ADDIS ABABA UNIVERSITY

COLLEGE OF BUSINESS AND ECONOMICS

DEPARTMENT OF ECONOMICS

Socio-economic Burden of Malaria: The case of Jabi-tehnan District

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A thesis submitted to the college of business and economics of Addis Ababa University in partial fulfillment for the Degree of Masters of Science in Economics (Economic Policy Analysis)

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This is to certify that the thesis prepared by Mihret Getaneh, entitled: ***Economic Burden of Malaria: The case of Northwestern Ethiopia***, and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Economics (Economic Policy Analysis) complies with the regulations of the University and meets the accepted standards concerning originality and quality.

Signed by the Examining Committee:

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Advisor ________________________Signature____________Date__________________

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Acronyms

G2SLS - Generalized Two-Stage Least Squares

2SLS - Two-Stage Least Squares

3SLS - Three-Stage Least Squares

ACT - Artemisinin Based Combination Therapy

API - Annual Parasite Index

ATSB - Attractive Toxic Sugar Bait

CAP-Africa - Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change

CAPI - Computer-Assisted Personal Interviewing

CLRM - Classical Linear Regression Model

CSA - Central Statistical Agency

DALY - Disability Adjusted Life Years lost

ETB - Ethiopian Birr

FAW - Fall armyworm

GDP - Gross Domestic Product

GFATM - Global Fund to Fight AIDS, Tuberculosis, and Malaria

HI - House improvement

HR - High Risk

ICIPE - International Centre of Insect Physiology and Ecology

IPTp - Intermittent preventive treatment of malaria for pregnant women

IRS - Indoor Residual Spraying

ITNS - Insecticide Treated bed nets

IVs - Instrumental Variables

KALRO - Kenya Agricultural and Livestock Research Organization

KAP - Knowledge, Attitude, and Practice

LLINs - Long-Lasting Insecticide Nets

LSM - Larval source management

MDGs - Millennium Development Goals

MR - Moderate Risk

NARO - National Agricultural Research Organization

OLS - Ordinary Least Squares

RBM - Roll Back Malaria Partnership

RDT - Rapid Diagnosis Test

RE - Random Effects

SB - Stemborer

SES - Socio-Economic Status

SNNP - Southern Nation Nationalities and People

TB - Tuberculosis

USD - United States' Dollar

VCM - Vector Control Management

VIF - Variance Inflation Factor

WHO - World Health Organization

WTP - Willingness to Pay

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Abstract

This thesis explores the economic burden of malaria incidence by controlling household practices regarding malaria prevention in Jabi-tehnan District. It uses household survey data collected by the Social Sciences and Impact Assessment Unit of the International Centre of Insect Physiology and Ecology (icipe). *This study aimed at assessing and examining factors contributing to malaria and the impact of the incidence by using both descrptive statistics and econometrics aproach. In the descriptive analysis, it is assessed that malaria causes on average 465 ETB expenditure per person, led to 29 days of absenteeism from school, and 10 workdays lost. We use OLS and RE for malaria deteminant regrssion. Maize productivity function is estimated by using OLS, RE, 2SLS, GLS, and 3SLS. In the first part of the econometrics analysis, the determinants of malaria incidence are estimated. The result from the estimation suggests household practices, nutritional status, and catching diseases other than malaria significantly determine malaria incidence. Household practices indicator variables significantly explain the difference in the incidence of malaria among households. In the second part of the econometric analysis, we estimate the impact of malaria on maize productivity by using various models (OLS, RE, 2SLS, GLS, and 3SLS). The results differ across models. Under OLS and RE model estimation: malaria negatively affects maize productivity while taking malaria as an exogenous variable. Malaria is insignificant in determining maize productivity in other models that uses instrumental variables. This may be attributed to the substitution of ill family labor with hired ones and/or cooperation of the community. We also found that malaria incidence in the household increases labor days per hectare since illness makes individuals far from being effective. This is estimated by using 3SLS. Based on the results from this study, we imply that any intervention of malaria reduction needs to consider the health-seeking behavior of households. This helps to deal with the systematic difference in households' practices regarding malaria and its prevention methods. Policies intended to reduce the burden of malaria should not only consider the short-run economic consequences, rather emphasize the burden it imposes on an individual's capacity.*

Key Words*: Malaria incidence, Jabi-tehnan, Health-seeking behavior, Economic burden*

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

In her book entitled "How Malaria Has Ruled Humankind for 500,000 Years" Sonia Shah articulates that one of the problems mankind suffered most in history is malaria. In the book Sonia also states that the severity of malaria is multidimensional; first, it is a medical problem that is a reason for many illnesses and deaths; second, it is a cultural problem−lack of awareness among the society on how to combat malaria; third, it is an economic problem−no adequate finance to tackle the problem; fourth it is a political problem−leaders around the world do not distinguish prevention of malaria as a political target(Shah, 2010).

Malaria is a leading global public health problem with enormous morbidity and mortality. An estimated 239 million malaria cases occurred in 2010 globally and declined to 217 million cases in 2016 (WHO, 2018). In 2019 WHO reported that the incidence of malaria has declined but still staggering. There were 228 million clinical cases in 2018 globally, which was lower than it was in 2017 (231 million cases). In the same year, the number of deaths has declined to 405,000 from 416,000 in 2017, and 93% of world malaria incidence was occurred in Africa followed by South-East Asia with 3.4% of cases and Eastern Mediterranean Region with 2.1% of global malaria cases (WHO, 2019). World malaria report of 2016 shows more than 1.8 million new malaria cases were informed in Ethiopia (WHO, 2016).

In addition to the impact of malaria on health, it has a huge and devastating impact on the wealth of an individual in particular and the economy of a country in general. The worst impact of malaria happens when it leads to death incidence if once a person deceases, the total amount of investment and the future working time vanish. This is highly disastrous since children under the age of 5 years are the most exposed group affected by malaria. The death incidence in childhood has an irresistible implication on tomorrow's labor force (Okorosobo et al., 2011). Malaria has a bidirectional relationship with poverty. It became one of the hindrances of economic growth and development constraining many developing countries across the world (Sachs and Malaney, 2002).

For many developing countries agriculture plays a great role in the economy. The impact of malaria on the agriculture sector is highly devastating. It affects the working-age population of rural households, which is shown through the reduction in quantity and quality of labor supply. Malaria affects the quantity of labor supply since the ill loss workdays partially or completely. It affects the quality of labor supply since the sick cannot be as productive as before. The likely impacts of malaria on rural households lie in the loss of productive labor time by the ill and other family members who switch their work time to caregiving. Malaria becomes one of the hindrances of economic development with huge costs (Asenso-Okyere et al., 2009).

It is possible to distinguish the cost of malaria to direct and indirect costs. The costs attributed to the individual and government expenditure for malaria prevention and treatment are considered as direct costs such as spending on insecticide-treated nets (ITNs), during a stay in the health center, transportation, and medical fee, running cost of health centers, infrastructure, education, and research. Out of the total expenditure on health, malaria accounts for 40% of public health expenditure in malaria-prone countries. The indirect costs of malaria are the spillover effects include the costs due to lost income, reduced agricultural productivity, lost working days, and the cost from death is forgone discounted lifetime income in the future. These problems are exacerbated in Africa (WHO, 2008).

Due to geographical and many other factors, sub-Saharan African countries are prone to malaria. This region accounts for almost 90% of global malaria cases (90% of 218 million cases) and 91% of all malaria death incidence (91% of 405,000) in 2018 (WHO, 2019).

During the last three decades, new approaches and medicines have been established for malaria prevention and control. The integration of malaria with other health programs both nationally and globally through the Roll Back Malaria Partnership (RBM) initiative of the WHO in 1998. The Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM) was established in 2002. These efforts helped to create awareness about malaria among societies. Though the first establishments of the malaria eradication campaign were started from 1956 to 1968, the latter efforts helped to reduce the global economic burden of malaria. WHO recommended the Global Malaria Eradication Campaign by introducing various global interventions to control malaria. The interventions consist of controlling malaria (diagnosis and treatment), Larval source management (LSM), House improvement (HI), Attractive Toxic Sugar Bait(ATSB), Targeting livestock, and scaling up the distribution of Insecticide-treated nets (ITNS), Intermittent preventive treatment of malaria for pregnant women (IPTp), Intermittent preventive treatment of malaria in infancy, and Indoor residual spraying (IRS) (WHO, 2009). Reduced morbidity and mortality from malaria over the last decade are gained through these interventions globally(Tizifa et al., 2018).

Despite these endeavors, the burden of malaria is still high. Malaria is still a cause of morbidity, mortality, impairment, school absenteeism (low human capital formation), lost days of work, lost productivity, and poverty (Burlando, 2012; Mathanga et al., 2015; Sachs and Malaney, 2002). One of the possible reasons for the persistence of malaria is the resistance of mosquitoes to the insecticide (Halliday et al., 2014).

The interventions need the help of changing the health-seeking behavior of people. Any economic evaluation of the impact of malaria needs to consider differences in health-seeking behavior, which could be captured through the practices of individuals for malaria prevention. This thesis estimates the economic impact of malaria while controlling for Practices of households in Northwest Ethiopia.

1.2 Statement of the Problem

Two lines of literature try to understand the socio-economic problems associated with malaria. The first line of literature focuses on households' health-seeking behavior. It analyzes individuals and/or groups of individuals Knowledge, Attitude, and Practices (KAP) on mosquitos and malaria control. Many studies on this line of literature assess the household's health-seeking behavior of malaria by using a series of questions regarding mosquitoes and malaria control(Cairo, 2011; Dave-agboola and Raji, 2018; Forero et al., 2014; Saha et al., 2019).

For example, a study in Bangladesh uses surveys asked questions and qualitative interviews on knowledge, attitudes, and practice regarding malaria prevention and treatment to analyze the health-seeking behavior of slash and burn cultivators, through assessing the knowledge, attitude and practices of prevention and treatment of malaria of this group and how it affects malaria (Saha et al., 2019).

A study in Colombia examines knowledge, attitude, and practices of 267 individuals categorizing the sample groups into high risk (HR) and moderate risk (MR) to malaria based on the annual parasite index (API)- parasite incidence per 1000 population. Less commitment to treatment, self-treatment, lack of indoor and outdoor vector prevention measures attributed to higher malaria risk in the region (Forero et al., 2014).

A descriptive and cross-sectional study to assess individuals KAP is conducted in Nigeria (Cairo, 2011) and (Atulomah et al., 2014). Knowledge was measured as a dummy variable and was figured as a weighted score one point for correct response and zero for an incorrect response, attitude indicator variables set as a categorical variable with different intensity, and malaria prevention seeking behavior was coded 0 for practices that put the individuals at risk, and 1 point otherwise.

Another community based cross-sectional study of KAP in Eritrea analyses an individual's preventive and treatment-seeking behavior. A series of questions about knowledge of malaria prevention and treatment-seeking behavior were asked for the respondents. Though malaria is preventable and treatable, lack of obedience to the preventive actions and delays in early treatment makes the disease major health challenge in the country(Andegiorgish, 2019). In addition to the great role of individuals' practices to prevent themselves, the influence of the neighborhood's knowledge, attitude, and practices are very important (Yaya et al., 2017).

Community-based study in Shewa Robit town in North-Eastern Ethiopia, which examined 425 individuals for malaria by using thin and thick Giemsa stained film. 284 individuals were examined for KAP (Knowledge, Attitude, and Practices). Regarding malaria prevention mechanisms the use of sleeping under bed nets, indoor, and outdoor residual spraying are mostly known and practiced. Knowledge and practices of malaria control and prevention mechanisms like a mosquito net, a house without a hole, and spraying insecticides and also living in a place which is located at least 500 meters from mosquito breeding sites was at a good level among the respondents (Abate et al., 2013).

