated the mean minimum temperature of Arsi Negele district which is showing the monthly variation from 1985 -2015. The effect of the mean minimum temperature on malaria transmission might not be suitable for developmental condition of the parasite. The lowest temperature occurs in the months of May, June, July, August, September and October with the temperature of about 6.2°C -12.6°C. In 2015 shows the highest temperature variation and in 1990 showing the lowest trend of temperature variation. This indicate the fact that there is temperature increment from (1985-2015) in the district.

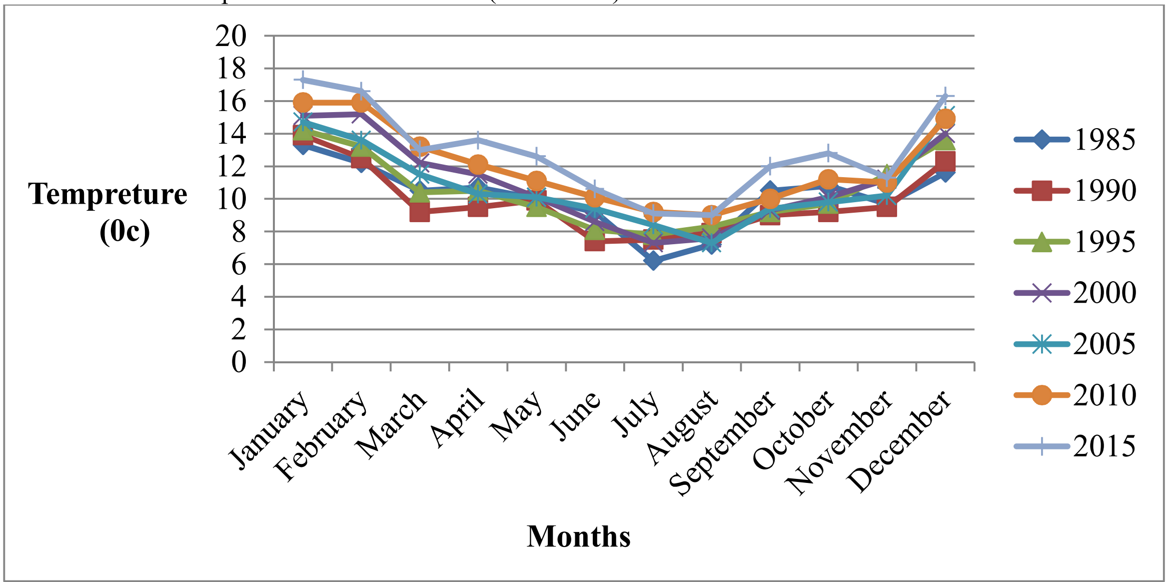

Figure 3 Monthly mean minimum temperature ^{0}c (1985-2015) in Arsi Negele district (data source NMA, 2015)

Mean Monthly Maximum and Minimum Temperature distribution

The following (figure 4) is depicting the mean annual maximum and mean annual minimum temperature in Arsi Negele district. Based the following trend of maximum temperature from 1985- 2015 is about 32°C in the months of January, February and March which happened to be the hottest maximum months throughout the year, while the months of April, May, June, July, August and September are the cold Maximum with a temperature of about 19.75°C – 24.4°C throughout the years from 1985-2015. From the mean minimum temperature trends, the highest minimum temperature is about 18°C in the months of January and February. However, there is almost uniform tread thought out the years with a little difference in the Months of June, July and August with the temperature of about 9°C.