The second line of literature focuses on studying the economic burden of the incidence of malaria in various parts of the world. A study that investigates the economic burden of malaria for instance cross-country study by taking 10 African countries used three approaches. Production function was used to capture the macroeconomic impact of malaria on GDP (gross domestic product). Cost of illness approach to estimate the direct, indirect, and institutional costs related to malaria illness. Willingness to pay (WTP) approach to estimate the cost of malaria on households welfare by determining the value they would have put on to reduce it (Okorosobo et al., 2011). A country-level study in Ghana analyzed the burden of malaria on GDP. Malaria is proxied by malaria index (related mortality and morbidity) and taken as an exogenous variable (Ankomah. et al., 2003).

Many studies in this line of literature consider malaria as an exogenous variable to analyze its economic impact on various outcomes. For example, some studies examined the economic burden of malaria at the macroeconomic level (Alonso et al., 2019; Ankomah. et al., 2003; Gallup and Sachs, 2001; Hailu et al., 2017; Nankabirwa et al., 2014). These studies model Economic growth (growth of real GDP) as a function of the malaria index. Malaria index is calculated by dividing the number of annual malaria outpatient morbidity by an estimated number of populations. Parallel to these works, it is essential to utilize the differences in malaria incidence across individuals before estimating its impact on other outcomes. The result from these studies shows that malaria has a negative and significant impact on the growth of real GDP. These studies remained silent about factors contributing to malaria incidence.

Malaria can be endogenous due to some reasons: maize productivity can be affected by household health seeking behavior through malaria-those who keep themselves from malaria may have more productivity and vice versa; simultaneity bias because of bi directional relationship between malaria and maize productivity. The direction of relationship from malaria to productivity- malaria may likely to reduce productivity. The direction from maize productivity to malaria may be those who are more productive have more income and able to keep themselves from malaria.

The studies mentioned above are either assessing an individual's health-seeking behavior or examine the impact of malaria on various outcomes. Those studies that investigate the burden of malaria take malaria as an exogenous variable. But many factors contribute to malaria incidence, meaning that it can be controlled within the system. This study assesses the health-producing behavior of households and most importantly links these behaviors of households with malaria incidence. After estimating how malaria is determined and will examine the impact of malaria on the economic variable. This will help to capture the path that malaria has from the factors contributing to the incidence of the impact it has on the economic outcome.

1.3 Hypothesis of the study

Based on the literature review, we hypothesize households that properly use malaria prevention mechanisms are less likely to be infected by malaria. We also hypothesize that malaria is expected to reduce school and workdays. Furthermore, malaria is expected to have a negative relationship with farm productivity.

1.4 Objective of the study

1.4.1 General Objective

The general objective of this thesis is to analyze the economic burden of malaria in Northwestern Ethiopia.

1.4.2 Specific Objectives

i. To assess the health-seeking behavior of rural households
ii. To examine factors contributing to malaria incidence
iii. To assess the effect of malaria incidence on school days of children
iv. To assess the effect of malaria on workdays of adults, and
v. To examine the impact of malaria on maize productivity

1.5 Methodology of the study

1.5.1 Data type and Source

The study used a cross-sectional household survey data collected in Northwestern Ethiopia. The household survey data is primary data collected by the Social Science and Impact Assessment Unit of the International Centre of Insect Physiology and Ecology (icipe).

1.5.2. Method of Estimation

Malaria incidence is more likely to be endogenous because of systematic differences across households in protecting themselves from malaria. Because we have multiple persons and plots within each household, the data we used provided as a unique opportunity to exploit the variation within households using random effect models, which will be discussed in detail in the next section. To capture the disparities we, therefore, use ordinary least square estimation (OLS), random effect (RE), two-stage least square estimation(2SLS), two Stage Generalized Least Squares (G2SLS), three-stage least square estimation(3SLS). The details of estimation methods are developed in the third chapter.

1.6 Significance of the study

Achieving the objectives of this study is going to have its contribution to the existing knowledge of malaria and its economic burden in Ethiopia in general and the study area in particular.

1.7 Limitation of the study

The major limitation of the study is it failed to include labor quality issues, which is an important component of labor supply analysis. Also, the study does not have information on the qualitative aspect of schooling.

1.8. Organization of the study

The rest of the thesis is structured as follows. Chapter 2 reviews the theoretical and empirical literature. Chapter 3 discusses the study area, data collection methods, and the econometric approach. Chapter 4 presents the findings of the study. Finally, chapter 5 presents the conclusion and policy implications.

CHAPTER TWO: REVIEW OF THEORETICAL AND EMPIRICAL LITERATURE

"*Where malaria prospers most, human societies have prospered least"*. Sachs and Malaney (2002) p.680

This chapter is organized according to the following sections: In the first section, we briefly discuss the link between disease and economic systems. In the second section, we review the global economic burden of malaria. In the third section, the theoretical foundation on the economic burden of malaria and the health-seeking behavior of households is presented. In the fourth section, we review the empirical evidence on the economic burden of malaria and the health-seeking behavior of households. In the fifth section, we evaluate evidence in the Ethiopian context. In the sixth section, we discuss the contribution of this study. In the last section, we present the conceptual framework of the study.

2.1 Diseases and Economic System

According to (Bujosa, 2000) there is a close relationship between diseases and the economic system. Most illnesses are the result of conflict between two economic systems: the microscopic nature of pathogenic animal species and the human species. The causes of the clash between the two systems are a need for food. Human diseases arise from the point of mutual equilibrium where the pathogenic species of animals should get food to survive. If human species were less powerful than animal species, the first would extinct from the world. On the other side if pathogenic species of animals cannot get food, it will vanish and with it the human disease it caused.

Throughout history economic growth has always posed serious population health challenges. It was a reason for many diseases like Tuberculosis (TB), syphilis, diphtheria, measles, and dysentery (Szreter, 2004). However, malaria is a typical disease of rural economies where the health system is not as good as in urban areas. Many associates the decline in mortality rate from infectious disease with the medical revolution, but it is learned that decrease in mortality did not have much connection with doctors' effort but with developments in economic conditions(Bynum, 2008).

2.2 Global Economic Burden of Malaria

Malaria levies a devastating burden on human beings in the history of mankind with other six major diseases such as; HIV/AIDS, diarrhea, tuberculosis, measles, pneumonia, and hepatitis B, which account for 85% of the world health burden. Malaria is a major health problem in Africa. This infectious disease has greatly accounted for the poor health status on the continent. Almost 90% of malarial death in the world is assessed to occur in Africa (Kumar, Valecha, Jain, & Dash, 2007).

The global pattern of growth of per-capita income or economic growth shows that there is a link between malaria and poverty. There are numerous channels by which malaria hampers development, including its effects on fertility, population growth, saving and investment, worker productivity, and brings absenteeism, premature mortality, and medical cost. There is an argument about the causal relationship between malaria and poverty. Some argue malaria causes poverty, some others argue that poverty is the one that causes malaria. Regardless of this debate, low malaria incidence significantly improves human capability and boost economic growth (Sachs and Malaney, 2002).

Besides worsening the health status of individuals, malaria imposes a huge economic burden on individuals and society at large. The most malarious countries of the world are those who are poor, and those countries who made significant changes in malaria prevention and control have had a better economic condition(Gallup and Sachs, 2001). The burden of malaria indicates that it is a critical developmental problem or can be a result of underdevelopment. From an aggregate perspective, it has a significant and negative impact on the growth of real GDP. In Africa malaria brought 1.3% annual reduction of economic growth which is USD 12 billion (Karunamoorthi, 2016).

Even though directly measuring the social burden of malaria is a difficult task, it can be seen through the magnitude of mortality and morbidity. Malaria is a reason for many schools and works absenteeism due to weaknesses and loss of productivity. This time may overlap with various farm activities such as planting and harvesting seasons(Sachs and Malaney, 2002).

Moreover, Malaria is a reason for huge private and public costs to prevent and control malaria. Private costs include individuals' expenses on controlling mechanisms, transportation costs to the medical center, diagnosis, drugs, and taking care of the patient. In 2016 the estimated figure shows total out-pocket expenditure from 106 malaria-prone countries due to malaria was around USD 556 million. In addition to private costs, the public in general incurred a cost due to malaria. These costs include government expenditure for prevention, health facilities, research, and education.

The estimates in 2016 show governments spent USD 1·2 billion to prevent and control malaria. In the same year, global assistance for malaria prevention reached USD 2·4 billion(Haakenstad et al., 2019).

Not so long ago, many studies of economic growth models have used malaria as an explanatory variable in cross country regression analysis, and have confirmed a significant relationship between gross domestic product (GDP) or per capita growth and economic burden of malaria(Gallup and Sachs, 2001). Others also suggest that countries with a substantial amount of malaria grew 1.3% per year less (controlling for other influences on growth), and 0.3% more economic growth is associated with a 10% reduction of malaria(Sachs and Malaney, 2002).

In 2003 a study conducted in Ghana shows in a country level malaria harms the growth rate of real GDP in an estimated econometric model. It found that an increase in one percentage point in the malaria morbidity rate would slow down the growth rate of real GDP by 0.41%. This figure is lower than what was estimated by McCarthy et al in 1998, which is 0.61%. The Cost of illness approach shows that a single malaria episode in the household brought an average cost of USD 16. Among the total cost incurred the major part of it goes to drugs. Morbidity due to malaria leads to a reduction in productive hours not only for the patients but also for the caregivers. In terms of the number of days lost due to illness, for the patient around 9 days, and the caregivers, 5 workdays lost. On average for school-aged children, a single case of malaria leads to missing four school days(Asenso-Okyere et al., 2009).

Malaria and Socio-Economic Status (SES) of households have a bidirectional relationship. SES affects the incidence of malaria, and malaria incidence affects SES. SES affects malaria through scant resources for malaria prevention and treatment mechanisms. In sub-Saharan Africa, households spend a high proportion of their income on malaria prevention measures, which is around USD 180 per year. In contrast, it is projected that malaria diminishes labor supply and labor productivity, which reduces a household's income level. From one to five adult's working day is lost per malaria episode, and the same amount of adult's days is lost due to taking care of ill children. Also, in the absence of formal health insurance, malaria leads to a high cost to be covered by the households. Furthermore, malaria may bring a shift in productive activities of households and may induce households to change their productive activities ex-ante, and such rearrangement may come at the expense of wealth accumulation(De Castro and Fisher, 2012).

2.3 Theoretical foundation on the link between malaria and development outcomes

2.3.1 The link between malaria and education outcomes

Most grand economic growth theories remain silent about health-related issues. For instance, the Harrod-Domar model which puts economic growth as a function of the level of saving, capital, and productivity(R. F. Harrod, 1939). For the obvious reason, productivity depends on the health status of workers, but this model does not explicitly mention the importance of health for economic growth. The other one is Solow-Swan growth theory explains economic growth as a process between inputs like capital, labor, and technology(Solow, 1956). This model also does not explicitly mention the significance of health for output.

The well-known economic theory which emphasized health is the human capital theory (Schultz, 1961). Human capital theory; starting from the early work of Adam Smith to the formalization of human capital theory by Becker (1964). This theory mentioned the importance of health for the economic growth of a country. According to this theory, the health status of individuals has an indispensable part of human capital formation, which ensures the productivity of individuals in combination with other components of human capital. The idea that health could be part of human capital gained power in the early 1970s, and it has remained a pillar in health economics textbooks.