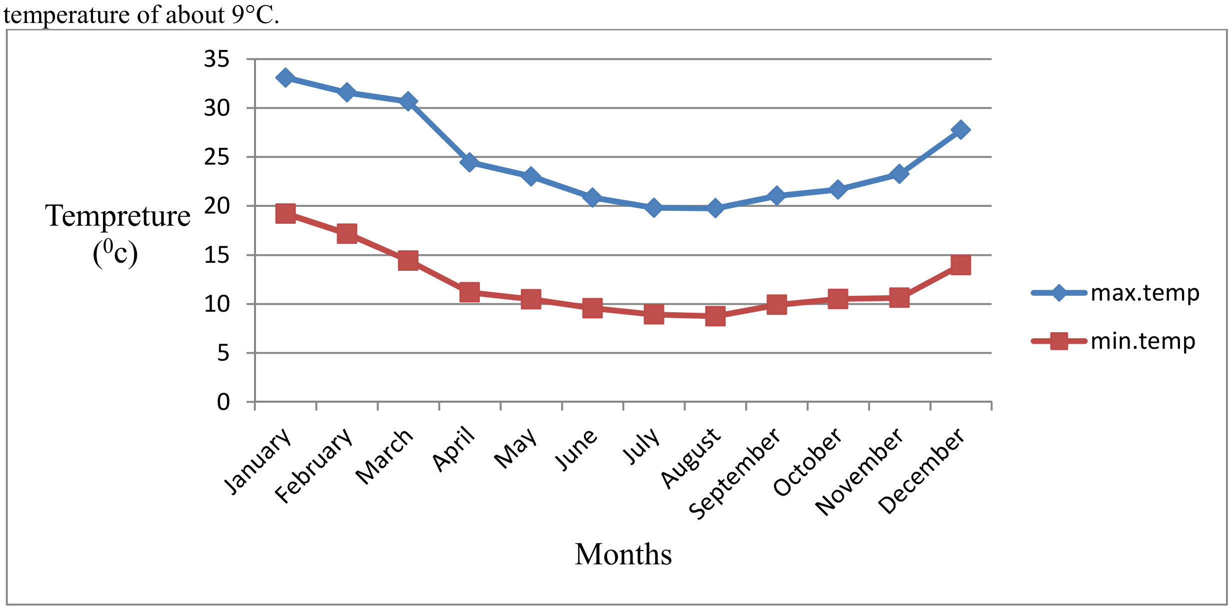

Figure 4 Monthly mean maximum and minimum temperature 0c (1985-2015) in Arsi Negele district (data source NMA, 2015)

Mean monthly Rainfall distribution

From the rainfall distribution (figure 5), the result vividly shows that, Arsi Negele district has two rainy seasons, autumn or short rainy season (March, April and May) and summer or long rainy season (June, July and August), While the dry seasons are the months of December, January and February, which alternatively rains throughout the years. It is also observed that the months with the highest rainfall are June, July and August with about 169.35 mm, 186.89 mm and 156.52mm respectively.

Generally, the rainfall distribution was declined across a year (1985-2015), which shows the changing of climate in the district.

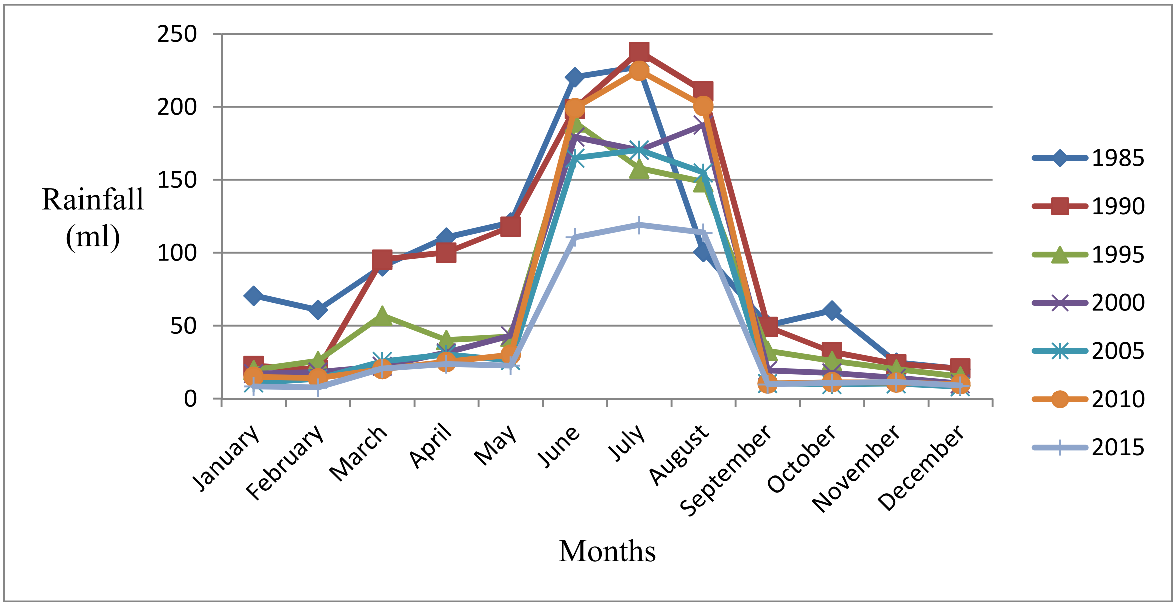

Figure 5 Monthly Average Rainfall Distribution (1985-2015) in Arsi Negele district (data source NMA, 2015)

Monthly, seasonal and annual variation of malaria cases in Arsi Negele district (2006-2015)

The below (figure 6), indicates that a fluctuating trend of malaria cases reported through the years 2006 to 2015. The incidence of malaria in the district appeared to have declined across a year (2006-2015), and there was statistically significant inter annual variation of malaria case occurrence in the study area ($p = 0.002$).

It was also, observed that malaria cases were occurred in almost every month of the year. However, the month with the highest peak of malaria cases in almost all years was September (end of the rainy season). There was not statistically significant variation of monthly malaria case occurrence.

The season with the highest average total malaria occurrence was spring (September, October and November) and the minimum malaria case was observed during winter (December, January and February). For total malaria cases, the seasonal variation was statistically significant ($p = 0.000$).

Generally, malaria cases was decreasing across a year which was ascribed to the increased attention to malaria control and preventive activities by different responsible bodies, increased awareness of the community on use of ITNs and other malaria control activities like elimination of mosquito breeding sites, increased accessibility of ITNs to community, increment of budget for malaria control and prevention activities (personal communication).