The vital role of people to national growth and development is recognized by most economists since long, which is measured by productive capacity or the contribution of human beings to output. Human capital became the major driving force of nations' economy outweighing different forms of wealth. Despite the economist's great attention to human capital, many of them have strained the simple fact that people invest in themselves and these investments are by far large (Schultz, 1961).

Enhancements in the education and health of individuals are vital to the development process. Individuals emphasize their health and education; this helps to increase an individual's capacity to work and this intern contributes to the development in the field. Human capital refers to the health, nutrition, formal education, and job training in the flesh of human beings. Though human capital has many components, health and education are the main ones. Improvements in human capital help individuals to acquire good health and education, and also it generates future income (Bardhan and Udry, 2000). The difference in the level of health and education is greatly responsible for differences in the level of earning individually and economic growth nationally (Schultz, 1961).

The notion of human capital for economic growth dates back to the time of Adam Smith1776, a pioneer of a classical economist who traced out the significance of the human capital investment for the economy and he later formulated the basis of what was later called human capital science. According to Smith, economic growth depends not only on physical capital but also human capital. He noted that building human capital is significant to bring about economic growth. In his book, *an inquiry into the nature and causes of the wealth of the nation* Smith recognized that an educated individual is by far productive and efficient than the one who does not. Human capital accumulation can be defined as the acquisition of talents due to education, health training, or apprenticeship. Most importantly, education and health as two principal components of human capital (Spengler, 1977).

In a very comprehensive way, there are three possible explanations for the relationship between health and education. The first one is poor health condition leads to a low level of schooling. The second possibility is as the level of education increases the health status also increases. The last possibility is there is another factor which affects both health and education. The relationship between health and education from health to education can be brought about from practices during childhood. If children experience poor health conditions, they are highly unlikely to go to school and attend properly in adulthood(Cutler et al., 2006).

Most importantly the difference in adult's income and employment status lay on the level of education and health of their childhood. Nowadays more emphasis is given to the impact of health on education because children's' health is an important factor that determines the performance and attainment of school. Developing countries are those who are facing life-threatening health challenges than developed ones(Suhrcke, 2011).

Malaria has a devastating impact on health and education. Education has an inverse relation with malaria. Less malaria leads to regular attendance of children, which is expected to increase educational performance, intern leads to better wage-earning ability in the future(Malaria Advocacy Working Group, 2016).

2.3.2 The link between malaria and farm productivity

When the agricultural sector sneezes, the whole economy of developing countries catches the cough since many in this region depend on their livelihood on agriculture. Agricultural output depends on the health of the labor force, which is laden by health shocks and diseases. Good health condition enhances the productivity of farm households, in contrast, bad health condition leads to less production and productivity (Awoniyi et al., 2018).

The relationship between health and agriculture is bi-directional: health affects agricultural production and agricultural production affects health. In both directions, there are positive and negative impacts that lead to better or worse results. Good health supports agriculture and poor health vice versa. Agriculture is important for good health conditions via food and other materials produced for food, medicine, and shelter, and agriculture leads to a major health problem in rural households like nutrition-related disease, malaria, a water-borne disease, and others (Asenso-Okyere et al., 2009).

There are three possible channels in which poor health affects agricultural production. Firstly, poor health reduces labor time due to illness and death. Secondly poor health status restricts the effort of the labor force to exert on a given agricultural activity, leading to a decline in productivity and its general effect on rural economies. Last but not the least, morbidity and mortality from malaria limit innovations in the agricultural sector, and modernization is far from being realized in this sector through a loss of knowledge of the productive working-age population in the sector and the loss of properties used to convey innovations. Since the vast proportion of the world poor population live under subsistence agricultural activities, these groups suffer excessively from malaria-related illness and death, a combined assessment of agriculture and health is essential to endorse agricultural growth and development and reduce persistent rural poverty(Dillon et al., 2010)

There is also another mechanism that one can see the impact of malaria on farm productivity. In the incidence of death of working age, in addition to the loss of farming knowledge, the supply of farm labor is affected, which intern distorts the flow of agricultural innovation. Malaria directly leads to shifting in farming techniques such as reducing the farming output due to a reduction in the workforce. If the farmers want to keep their production as before, they should hire another labor from outside, which brings additional costs to the family. But the big problem with the hired labor is, they might not be a perfect substitute for the family labor. It is projected that recurrent bouts of malaria in agricultural households would cause a decline in farm income and farm output, and cause food insecurity and an increase in poverty (Asenso-Okyere et al., 2009).

2.3.3 Malaria Control Methods

To reduce the impact of malaria, global interventions have been taken place by World Health Organization and respective governments. In 1998 WHO initiated the Roll Back Malaria Initiative (RBM). The RBM gets momentum since the Abuja Malaria Summit in 2000. Since then the international community has given special attention to malaria prevention and control. The Global Fund to Fight against AIDS, Tuberculosis, and Malaria established in 1998. Since then spending to reduce malaria has doubled specifically with the foundation of the global target of RBM to reduce malaria-related morbidity and mortality by 2010 starting from 2000(WHO, 2008).

There are various strategies for malaria prevention. One strategy is Vector Control Management (VCM) consisting of Insecticide-treated mosquito nets (ITNs), Indoor Residual Spraying (IRS), and Larval source management (LSM). These strategies are designed to limit the ability of a vector to transmit the disease (WHO, 2010). IRS is done by spraying insecticides on the roofs and walls where the mosquitos are highly likely to rest upon. LSM is the management of the potential breeding sites for mosquitoes(aquatic habitats), to prevent the development of the vector(Fillinger and Lindsay, 2011).

The major VCM: ITNs and IRS, reduce the risk of malaria by controlling the indoor spread of mosquitoes. The effectiveness of the IRS depends upon the formulation of insecticide and the surface which is sprayed, it could long last from 3-6 months. These two methods are effective in malaria control, but not adequate to eradicate malaria. The major reason for the ineffectiveness of these vector control methods resistance of insecticides nets and revelation to mosquito outside bed hours(Gari and Lindtjørn, 2018).

Relying only on VCM cannot significantly reduce malaria incidence. Another strategy is needed for example House improvement (HI) comprises screening in ventilators, closed eaves, early closing of windows, and doors help to protect oneself from mosquito, which transmits malaria infection. The development of HI is to lessen the indoor contact between human beings and mosquitoes(Killeen et al., 2016). Improved houses are evidenced to eliminate malaria in the USA and Europe(Zhao et al., 2016). Though house screening is not a recent development, it is still far from being prioritized(Getawen et al., 2018).

The global commitment of VCM is promising. WHO promotes universal coverage of insecticide-treated bed nets (ITNs), IRS, and LSM particularly in sub-Saharan African countries. House screening also needs such global commitments, but before diverting resources from VCM to House screening, issues related to screening should be addressed. For instance, the life span of screens, and efficiency if holes develop. Further evidence on house screening is needed since it has huge costs. If screening is not effective when a hole develops, should it have supplemented with an insecticide? Though the effectiveness of house screening is under experiment, the integrated approach of VCM and HI will be more effective (Killeen et al., 2016).

Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change (CAP-Africa) have a program of integrated vector control management in Ethiopia- Amhara National Regional State, Kenya- Kenya Agricultural and Livestock Research Organization (KALRO), Tanzania- Agricultural Research Institute, Uganda- National Agricultural Research Organization (NARO). The main component of the integrated approach is house screening to help other malaria prevention measures (Asale et al, 2020).

The role of households to prevent the disease is undeniable, but there is a need for an integrated approach of malaria prevention with the existing mechanisms to reduce the burden significantly. These approaches are used not only to prevent malaria but also other diseases that affect the cardiovascular system(Musoke et al., 2018).

2.3.4 Health-seeking behavior of the households

According to Ward, Mertens, and Thomas: the health-seeking behavior of individuals can be defined as “any activity undertaken by individuals who perceive themselves to have a health problem or to be ill to find an appropriate remedy” Ward et al. (1997) page.21. Household behavior, society norms, expectation, and characteristics related to health providers determine the decision-making process of individuals, which in turn shape households' health-seeking behavior(Olenja, 2003). Health seeking behavior of individuals cannot be understood solely. It co-exists with socio-cultural factors and quality of health services because these factors determine household behavior regarding the prevention and treatment of any disease(Ward et al., 1997).

Health seeking behavior of households regarding the prevention and treatment of malaria determines the burden of the disease. Improvement in the awareness of individuals about the disease and its devastation contribute to the declining global burden of malaria (Dave-agboola et al., 2018).

Knowledge, Attitudes, and Practices (KAP) studies give an insight into the knowledge, the belief, and deeds of the communities towards the topic in concern. In this case, it provides what is the health-seeking behavior of households towards prevention mechanisms. KAP helps to identify the knowledge gaps in malaria prevention mechanisms, the belief towards different controlling mechanisms, and the behavioral outlines that may ease thought and action towards different prevention mechanisms(DaBreo et al., 2016).

2.4 Empirical evidence on malaria

2.4.1 Empirical evidence on the impact of malaria on education outcomes

The study of the impact of malaria on education outcome is not scant. The main concern here is how does malaria affects educational outcomes meaning that the mechanism through which malaria and educational outcomes are connected. There is a possible way that malaria and education outcomes are related like the biological, clinical and behavioral outcome, which affects the mental process in knowing, learning, and, understanding (Thuilliez et al., 2010).

A study conducted in Kenya in 2000 found that about 13-50 health-related absence from school is ascribed to malaria 20 school days are missed per child because of malaria (Kuecken, 2013).

The other study conducted in Kenya by 2009 shows that those Kenyan children who are infected by malaria through pregnancy suffered a lot for instance from 1,854 children with this case 302 died and 16% of the survivors were neurologically impaired. Another study conducted in Kenya found similar results and adding details on the consequences of malaria on cognitive ability. Deficits in memory, attention, visuospatial skills, language and executive functions are the impact of malaria. Though cerebral malaria is the major, it is the only one to cause the above distortions (Thuilliez, 2009).

Living in a village that is less vulnerable to malaria increases the schooling level of children by nearly 110 days annually compering to living in a malarious area, this figure is huge in a country where schooling is very minimal. Education level also reduced by future sickness expectations; if parents expect the epidemic is coming in the future, they don’t allow children to go to school. This makes children to entry school lately and/or no entry at all (Burlando, 2012).

In 2010, the study assesses the impact of malaria eradication campaigns from the 1940s to 1970s in Paraguay and Sri Lanka on education attainment and literacy and found that a negative and significant impact of malaria incidence on education in both countries. On average a 10 % decrease in malaria incidence brought 36 more school days compared with the time that they were sick and it increases in the probability of being literate from 1% to 2% (Lucas, 2010).

2.4.2 Empirical evidence on the health-seeking behavior of households

There are many studies which assess the household's health-seeking behavior of malaria and how this contributes to the outcome of malaria. One study in Bangladesh analyzes the health-seeking behavior of slash and burn cultivators, which are the most vulnerable group to malaria in South-East Asia through assessing the knowledge, attitude, and practices of prevention and treatment of malaria in this group. The result shows a high level of knowledge, and good attitudes towards malaria intervention programs together with promising malaria prevention and treatment-seeking behavior among the sample representative of slash and burn cultivators in Bangladesh. This is guaranteeing the goal - malaria elimination in Bangladesh to be achieved by 2030 (Saha et al., 2019).

A study in Colombia by classifying the sample groups into high risk (HR) and moderate risk (MR) to malaria based on the annual parasite index (API)- parasite incidence per 1000 population examines the knowledge, attitude, and practices of 267 residents. In both HR and MR regions it is found that there is no significant variation in knowledge of malaria symptoms, but there is a significant difference in knowledge and attitude about transmission mechanisms, anti-malaria uses, and malaria diagnosis about between the two regions. 93.5% and 94.3% of respondents in MR and HR regions respectively indicated that they use insecticide-treated nets (ITNs) to protect themselves from malaria. 75.5% of respondents in HR did nothing regarding outdoor malaria prevention mechanisms. Though the figure shows there is a high level of knowledge in the study regions, substantial gaps continued regarding practices. Less commitment to treatment, self-treatment, lack of indoor and outdoor vector prevention measures attribute to higher malaria risk in the region (Forero et al., 2014).