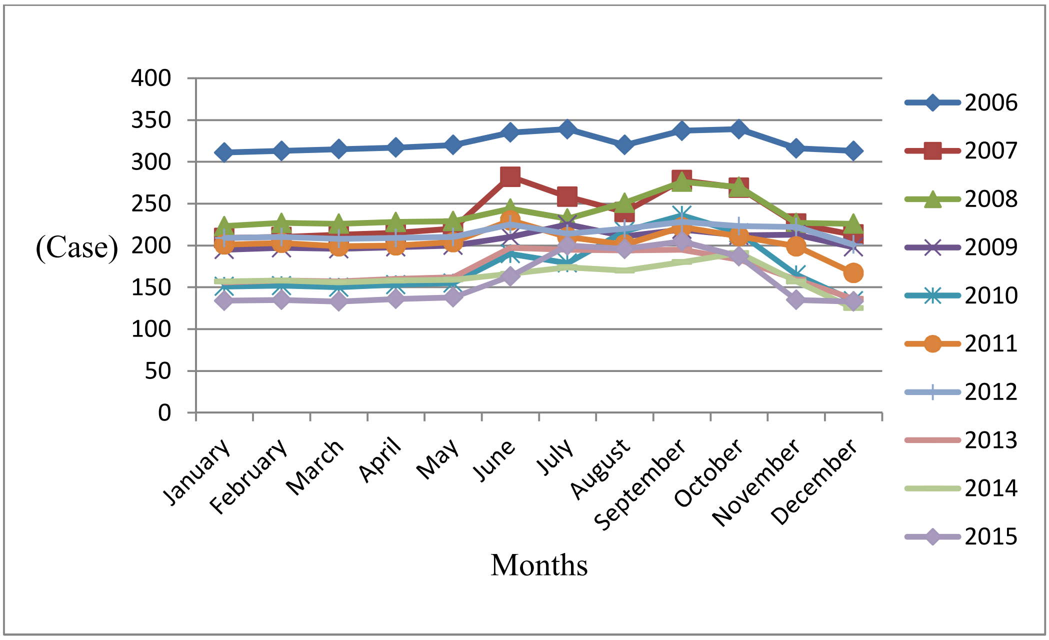

Figure 6 Monthly malaria case distributions (2006-2015) in Arsi Negele district (data source, Arsi Negele health office, 2015)

Correlations Analysis between Climates Variability and Malaria cases (2006-2015)

The below (figure 7), indicates that the relationship between malaria incidence and meteorological variables for the last ten years (2006-2015).

It shows that an increase and decrease in malaria case across a years was followed consistently the increase and decrease in rainfall amount. Hence, malaria case occurrence was highly correlated with the fluctuation of rainfall amount. However, maximum and minimum temperatures were not correlated with malaria cases.

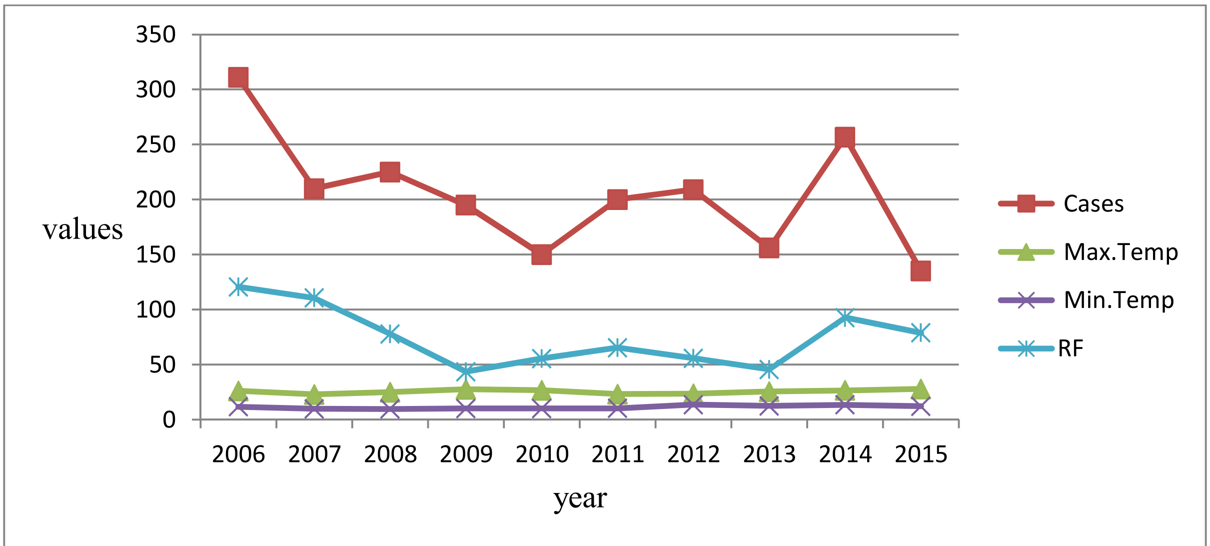

Figure 7 Relationship between monthly malaria case and metrological factors in Arsi Negele district (2006-2015)

Pearson's Correlation Coefficient (PCC)

The relationship between malaria and meteorological variables was checked by Pearson's correlation and linear regression analyses. Pearson's correlation analyses were conducted to relate monthly total malaria cases with meteorological variables (maximum temperature, minimum temperature and total rainfall).

According to correlation findings, monthly mean maximum and mean minimum temperature were negatively correlated but monthly total rainfall was positively related with total monthly malaria case occurrence.

The finding implies that meteorological variables can affect malaria transmission either positively or negatively even if the correlation was less likely linear. This finding contradicts with the findings in Shuchen

County, China Donald and Pend (2000) and Highlands of Madagascar (Bouma, 2003) which showed that all meteorological variables were positively correlated with malaria.

The present study was undertaken at different altitude in Arsi Negelle district. Correlation between malaria and climate vary with altitudes (Gebere-Mariam, 1984). The correlation coefficient for the association between monthly malaria cases and some meteorological factors was greater than other meteorological factors. This indicates that one meteorological factor plays greater role in malaria occurrence or transmission than others which coincide with the finding from Dehradun, Uttaranchal, India (Anthony and McMichael, 2000). Shuchen County, China Donald K and Pend BI. (2000), Rwanda Loevinsohn, 1994; Madagascar Bouma, 2003) and east Africa Highlands Rogers and Randolph (1763-1766)

In this study, the correlation coefficient for the association between mean monthly rainfall and monthly malaria cases was greater than that of the correlation coefficient for the association between any other measured meteorological variables and monthly malaria cases. This study indicates that total monthly rainfall was the most significant factor that positively correlated with malaria transmission dynamics in the study area.

The same results can also found in Shuchen County, China Donald and Pend (2000) and New Halfa, Eastern Sudan Ishag *et al*., (2005). On the other hand, the correlation coefficients for the linear regression between the mean monthly maximum and minimum temperature and mean monthly malaria cases were negative. This finding was similar to a study in India Anthony and McMichael. (2000).

This is important in the hot months, in which an increase in temperature would limit vector and parasite survival and therefore cause a decrease in malaria transmission rates. This finding contradicts which the findings in Shucher County, China which concluded that an increase in monthly maximum and minimum temperature should cause an increase rather than a decrease in malaria rates, Donald and Pend (2000). This variation could be due to differences in local climatic condition in China and Arsi Negelle district.

That is the large number of months in Arsi Negelle that are hotter than months in China - this makes sense in the hot months, in which an increase in temperature would limit vector and parasite survival and therefore may cause a decrease in malaria transmission rate. The most likely explanation for the finding that increases in temperatures is correlated with a decrease in malaria cases is the significant autocorrelation between monthly temperature and rainfall. This hypothesis is supported by the finding of high negative correlation between temperature and rainfall. This indicates that, for a given amount of moisture in air, an increase in temperature cause a decrease in rainfall, which can limit Anopheles survival. The correlation between maximum temperature and rainfall may also lead to an explanation of the negative correlation coefficient between maximum temperature and malaria cases occurrence.

The negative correlation between maximum/minimum temperature and rainfall in hotter months may decrease Anopheles breeding or increase dryness which may be the limiting factor for malaria transmission. Although all meteorological variables were less likely to predicts the occurrence of malaria in Arsi Negele district.

This finding contradicts the findings in Dehradun, Uttaranchal, India Anthony and McMichael. (2000), Shuchen county, in China Donald and Pend (2000), Rwanda Loevinsohn (1994), Madagascar Bouma (2003) and east Africa Highlands Rogers and Randolph. (1763/66) which concluded that meteorological variables were highly likely correlated with malaria occurrence and the prediction was higher than this finding with higher R square value.

Table 1, Simple Linear regression for monthly total malaria case occurrence and meteorological variables in Arsi Negele district, 2006-2015

Variables	Beta	R square	P- value
Maximum temperature	-.644	.415	.044
Minimum temperature	-.657	.431	.039
Rainfall	.720	.519	.019

Socio-economic determinants of malaria incidence

In this section, Binary Probit Regression model was applied to determine the demographic and socio-economic factors influencing malaria incidence in the study area. Before fitting this model, the problem of multi-collinearity among continuous explanatory variables was checked by using variance inflation factor (VIF), and that of the dummy variables were by contingency coefficient. The value of contingency coefficient less than 5 assumes weak association between variables. The result of contingency coefficient and variance inflation factor showed that there was no multi-collinearity problem among the explanatory variables.