The result in Oyo south-western Nigeria shows among 192 respondents, 93.2% of them know that mosquito bites transmit malaria, 38.7% of adults and 13.7% of children took the correct dosage. Self -treatment at home accounts for 90% of first malaria treatment methods by using local herbs or drugs from the medicine store. Only 16.7% of respondents use insecticide-treated nets (ITNs). 8.9% of residents did not have a windows screen. Among the households with screened windows, 8.9% had rusty and torn nets. Positive malaria-related KAP is highly dependent upon the education level of the household head. Environmental hygiene and types of windows were highly associated with the prevalence of malaria(Adedotun et al., 2010).

Community-based study in Shewa Robit town in North-Eastern Ethiopia, which examined 425 individuals for malaria by using thin and thick Giemsa stained film. Only 2.8% of participants were positive for *Plasmodium* parasites. 284 participants were evaluated to measure KAP about malaria. They all heard about malaria before. 85% of respondents confined the cause of malaria to mosquito bites. Greater than 20% of respondents mentioned exposure to cold weather, hunger, chewing maize stalk, lack of personal hygiene, and body contact with patients as a cause of malaria in addition to mosquito bites. Regarding malaria prevention mechanisms the use of sleeping under a bed net, indoor, and outdoor residual spraying are mostly known and practiced. Knowledge and practices on malaria control and prevention mechanisms like a mosquito net, a house without holes in the wall and sprayed with insecticides and also living in a place which is located at least 500 meters from mosquito breeding sites were mentioned by respondents (Abate et al., 2013).

2.4.3 Socio-economic factors associated with malaria

Malaria related morbidity and mortality have been declining, but it remains the major health problem in Ethiopia. The trend of malaria in the nation shows on average around 9 million malaria incidences occur annually. In Ethiopia, the major epidemics of malaria occur every five to eight years. In the year of epidemics in addition to the annual cases, 6 million additional malaria cases are recorded. In 9 months of 2003, 114,000 people died because of this infectious disease(Adugna, 2006).

Around 50 million people in the country are living in the area, which is vulnerable to malaria. More than 75% of areas in the country are prone to malaria, making malaria the most dangerous health and developmental challenge in the country (Ayele, 2012).

Malaria transmission in the country shows seasonal and fluctuating patterns. The transmission reaches its highest stage from September to December after rainy seasons in some parts of the country, which coincides with the major harvesting and planting time(Minister of Health, 2015). Altitude has a great effect on the distribution of malaria among regions. Most highlands are less likely to be conquered by the vector which transmits malaria infection. The relatively low areas of Northern and Eastern Highlands are confined to malaria endemicity. Presently, areas which are lower than 2000 meters above mean sea level of altitude are thought to be malarious and occasionally it affects areas up to 2300 meter above mean sea level (Adugna, 2006).

Moreover, the intensity of transmission depends on climate (rainfall, humidity, and temperature), topography (vegetation cover, hydrology, and land use), population movement, and human settlement(Girum et al., 2019).

According to the 2014 World Bank Report, Malaria related costs are high among rural households of Ethiopia. Since greater than a quarter of the population in the country are living in destitution. This problem is even worse among rural households. The fluke of malaria peak season and main farming activities combined with the frequent nature of malaria imposes an intolerable burden on poor rural households whose primary source of living is subsistence farming and does not have other coping mechanisms (World Bank, 2014).

A country-level study aimed at assessing the burden of malaria in terms of death rate and Disability-Adjusted Life Years lost (DALY) between 2000 and 2016 by using data set from Global Health Estimate 2016 and the result shows 2,927,266 new malaria cases were in Ethiopia. This brought around 4,782 deaths with a crude death rate of 4.7/100,000. Moreover, it leads to 365,900 years of DALY (178,900 years among females and 187,000 years among males). Malaria alone accounts for 0.78% of total DALY in Ethiopia and 1% of malaria-related global DALY. Mortality and DALY due to malaria are somewhat higher among males; and under 5 children are highly infested (Girum et al., 2019).

A baseline survey from December 2006 to January 2007, in Amhara, Oromia and Southern Nation Nationalities and People (SNNP) regions of Ethiopia analyses the data by a generalized linear model that was collected at the Carter Center. The outcome variable is the presence or absence of malaria using the rapid diagnosis test (RDT). The result from RDT shows there is a substantial difference in malaria across age and gender. The major determinants of malaria were identified such as; materials used for walls and material used for roofing, source of water, trip to obtain water, toilet facility, the total number of rooms, the availability of clean water. Malaria rapid diagnosis found to be higher among households who live in houses with thatch and stick/mud roof and earth/local dung. Moreover, the housing condition, source of water, and its distance, gender, and ages in the households were acknowledged to have two-way interaction effects (Ayele, 2012). The Ethiopian government has been made different efforts like providing prevention tools and treatment mechanisms. Starting from 2003, the health extension program was launched as part of primary health care service, however, it is still a major health problem in many parts of the country(Alelign and Dejene, 2016).

In 2005 estimated figure shows if malaria prevention mechanisms have fully deployed, it would have saved 70,4000 people every year. In the same year, the total number of ITNs accessed to the society was 4.5 million, which by far less than needed to reach 100% coverage (20 million ITNs)(Adugna, 2006).

The incidence of malaria depends on natural factors like climate. The nurture duration of mosquitoes is highly dependent on temperature since the parasites are sensitive to temperature. Mosquitoes are highly likely to breed in warmer environments than cooler areas. Due to this fact malaria is high in lowland and hot areas compared to highlands. It is most prevalent in tropical and sub-tropical regions of the world, where many poor countries are located(Paaijmans et al., 2009).

Though transmission and distribution of malaria largely depend on the climate, it is learned that socioeconomic status can widen the incidence of malaria(De Castro & Fisher, 2012). Low socio-economic status aggravates malaria transmission since the poor cannot use different prevention methods. The success of malaria elimination in countries like the United States, Greece, Spain, and Italy was an outcome of combined improvement in socio-economic status and preventive methods. Poor nutritional status also exacerbates malaria incidence by lessening immunity. However, unaccompanied economic development is not a sufficient condition to eradicate malaria. Countries even with higher year-round temperatures and wealth like the United Arab Emirates and Oman are still malarious (Sachs and Malaney, 2002).

In developing countries in addition to those factors mentioned above housing condition determines malaria incidence. For instance, unscreened windows and open eaves allow the mosquitoes to enter the house and infect people (Mirza, Hashim, & Sheikh, 2017). The other housing factor is animals sheltered in the main house increase the likelihood of the infection because animals' urine age ranging from 1 to 7 days affects the oviposition response of mosquitoes(Kweka et al., 2011).

Above all Individuals, Knowledge, Attitude, and Practices (KAP) regarding malaria and its prevention methods is of very importance. It is expected that those who know more about malaria are less vulnerable than those who don't. Though mere knowledge about malaria does not guarantee to be free from malaria, it should be accompanied by practices. Practices such as; not using bed nets properly, late closing of doors/windows, staying outside late-night and living around stagnant water increase the probability of being bitten by mosquitoes. Households can reduce the risk by using ITNS and IRS and also by using different precautions (which help to reduce the likelihood of being infected by a mosquito(Mirza et al., 2017).

2.5 Evaluation of the Theoretical and Empirical Evidence in the Ethiopian Context

Most theoretical approaches to the assessment of Knowledge, Attitudes, and Practices (KAP) of malaria can be adapted to the Ethiopian context. Moreover, empirical evidence on KAP tried to assess the knowledge, attitude, and practices of rural households in Ethiopia. For instance, a community-based survey was taken in North East Ethiopia to examine the household's knowledge and attitude about malaria and practices regarding preventive mechanisms (Abate et al., 2013) and linking knowledge and practices with malaria tests during the time of the survey. This study concluded there was a good level of knowledge about the cause, symptom, transmission, and preventive methods of malaria and this is manifested through a low level of malaria prevalence (2.8%). Treatment seeking behavior of households is missing in the study which can capture health producing behavior of households and might affect the probability of getting infected by malaria next time.

There is some empirical evidence on the economic burden of malaria in Ethiopia such as a study conducted in south-central Ethiopia(Hailu et al., 2017). This study examines the direct, indirect, and total cost of malaria and linking with socio-economic status. The direct costs include direct medical costs and non-medical costs. Indirect costs were measured by the number of missed working days of the patients and caregivers due to malaria illness. The number of missed days of patients and caregivers were converted to monetary value. Changing the number of working days lost to monetary value by using the average wage rate of agricultural workers may not capture the variability in an economy where the labor market is barely organized. A community-based cross-sectional study from western Ethiopia on the economic burden of malaria (Tefera, Sinkie, & Wolde Daka, 2020) uses the same approach with the previous study but differs in the measurement of the indirect cost of malaria. Indirect costs of malaria were measured by lost workdays. The result is the same as the previous study that concluded malaria remains to substantially impose a huge economic burden on the rural households of Ethiopia.

2.6 Approach and Contribution of this study

In this study, practice-related variables regarding malaria prevention methods and malaria incidence are assessed. This study links practices of households about malaria with malaria incidence. This helps to connect which practices of households exposed to malaria, and which do not.

Coming to the economic burden of malaria, this study identifies different outcomes such as; lost school days, lost workdays, and farm productivity. Lost school days can capture the impact of malaria on children, lost workdays can capture the burden among adults. In addition to these, this study estimates the impact of malaria on farm productivity.

2.7 Conceptual Framework

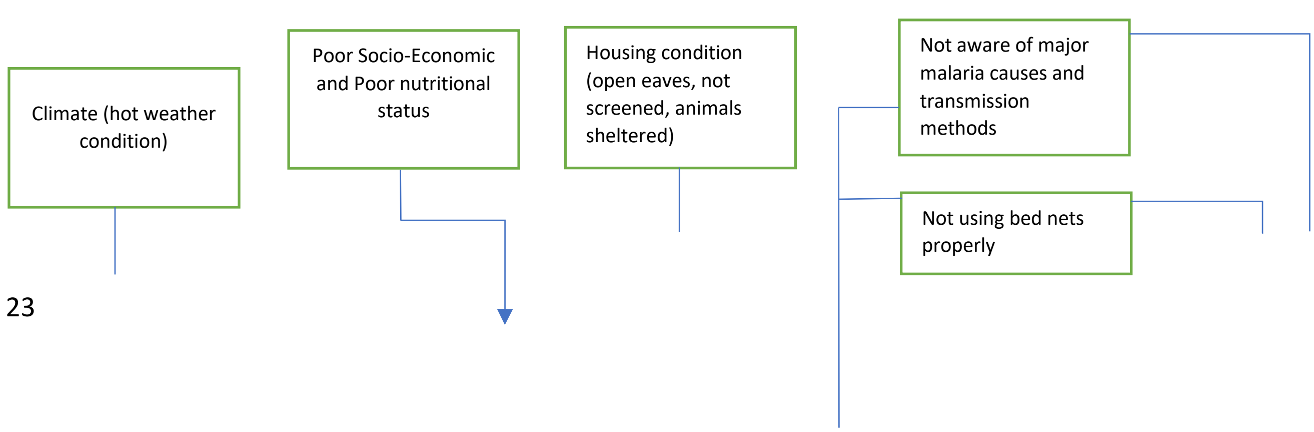
Based on the literature review above, the conceptual framework for this study is shown in figure 2.1 below. The figure contains two parts: factors contributing to malaria incidence and the outcomes of malaria. The first part contains various factors that contribute to the incidence of malaria. Climatic factor (hot weather condition) creates favorable conditions for mosquitoes to breed and this leads to malaria incidence. Poor socioeconomic status also aggravates malaria since the poor cannot afford various prevention mechanisms. Poor nutritional status causes malaria by lessening immunity. Housing conditions also determine the incidence of malaria. Those who live in houses with open eaves and animals sheltered in the main house are vulnerable to malaria. Moreover, practices such as not using bed nets properly, late closing of doors/windows, staying outside late-night, and living around stagnant water increase the probability of being infected. Households can reduce the risk by using ITNS and IRS and by adjusting their practices regarding malaria preventions.

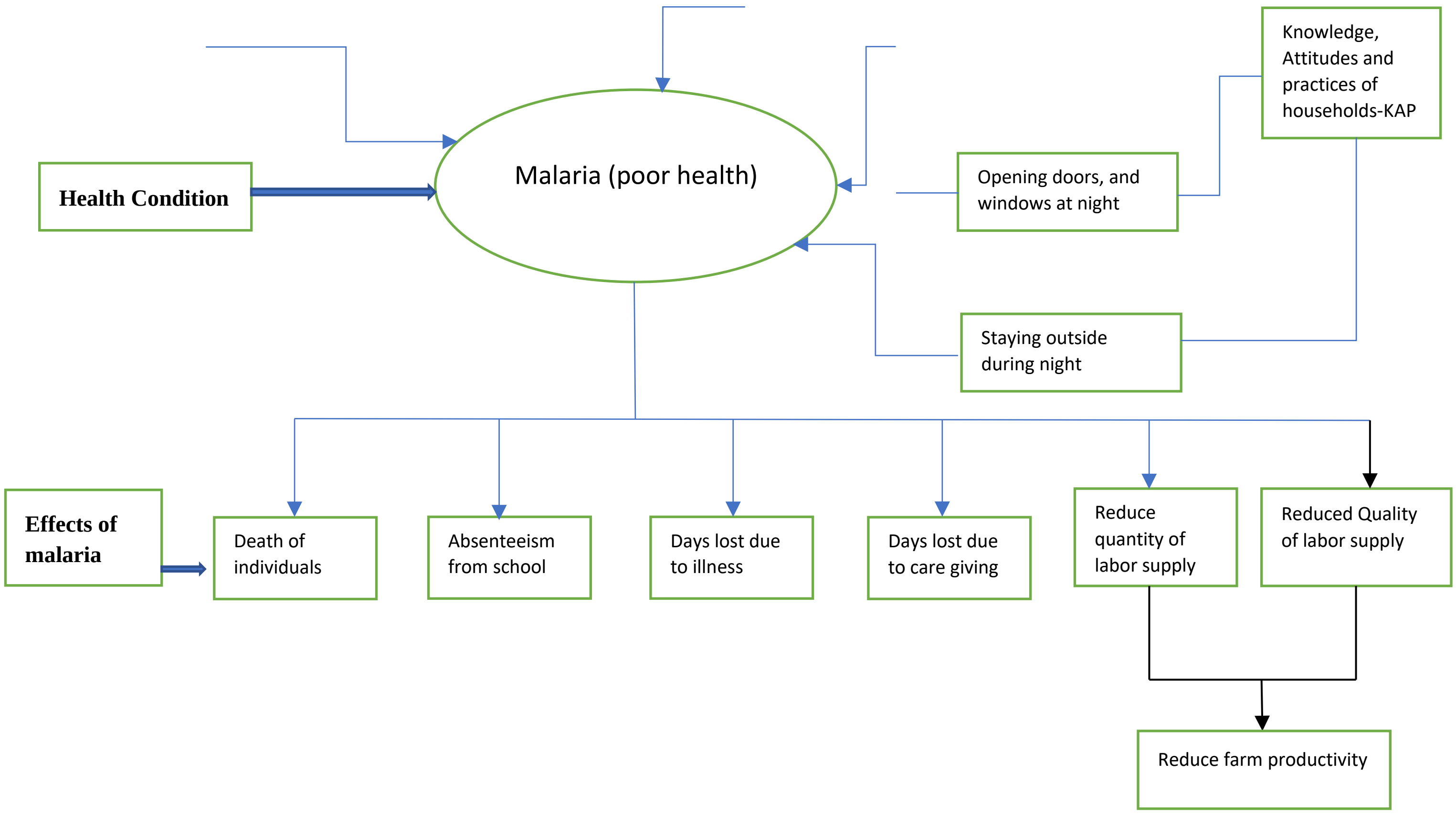
The second part of the diagram comprises various outcomes of malaria. The burden of malaria in the agricultural sector lies in the lost productive time by the ill person and the member of the household who devote their time to take care of the sick person. Malaria makes the person absent from working place during illness and recovery period (Abimbola, 2007). When farm family's loss a member in a household through death, or illness, or caretaking, the capacity to generate income from wage labor or participating in off-farming activities declines, this negatively affects food security and standard of living of the rural households. The weakness of economically active population reduce the quantity of labor supply (Death of individuals or number of days lost due to malaria; Malaria makes the person absent from working place during illness and recovery period) and also the quality of the labor(Reduced work capacity) even if an ill person go for work he/she will not be effective as normal days(Asenso-Okyere et al., 2009).

Malaria incidence leads to school absenteeism, dropouts due to illness of students and when a parent is ill, children substitute adults to take care of the sick family members. Moreover, high malaria incidence leads to late entry of school and can probably hinder entry at all. Malaria affects education outcomes through missing classes due to malaria-related illness and recovery period, so malaria leads to absence from school, the low performance of students, and grade retention(Thuilliez et al., 2010). Malaria brings the cost to the individual, society, and government for malaria prevention and treatment. Spending on insecticide-treated nets (ITNs), indoor residual spraying (IRS), and other prevention methods can be regarded as the pre malaria cost. Costs for medication, diagnosis, transportation, during a stay in health centers are treatment-related costs(WHO, 2008).

Malaria affects farm productivity in two ways (1) it reduces the quantity of labor supply: individuals who are infected by malaria are highly likely to lose workdays (2) it reduces labor quality: even though individuals who are ill going for work, they no longer be effective as before. Due to this malaria affects productivity through malaria incidence.

In a nutshell, the burden of malaria in the agricultural sector lies in the lost productive time by the ill person and the member of the household who devote their time to take care of a sick person. To the worst, the death of an ill person leads to a complete loss of the labor time of a dead person. This takes labor supply from farm activities and may harm the adoption of labor-intensive technologies. When farm family's loss a member in a household through death, or illness, or caretaking, the capacity to generate income from wage labor or participating in off-farming activities declines, this negatively affects food security and standard of living of the rural households (Asenso-Okyere et al., 2009).





Source: Adapted from Asenso-Okyere et al., 2009

Figure 2. 1: Factors contributing to malaria incidence and outcomes of malaria

CHAPTER THREE: MODELLING ECONOMIC BURDEN OF MALARIA AND ESTIMATION STRATEGY

This chapter is organized according to the following sections: In the first section, we discuss the data source. In the second section, we describe the study area. In the third section, we state data collection methods. In the last section, we present the empirical model of the study.

3.1 Data Source

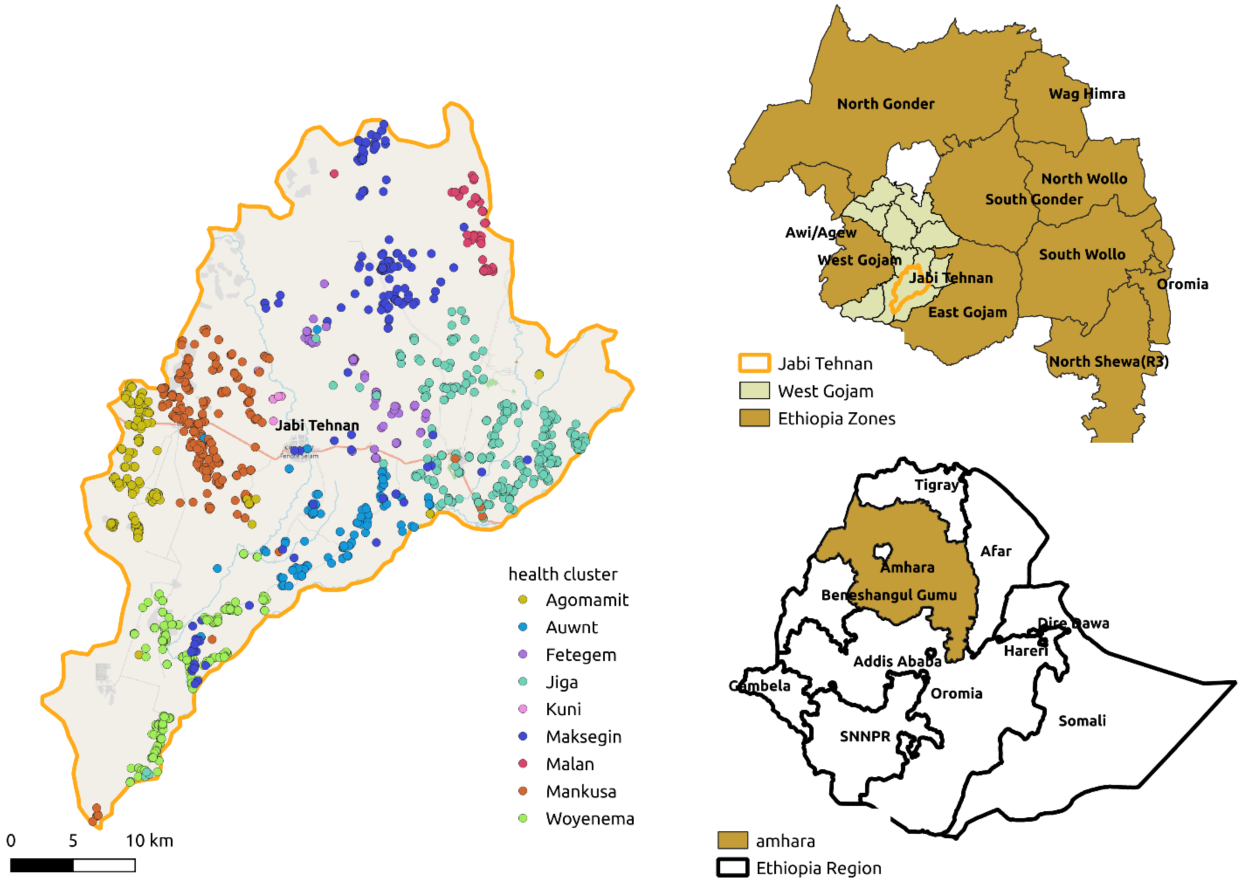
The data for this study is obtained from the Social Science and Impact Assessment Unit of the International Centre of Insect Physiology and Ecology (*icipe*). It was collected by the *icipe*'s "Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change (CAP-Africa)" project in June and July of 2019. This project is aimed at improving health and food security in four countries; Ethiopia, Kenya, Tanzania, and Uganda between 2018 and 2022. The focus of this study is based on the data collected in Ethiopia.

3.2 Study Area

The study and the CAP Africa project area are in Northwestern Ethiopia (Figure 3.1). Specifically, it is the Jabi-tehnan district of the Amhara Regional State of Ethiopia. The capital city of the district is Finote-Selam. The district is bordered with Sekella district in the northwest, Dembecha district in South East, Quarit district in the north, Bure district in the west, Dega Damot in the east.