So, all the seven explanatory variables were included in the model. The probit regression model correctly predicted the 97.4% of the total sample.

The results of the maximum likelihood estimation of the probit model indicated that two variables didn't significantly affect MALINC, namely, sex and Age of the households. This might be because of different reasons which need further study.

Total cash income of the household head (TINCOME), availability of the mosquito net (MOSQNET), house quality (HAUSEQ), education level of the household head (EDULHH) and household's perception of the impacts of climate variability on malaria incidence(PERCEP) were found to be negatively and significantly related to malaria incidence.

Table 2 Estimation of the probit Model Output for the malaria incidence rate

MALINC	Coef.	Std. Err.	z	P>z	Marginal effect
SEX	-.8621077	.6323888	-1.36	0.173	-.0340279
AGE	.0227893	.0226017	1.01	0.313	.0013684
EDU	-.4614953	.1864823	-2.47	0.013**	-.02771
INCOME	-.0002293	.0000885	-2.59	0.010**	-.0000138
HOUSEQ	-1.621371	.4297848	-3.77	0.000*	-.0973535
MOSQNET	-.9162053	.4195185	2.18	0.029**	-.0827176
PERCEP	-1.090261	.4595835	2.37	0.018**	-.1228286
_cons	4.288965	1.226359	3.50	0.000	-.0340279

Note: *, ** significant at 1% and 5%, respectively

Probit regression

Number of observation = 143
LR chi2 (7) = 72.52
Prob > chi2 = 0.0000
Pseudo R2 = 0.5749

Log likelihood = -26.811994

Y = Pr (MALINC) (predict)
= .97418132

The interpretations of the significant variables are presented here under.

Total Income

Total cash income, had a significant and negative effect on the rates of malaria incidence and significant at less than 5 % probability level. This means that for one unit increase in total income of the household head, the probability of malaria incidence decrease by 0.00138%. This indicates that the households with high annual income could control malaria incidence by implementing different coping mechanisms than households with low income. The marginal effect of the household income indicated that as income of households' increases, the probability of malaria incidence decreases. This study contradict with the findings of Dale *et al.,* (2005) found that low-middle income was significantly associated with malaria incidence in Indonesia.

Educational status of the household

The sign of this variable is consistent with expected hypothesis and it was negatively related with the dependent variable. The coefficient was significant at less than 5% probability level. This indicates that the probability of malaria incidence decreases as household head become educated than those households who are not educated.

This means that a unit increases in formal education decrease the incidence of malaria by 2.8%. This could be as households head educated; they acquire knowledge on how to make a living and how to use different mechanisms to overcome malaria incidence in the area. This empirical finding contradicts study of (Dale *et al.,* 2005) found that lower education levels were significantly associated with malaria incidence.

House Quality of the households

This variable took the expected sign and its coefficient was highly significant at less than 1 percent probability level. It had a negative and strong relationship with the dependent variable showing that household heads with better quality house control malaria incidence than household with low quality house.

A unit increases in quality of houses decrease the incidence of malaria by 9.7%. This could be possibly because better quality houses hamper the reproduction of mosquitoes causing malaria parasite. The study is consistent with the study (Gaunawardena *et al.* 1998) found that Housing type and quality can directly influence malaria incidence. Also Koram *et al.,* (1995) found that children living in poor quality housing and crowded dwellings were infected with malaria more frequently than other children living in better housing conditions in per urban areas in Gambia.

Mosquito Net

Mosquito net using was hypothesized as negative variables for malaria incidence. Because, as the household accessed to mosquito nets, the probability of malaria infestation decreases. Hence, as expected the probit model showed that the variable was significant at less than 5% probability level and negatively related with malaria incidence.