The elevation of the district ranges from the lowest point (1,500 meters) to the highest point (2,300 meters) above the sea level. The landscape of the district is mainly with flat plain areas (65%) and the rest of the areas are mountainous (15%), undulating (15%), and valley (5%). The annual rainfall extends to 1,250 mm with the major rainfall season from May to September. The temperature of the district varies from the average minimum (14 °C) to the average maximum(32 °C) (Asmare and Gure, 2019).

The Jabi-tehnan district consists of 38 rural kebeles and two town administrations. The population of the district of Jabi-tehnan is 179,342 of which 93% of the inhabitants live in rural areas (CSA, 2008). Agriculture is the primary source of livelihood for most of the population in the district. The district is known for its maize production. It covers 5% of the Amhara Regional State maize production, and 1% of Ethiopia maize production in 2018 (CSA, 2019; JBOA, 2018).



Source: Asale et al (2020).

Figure 3. 1: Map of the Jabi-tehnan district.

The district is one of the malarious districts in the Amhara Regional State. A test conducted at Jiga health center between September of 2009 and August of 2013 shows among 194,818 patients examined for malaria 25.4% of them had confirmed the prevalence of malaria (Ayalew, Mamo, Animut, & Erko, 2016)

The government has been undertaking various methods to protect societies from malaria. Not so long that Millennium Development Goals (MDGs) had introduced different intervention mechanisms such as early diagnosis, artemisinin-based combination therapy (ACT), and the use of vector control mechanisms to prevent malaria including insecticide-treated bed nets and indoor residual spray (United Nations, 2015).

The 2006-2010 National Strategic Plan designed to fasten different intervention mechanisms of malaria control and to reduce the burden of malaria by 50% (Minister of Health, 2015). This plan has the same strategies of malaria reduction methods with MDGs and targeted to ensure 100%

coverage of Long-Lasting Insecticide Nets (LLINs) and 60% of IRS coverage in malaria-endemic areas. Though the strategic plan made improvements in the distribution of vector control, it failed to achieve the targets.

Updated National Strategic Plan for Malaria Prevention Control and Elimination in Ethiopia was established from 2011 to 2015 as an extension to the previous plan. In addition to the previous plan, the new plan widens the strategies to accelerate the reduction of malaria including LLINs, IRS, active case detection, and active surveillance and epidemic control. To ensure the reachability of the benefits to all the population, the plan had monitoring and evaluation of malaria control from the highest to the lowest administrative units (Federal to Kebele level) (Minister of Health, 2015). In the Jabi-tehnan district, using bed nets for other purposes became a hindrance to achieving malaria reduction goals (Asale et al., 2020).

3.3 Description of the Data

The *kebeles* of the district are divided into 115 sub-*kebeles*. The survey covers the cropping calendar of 2018/2019. As a sampling frame for this study up to date census of one to five group leaders and the members were used. In each of sub-*kebele,* there is a list of one to five group leaders and individuals under them provided by Jabi-tehnan District Bureau of Agriculture. Nearly 27 households were randomly picked per sub-*kebele*. Depending on the size of sub-*kebeles*, the number of households varies from one to another. The sample size of the study is around 3010 households and nearly 15000 individuals.

A structured questionnaire was used to collect the data. The questionnaire includes details on household-level socioeconomic and demographic factors, plot-level characteristics, the volume of production, the economic burden of malaria, seeds use, and production constraints including Fall armyworm (FAW) and Stem Borers. Among these parts of the questionnaire, this study uses the information related to the household's health producing behavior regarding malaria prevention and control and the economic burden of malaria.

The data were collected by trained enumerators (28 enumerators and 4 supervisors). The enumerators and supervisors received a one-day training and have had a day piloting of the questionnaire before the actual data collection started. The training and the piloting helped us to ensure that enumerators and supervisors understand the questionnaire. The data collection was collected in the Computer-Assisted Personal Interviewing (CAPI) system designed using CSPro software. Before we started data collection, we asked consent from farmers, and it was only collected based on the willingness of respondents.

3.4 Empirical model

In econometrics modeling, the problem of endogeneity arises when explanatory variables are correlated with the error term for various reasons: (a) explanatory variables measured with errors, (b) omitted variables correlate with the explanatory and dependent variable, and/or (c) explanatory and the dependent variable is simultaneously determined. Running a simple one-stage OLS regression of endogenous explanatory variables on outcome variables leads to biased and inconsistent estimates of coefficients.

In the context of our study, the incidence of malaria might be endogenous because of differences in individuals' and households' practices of controlling malaria. For example, differences in the usage of insecticide-treated bed nets may create systematic differences in the incidence of malaria.

We model the impact of malaria incidence on farm productivity using the two-stage least squares (2SLS). In the first stage, the incidence of malaria is estimated as shown in equation (1).

$$M_{ij} = \alpha_0 + \alpha'_1 \boldsymbol{KAP_{ij}} + \alpha'_3 \boldsymbol{Z_{ij}} + \alpha'_4 \boldsymbol{V_j} + \epsilon_{ij} \tag{1}$$

Where the indices *i* and *j* represent individual and household, respectively. Where represents the incidence of malaria, which takes the value of 1 if at least one individual in the household was sick by malaria and, 0 otherwise and; is a vector of practices in malaria control and prevention by household *j* (see table 3.1 panel B); is household-level characteristics controlled in the regression (see table 3.1, panel E); is a vector of kebele dummy variables to control for differences across kebeles; is the classical error terms of person *i* in household *j*.

In the second stage, we estimate the economic burden of the incidence of malaria using equation (2).

$$lny_{pj} = \beta_1 \widehat{M}_j + \alpha'_2 \boldsymbol{X_{pj}} + \alpha'_3 \boldsymbol{Z_j} + \alpha'_4 \boldsymbol{V_j} + u_{pj} \tag{2}$$

Where the indices *p* and *j* represent plot and household, respectively. Where represents the key variable of interest: the natural logarithm of maize productivity (kg/ha) in plot *p* of household j; is the predicted probability of the incidence of malaria in equation (1) and the logarithm of total days lost; is a vector of plot characteristics, investment, and shocks (see table

3.1, panel C and D); is the classical error terms of plot p in household j. The rest of the variables are as defined in equation (1).

KAP_{ij} in equation (1) serves as an instrumental variable to estimate equation (2) since (1) is highly correlated with malaria incidence. The difference in individuals KAP may create difference in malaria incidence (2) but individuals KAP is not directly correlated with maize productivity.

The consideration in the estimation of equation (2) is that y_{pj} is very likely to be correlated with M_{ij} and M_{ij} is determined by many factors (endogenous). The estimation of M_{ij} on y_{pj} leads to the violation of the basic assumption of exogeneity of the regressors. To get consistent and unbiased estimates; instrumental variables (IVs) or two-stage least squares (2SLS) estimation is suitable.

Test for endogeneity

Table 3. 1**: Hausman test for endogeneity**

Test for total number of workdays lost due to malaria	Test for malaria dummy
Tests of endogeneity Ho: variables are exogenous Durbin (score) chi2(1) = 3.59748 (p = 0.0579) Wu-Hausman F (1,5224) = 3.553 (p = 0.0595)	Tests of endogeneity Ho: variables are exogenous Durbin (score) chi2(1) = 1.50331 (p = 0.2202) Wu-Hausman F(1,5224)=1.48413 (p = 0.2232)

Source: Authors' computation

From the above table, we can see that it is not possible to reject the exogenous nature of malaria dummy, but we can theoretically argue this. When we take intensity of malaria captured through work days lost due to illness and care giving. The test shows we reject the null hypothesis of exogenous nature of the variable at 10% level of significance. Which necessitates instrumental variable estimation through mediation analysis from the health seeking behavior to maize productivity. Here we can intuitively argue the endogeneity of malaria though the test for the dummy shows failing to reject the null. Malaria and maize productivity may have a bi directional relationship (1) malaria illness affects maize productivity through affecting labor supply (2) maize productivity may affect malaria incidence. Those households who are productive have higher income and afford malaria prevention mechanisms so that less likely to infected by malaria.

The basic identification condition for the IVs to serve as valid instruments to dependably estimate equation (2) is that the instrument should highly correlated with M_{ij}[cov (KAP_{ij}, M_{ij}) ≠ 0] and on contrarily, the instrument must uncorrelated with u_{pj}[cov(KAP_{ij}, u_{pj})=0]. To test for the instrument's validity, we can use the significance of KAP_{ij} in equation (1).

In equation (1): it is assumed that there is no correlation between KAP_{ij} and ϵ_{ij}. The key identification criteria for KAP to be a valid instrument; the coefficient of $KAP_{ij}(\alpha_1)$ should be different from zero. Therefore, a test H_0: $\alpha_1 = 0$ can be made against alternative hypothesis H_1: $\alpha_1 \neq 0$.

In equation (2) the outcome variables (y_{pj}) is estimated by using the predicted value of malaria incidence ($\widehat{M}_j$) and other controlled variables in the equation (see table 3.1 panel C, D, and E).

Both the effect of malaria and total workdays lost due to malaria on maize productivity is estimated by OLS, 2SLS, 2GLS, and RE model performed by using STATA statistical software, version 15.

The use of RE and G2SLS while cross section is because we have multiple persons within each household, the data we used provided as a unique opportunity to exploit the variation within households using random effect models and Furthermore, within households, there are multiple maize plots, which enabled us to estimate random effects productivity functions. The use of panel data estimation for cross section data is shown in the formula for estimator of GLS below.

$$\hat{\beta}_{GLS} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)' + \psi T \sum_{i=1}^{N} (\bar{x}_i - \bar{x})(\bar{x}_i - \bar{x})' \right)^{-1} \times \left(\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)(y_{it} - \bar{y}_i) + \psi T \sum_{i=1}^{N} (\bar{x}_i - \bar{x})(\bar{y}_i - \bar{y}) \right),$$

Source: Verbeek (2004)

In panel data N represents the number of individual observations and T represents time element. Here the estimator operates by deducting the mean value of individuals observation from the observation of individual i at time t. In cross section data we don't have time element. The person-level differences and multiple plots within a household serve as a time element. Alternative approach for cross section data is N represents number of households T represents the multiple individuals in a household in malaria regression and multiple plots in maize productivity regression.

To address the issue of heteroskedasticity, we compute the heteroskedasticity-robust standard error (Wooldridge, 2012). And also, we use G2SLS, which more efficient than OLS under heteroscedasticity.

The usual assumption of independency across observations might fail in our estimation of malaria incidence and total days lost due to malaria on maize productivity. Estimation without some adjustment leads to the underestimation of standard errors. To capture the dependency across observations we cluster standard errors by household id(hh_id) because there is a dependency(correlation) across individuals within a household. For example, members of household 1 may have the same answer for the questions because they share a lot in common.

We further conduct three-stage least square(3SLS) estimation because it goes one step ahead to 2SLS and estimates the equations simultaneously. The two suspected endogenous suspected variables are malaria (lost days due to malaria) and labor supply. In the second equation log of maize, productivity is estimated as a function of the predicted value of malaria incidence and log of total workdays lost due to malaria, and other independent variables that can affect maize productivity. One of the explanatory variables included in the regression is the labor supply (log of labor days per hectare). Labor supply should be tested for endogeneity because it can be affected by malaria incidence. The difference in malaria incidence and workdays lost due to malaria can create a systematic difference in labor days per hectare. Labor supply is estimated in equation 3 as follows

$$lny_{pj} = \beta_1 \widehat{M}_{ij} + \alpha'_2 \boldsymbol{X_{pj}} + \alpha'_3 \boldsymbol{Z_j} + \boldsymbol{V'_j} \alpha_4 + u_{pj} \tag{3}$$

Where lny_{pj} represents the logarithm of labor days per hectare. The rest of the variables are as defined in equation (1) and (2). In 3SLS the three equations solved simultaneously.

Table 3. 2: Definition of the dependent and independent variables

Variable name	Description
Panel(A): Outcome variables	
Malaria incidence	Dummy variable takes 1 if individual *i* in household *j* was sick because of malaria, 0 otherwise.
Maize productivity(lnyield)	Natural logarithm of the amount of maize produced per plot size in household *j*(kg/ha)
Panel(B): Households malaria control practices	
Sleep under bed net	Dummy takes 1 if all family members sleep under bed net, or otherwise
Eave of the house2	Dummy variable takes 1 if the eave of the house is completely closed, 0 otherwise
Eave of the house 3	Dummy variable takes 1 if the eave of the house is partially closed, 0 otherwise
Animals sheltered	Dummy variable takes 1 if animals sheltered in the main house, 0 otherwise
Panel(C)- Plot shocks	
Pest incidence2	Dummy variable takes 1 if both Stem borers (SB) and fall armyworm (FAW) have occurred in plot *p* of household *j*, 0 otherwise
Pest incidence3	Dummy variable takes 1 if fall armyworm (FAW) has occurred in plot *p* of household *j*, 0 otherwise

Pest incidence4	Dummy variable takes 1 if Stem borers (SB) has occurred in plot *p* of household *j*, 0 otherwise
Pest incidence 1	Neither FAW nor SB occurred
Striga	Dummy variable takes one if a maize plot *p* in household *j* infested by Striga, 0 otherwise
Other shocks	Dummy variable takes 1 if a maize plot is infested by other shocks, 0 otherwise
Panel D Plot level investment and characteristics	
Urea used	Log of Urea use (kg/ha)
Battese urea	Dummy variable takes 1 if no Urea used in the maize plot *p* in household *j*, 0 otherwise
Dap used	Dap used(kg/ha)
Battese dap	Dummy variable takes 1 if no dap used in the maize plot p of household *j*, 0 otherwise
Seed	Seed used (kg/ha)
Herb used	Herb used(kg/ha)
Battese herb	Dummy variable takes 1 if no herbicides used in the maize plot *p* of household *j* , 0 otherwise
labor supply	Natural logarithm of labor (Days/ha)
Manure	Dummy variable takes 1 if the maize plot *p* of household *j* received manure, 0 otherwise
Irrigation	Dummy variable takes 1 if maize plot *p* in household *j* was irrigated, 0 otherwise
Farm size	Natural logarithm of total farm size(ha)
Intercropping	Dummy variable takes 1 if the maize plot *p* of household *j* was intercropped, 0 otherwise

Previous crop	Dummy variable takes 1 if the previous season of maize plot p in household *j* was maize, 0 otherwise
Crop residue	Dummy variable takes 1 if the crop residue left on the maize plot *p* of household *j*, 0 otherwise
Panel(E)- Household characteristics	
Family size	Total number of persons in a household
Sex	Sex of household head takes 1 for male, 0 otherwise
Age	Age of household head in years
Education head 1	Dummy variable takes 1 if the head is illiterate, 0 otherwise
Education head 2	Dummy variable takes 1 if the head is with primary schooling, 0 otherwise
Education head 3	Dummy variable takes 1 if the head is with schooling- secondary and above, 0 otherwise
ln livestock ownership	The natural logarithmic of livestock ownership (‘000s ETB)
Mobile ownership	Dummy variable takes 1 if the household owns mobile phones, 0 otherwise
HFAIS	Households Food Access Insecurity Scale (Categorical variable ranges from 0 to 8). 0 shows that there is no problem, and 8 shows the problem is high.
Total workdays lost due to malaria	Natural logarithm of total lost adult working days due to malaria

CHAPTER FOUR: DESCRIPTIVE STATISTICS AND ESTIMATION RESULTS

This chapter is organized according to the following sections: In the first section, we discuss the socio-demographic characteristics of households in the district. In the second section, we assess the knowledge of households regarding malaria and malaria prevention methods. In the third section, we discuss practices of households regarding malaria and malaria prevention methods. In the fourth section, we assess malaria incidence in the district. In the fifth section, we assess outcomes of malaria incidence. In the sixth section, we present diagnostic tests. In the last section, we present the regression results.

4.1 Socio-demographic characteristics of households

Table4. 1: The demographic characteristics of the households in Jabi-tehnan.

Variable	Mean	Std.Dev.	Min	Max
Family size (Number)	4.99	1.952	1	13
Sex of household head (1 = Male)	0.863	0.344	0	1
Age of household head (Years)	46.869	12.893	17	90
Head Illiterate (1/0)	0.549	0.498	0	1
Head Schooling primary (1/0)	0.377	0.485	0	1
Head Schooling secondary and above (1/0)	0.074	0.262	0	1
Spouse illiterate (1/0)	0.802	0.399	0	1

Spouse schooling primary (1/0)	0.155	0.362	0	1
Spouse Schooling secondary and above (1/0)	0.044	0.205	0	1
Food Access scale (0=No access problem)	1.629	1.702	0	8
Value of livestock ownership 000(ETB)	28150.98	13721.22	100	92833.34
Altitude (Meters above sea level)	1947.385	234.091	753	3140
Cellphone ownership (1/0)	0.449	0.497	0	1
Number of households 2994				

Source: Author's computation

Originally 3010 households were assessed for this study, but 16 of them were dropped due to missing key information. Only 2994 households are used for the study. The people are residing in a place on average 1947.38 meters above mean sea level with a minimum 753 meter and a maximum of 3140 meters above mean sea level. 86.3% of households are male-headed and the rest are female-headed. Demographic data revealed that the ages for the household's head ranged from less than 17 years to 90 years with the mean and standard deviation 47 years and 12.89 respectively. On average most households had five members ranged from one to thirteen members per household.

54.9% of the household head are illiterate, the rest 45.1% of household heads are classified by their level of education. 37.7% of them had attended primary school, and the rest 7.4% household heads had attended secondary and/or above. Regarding spouse education, 80.2% of them were illiterate. The rest 18.16% of spouses are classified based on their level of schooling. 15.5% of them were with schooling attended primary school and the rest 4.4% were with schooling secondary and/or above). Comparing the education level of household head and spouse, the level of illiteracy among spouses is by far greater than that of the head. This shows that most spouses are female and less likely to attend formal schooling and stay at home serving the entire family. The variable HFIAS stands for the household's food insecurity access scale, which is proxy indicators for nutritional status with a mean 1.62 ranging from 0 to 8 shows that there was a problem of food security during the time but was not serious. On average households had livestock that worth 28150.98 ETB that extends to a maximum of 92833.34 ETB. Only 44.9% of households own mobile phones.

4.2 Knowledge of households regarding malaria and its prevention methods

Table4. 2: Knowledge of respondents about malaria and its prevention methods

Variable	Mean	Std.Dev.	Frequency
Heard of malaria before (1/0)	1	0	14,940
Source of malaria information Health extension worker (HEW) (1/0)	0.775	0.418	11,576
Source of malaria information Family member (1/0)	0.142	0.349	2,121
Source of malaria information from neighbor (1/0)	0.055	0.228	820
Source of malaria information Mass media (1/0)	0.008	0.088	116
Source of malaria information School (1/0)	0.012	0.111	186
Source of malaria information Church/mosque (1/0)	0.007	0.083	103
Source of malaria information Other specify (1/0)	0.001	0.035	18
Causes of malaria Mosquito bite (1/0)	0.872	0.334	13,027
Causes of malaria Exposure to sun (1/0)	0.039	0.193	580
Causes of malaria Cold Causes of malaria weather (1/0)	0.083	0.276	1,244
Causes of malaria Other specify (1/0)	0.006	0.077	89

Malaria breeding sites Stagnant water (1/0)	0.645	0.478	9,641
Malaria breeding sites Ditch (1/0)	0.046	0.209	682
Malaria breeding sites Hoof print (1/0)	0.009	0.097	141
Malaria breeding sites Swampy areas (1/0)	0.105	0.307	1,573
Malaria breeding sites Pond (1/0)	0.081	0.273	1,215
Malaria breeding sites Dirty place (1/0)	0.076	0.265	1,134
Malaria breeding sites Cattle shed (1/0)	0.008	0.089	119
Malaria breeding sites Tall grass (1/0)	0.002	0.048	35
Malaria breeding sites Latrine (1/0)	0.003	0.058	51
Malaria breeding sites Do not know (1/0)	0.023	0.15	345
Malaria breeding time Night (1/0)	0.937	0.243	13,995
Malaria breeding time Day (1/0)	0.004	0.063	60
Malaria breeding time Always (1/0)	0.029	0.169	438
Malaria breeding season Sept-Nov (1/0)	0.794	0.405	13,995
Malaria breeding season Dec-Feb (1/0)	0.037	0.189	60
Malaria breeding season March-May (1/0)	0.016	0.124	438
Malaria breeding season June-Aug (1/0)	0.154	0.361	447
Malaria major symptom Fever/hot body (1/0)	0.404	0.491	6,030
Malaria major symptom Shivering (1/0)	0.408	0.491	6,094
Malaria major symptom Weakness (1/0)	0.018	0.133	269
Malaria major symptom Muscle Pain/Joint pain (1/0)	0.047	0.213	709
Malaria major symptom Headache (1/0)	0.053	0.224	791
Malaria major symptom loss of appetite (1/0)	0.009	0.094	133
Malaria major symptom Thirsty (1/0)	0.009	0.093	131
Malaria major symptom Chills (1/0)	0.034	0.181	504
Malaria major symptom Vomiting (1/0)	0.016	0.125	237

Malaria major symptom Do not know (1/0)	0.003	0.053	42
Malaria major prevention methods Sleeping under net (1/0)	0.693	0.461	10,358
Malaria major prevention methods Wearing long sleeved cloths (1/0)	0.011	0.106	169
Malaria major prevention methods Fire and smoke (1/0)	0.009	0.093	131
Malaria major prevention methods Spraying insecticide (1/0)	0.012	0.111	185
Malaria major prevention methods Cleaning the environment (1/0)	0.233	0.423	3,478
Malaria major prevention methods Screening windows & doors (1/0)	0.005	0.071	76
Malaria major prevention methods Do not know (1/0)	0.035	0.183	516
Number of persons 14940			

Source: Author's computation

A series of questions were asked to measure the knowledge of households on malaria cause, symptom, preventive measures, and site, time, and season for mosquitoes breeding. The finding shows, that the general awareness of malaria was high among the household of Jabi-tehnan district, almost all had heard about malaria. This is anticipated because the district is known for its malaria endemicity(Asale et al., 2020). 77.5% of them obtained information about malaria from Health extension workers. This shows the importance of health extension workers to aware of the society about the disease in line with the government's effort to prevent and control malaria. The health extension program had achieved successes in (family planning, immunization, malaria, TB, HIV, and community satisfaction) in its first five-years (2013-2018) implementation. Improved Knowledge and caretaking; increased utilization and construction of latrine and high level of societal satisfaction were the fruits of health extension programs (Assefa et al., 2019). The rest 14.2%, 5.5%, 0.8%,1.2%, and 0.7% heard about malaria from family member, neighbor, mass media, school, and church/mosque respectively. The remaining 0.1% heard of malaria during illness.

Their knowledge of malaria causes was at a good level; 87.2% of them knew that mosquito bite causes malaria, which was similar with the result of many studies that assess households knowledge and treatment-seeking behavior in Eritrea, Ghana, India, and Colombia (Andegiorgish, 2019; Forero et al., 2014; Laar et al., 2013; Saha et al., 2019) respectively. 3.9%, 8.3%, and 0.60% of them knew that malaria is caused by exposure to the sun, cold weather, and other factors like lack of personal hygiene, and drinking dirty water respectively.