The marginal effect of the mosquito nets indicates that a unit increase in use of mosquito nets decrease malaria incidence by 8.3%. However, only accessing households with mosquito nets could not reduce incidence of malaria unless strong awareness and training how to use is given. This study is consistent with the previous study done in Bioko Island, of Equatorial Guinea found that prevention of malaria incidence were associated to household ITN (insecticide treated nets) ownership García-Basteiro *et al. (*2011).

Perception

Household's perception on the impacts of climatic factors influencing malaria incidence had a negative sign. Its coefficient was significant at 5% probability level. The result of the probit model showed that a household who perceives climate variability as a problem in malaria incidence is more likely to reduce malaria incidence than a household who does not perceive climate variability as a problem.

The marginal effect of perception of the households indicates that a unit increase of the household's perception on the impacts of climatic factors influencing malaria incidence decrease malaria incidence by 12.3%. The reason may be households who have perception on climate change impact on malaria could have coping strategies at their own cost to further tackle malaria infestation problem. Similar study was done in Uganda found that perception level of households on the climate variability influencing the spread of malaria was negatively correlated with the propagation of malaria (Caroline, 2012).

Conclusion and Recommendation

Conclusion

From the current study, the following conclusions were drawn:

- Majority of the respondents in the study area perceived that there has been variability in the important climatic factors (temperature and rainfall) in their area. However, the perception of the households has been influenced by the agro-ecological zone of their kebele. That is, majority of the households living in lowland areas believed that there has been variability in temperature and rainfall.
- From the analysis of climate data for the last two decades, it was concluded that total monthly rainfall was found to be strongly correlated with the incidence of malaria in the study area.
- Educational status, income, perception, quality of house to live and access to mosquito nets were negatively correlated to the incidence and transmission of malaria in the study area.

Recommendations

On the basis of the conclusions made above, the following recommendations are forwarded.

- ✓ The local governmental officials and other relevant stakeholders should actively engage in providing intensive training on environmental sanitation and housekeeping to control malaria incidence.
- ✓ More attentions should be given for the education in the study area to improve the perception of the community concerning the impact of climate change on the incidence of malaria in the district. This can be done by giving trainings related to environment and climate change and how to care in protecting themselves against malaria.
- ✓ Designing and implementing coordinated community based projects to control climate based-malaria incidence in the district might be a good approach.
- ✓ Moreover, concerted efforts should be made by the district health office and supporting organizations to distribute mosquito nets and awareness creation on how to use them.
- ✓ The Public Health Offices should collaborate with the National Meteorological Agency in the development and implementation of early warning system that should be provided to the communities to prepare themselves before the onset of the season in which the incidence of malaria is prevalent especially in vulnerable areas.
- ✓ The local government of the district should encourage and support health care centers to collect and manage all relevant records on the incidence of malaria in order to provide important data that may be needed for better planning of disease management and also support research in the field.
- ✓ Since, transmission of malaria is very complicated, so that detailed ecological and epidemiological studies are still needed to assess the level of local risk. Further studies that account for all possible confounding factors and that are done at a smaller spatial scale, will improve our understanding of which factors will most affects malaria transmission dynamics in the study area may be necessary.
- ✓ District local government should encourage local communities to build drainage channels that could easily let rain water out rather than flooding, manipulate and control the local habitats by removing hollows, small ponds, pools containing water for breeding, conduct regular cleaning campaigns for sites

and places where mosquito vector is abundant.

- ✓ There is a need of health education and awareness campaigns at the community and individual levels. This will help bring positive behaviours at work and leisure at home towards malaria prevention and control. For example proper dressing behaviours while going to the garden in the morning, in the evening hours at home and when going to sleep, early and proper treatment seeking, vector control, and moving at good times of the day when mosquitoes are not active. Whenever possible it is important to wear suitable clothing's especially after dusk, thorough check inside houses in the evening and use bed nets to avoid Anopheles mosquito bites.
- ✓ National government should plan funding for various district activities in time such that they as district leaders in charge of health can try to handle the climate variation impacts in case they occur.

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