The majority of the studied population (64.6%) of them believed that stagnant water is the major breeding sites for mosquitoes. 10.5%and 8.1% mentioned swampy areas and ponds are the main breeding sites for mosquitoes. The rest of them thought anopheles mosquitoes breed in areas such as; ditch, hoof print, dirty place, cattle shed, tall grass, latrine. 2.3% of the respondents do not know the place that mosquitoes breed.

Of all participants surveyed 79.4% of the respondents associate from September to November as a major season for malaria transmission. This season coincides with the pick malaria transmission season(September to December) of malaria transmission in Ethiopia (Adugna, 2006). This shows a good level of understanding regarding the season of malaria transmission. The rest of the respondents 3.7%,1.6%, and 15.4% confined December to February, March to May, and June to August as a major transmission season for malaria.

Knowledge about mosquitoes biting time was high with 93.63% of the respondents stated that mosquitoes usually bite at night. Mosquitoes are most active during night time. Because the sun can dehydrate them, they avoid exposure to the sun(Shah, 2010). 0.4% of the respondents stated that day time is the usual time for mosquitoes to bite. 2.9% of them said mosquitoes can always infect human beings. The rest 3% do not know the time for mosquitoes biting.

Symptoms such as fever/hot body and shivering are the two most frequently mentioned signs and symptoms of malaria account for 40.4% and 40.8% respectively. Though respondents also identified weakness, muscle pain/joint pain, headache, loss of appetite, thirsty, chills, and vomiting as a symptom of malaria, the numbers were not convincing.

Most of the respondents (69.4%) know sleeping under the net could protect themselves from malaria infection. 50% of malaria incidence can be reduced by insecticide-treated bed nets (ITNs). ITNs become one of major malaria controlling and prevention mechanisms in the world and also in Ethiopia (Ayalew et al., 2016). Cleaning the environment was mentioned as prevention methods by 23.3% of respondents. The rest mentioned wearing long-sleeved clothes, Fire and smoke, spraying insecticide, screening windows, and doors as a prevention mechanism. A small proportion of respondents (0.2%) included eating properly (not to get hungry) and consuming garlic as other prevention mechanisms.

4.3 Practices of individuals regarding malaria prevention methods

Table 4. 3: Practices of individuals regarding malaria prevention methods in the district

Variable	Mean	Std.Dev.	Min	Max
Time spent outside< 6 years old	1.568	0.656	0	4
Time spent outside 7-10 years old	1.719	0.73	0	5
Time spent outside for females > 10 years old	1.834	0.787	0	4
Time spent outside for males >10 years old	2.284	0.817	1	8
Average usual time spent outside at night	1.917	0.705	1	8
Total number of bed nets owned	0.531	0.905	0	6
Do not have bed nets	0.689	0.463	0	1
children <=14 sleep under bed net(1/0)	0.021	0.145	0	1
Adults>14 sleep under bed net(1/0)	0.11	0.313	0	1
All family members sleep under bed net (1/0)	0.151	0.358	0	1

Animals sheltered within the main house (1/0)	0.412	0.492	0	1
Eave open (1/0)	0.168	0.374	0	1
Eave fully closed (1/0)	0.568	0.495	0	1
Eave partially closed (1/0)	0.264	0.441	0	1
Mosquitoes cannot enter in the main house(screened) (1/0)	0.103	0.303	0	1
Number of persons 14940				

Source: Author's computation

In the section of health producing behavior, different questions were asked that helps to capture households' practices regarding malaria prevention mechanisms. Children under the age of 6 on average spent more than 1 hour and 30 minutes of outdoor every night. Children 7 to 10 years old stay outside 1 hour and 40 minutes every night on average, and also for females above 10 years 1hour and 50 minutes outside. The figure is higher for males above 10 years old that stayed outdoor on average 2 hours and 20 minutes but with a great variation with a minimum of 1 hour and a maximum of 8 hours. Which shows that male above 10 years old is highly likely to stay longer outdoor.

On average for all age groups, individuals stay 2 hours outside during the night. Examining the time that individuals stay outside at night is important because mosquitoes are active during night time. The longer the time spent outside during night time is the higher the probability of being bitten by mosquitoes.

It obvious that using a bed net is so important to prevent malaria. Only 46.9% had bed nets, and the rest were without bed nets. On average each household had 5-bed nets. Only 11% of the adults who had bed net were sleeping under it properly. A small proportion of children (2.1%) of them used the nets properly. This shows even those who had bed nets, did not use it properly. In the

Jabi-tehnan district, using bed nets for other purposes became a hindrance to achieving malaria reduction goals (Asale et al, 2020).

41.2% of individuals live with the shelter that animals live in the main house. This increases the chance of getting infected by mosquitoes since animal urine creates a conducive environment for mosquitoes to grow (Kweka et al., 2011). Regarding the eave of the house, more than half of individuals in the district (56.8%) live in the house with a fully closed eave. However, 26.4% of them live in the house with partially closed eave, and most importantly 16.8% live in the house with the open eave. Only 10.3% of individuals living with a screened house.

Generally, all of the discussions above tried to assess the level of practice in the district. We divided the practices of households into two groups (1) those practices that exposed to malaria (2) those practices that lessen malaria incidence. Though there are good practices to reduce malaria among households such as closing eaves of the house, sleeping under bed nets, sheltering animals outside the main house, not staying outside at night, these are limited to some households. For instance, the majority of the households did not sleep under bed nets, only 11% of adults sleep under bed nets properly.

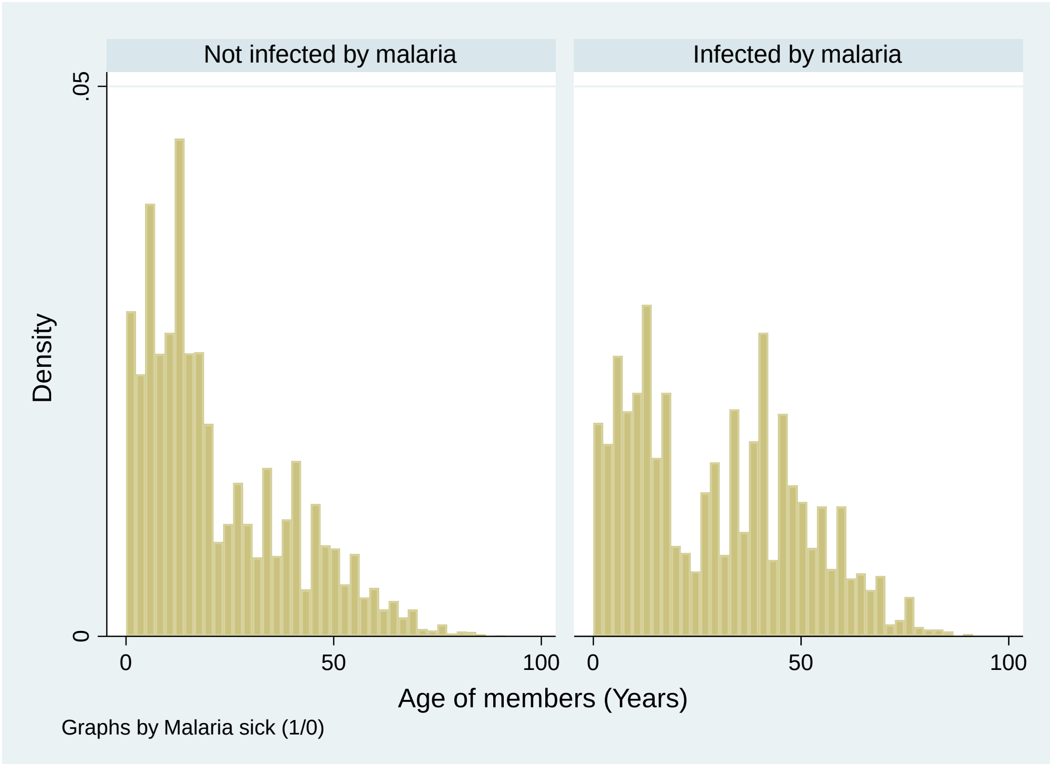
4.4 Assessment of malaria incidence

Table4. 4: Malaria incidence

Variable	Mean	Std.Dev.	Min	Max
Malaria sick (1/0)	0.136	0.342	0	1
Sick other than malaria (1/0)	0.067	0.25	0	1
Number of persons 14940				

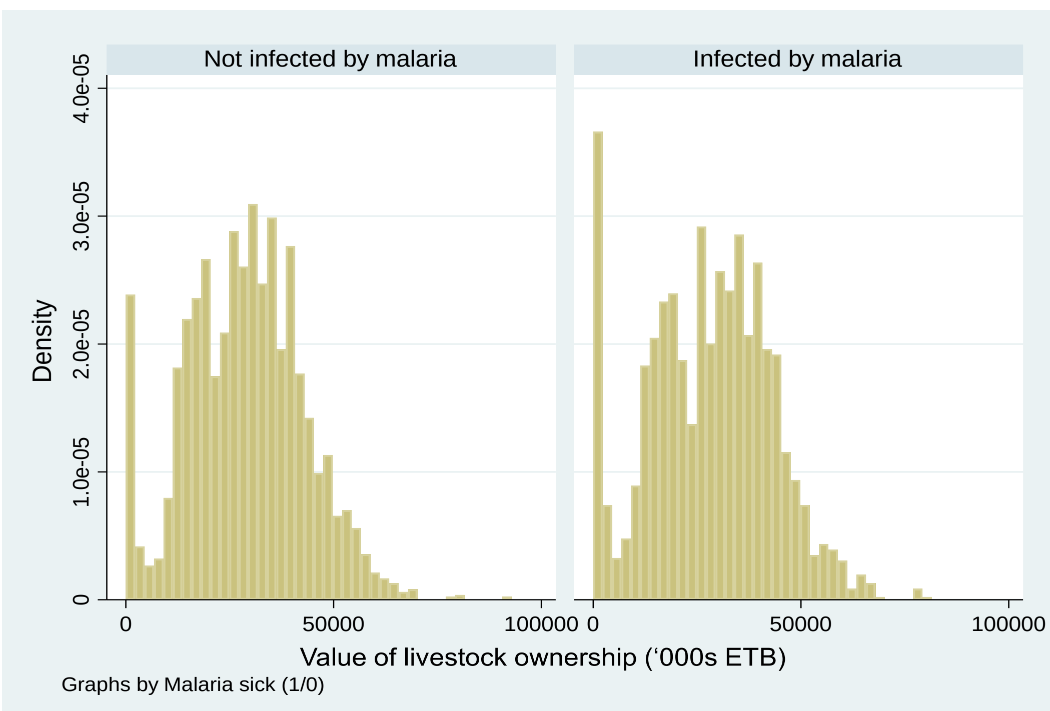
Source: Author’s computation

In table 4.4, we present malaria incidence in the Jabi-tehnan district. In the district around 13.6% of the population was sick by malaria in 2018/2019. This figure is even higher than the total incidence of other diseases, which accounts for 6.7% of the studied population. This shows malaria is a serious problem outweighing the combination of incidence of other diseases. The major diseases other than malaria are Ekek, Diarrhea, Tuberculosis, eye diseases, and skin diseases.



Source: Author's computation

Figure 4. 1: Malaria incidence by age



Source: Author’s computation

Figure 4. 2: Malaria incidence by livestock ownership

Two figures above were plotted for malaria incidence by age and the value of livestock ownership. Figure 4.1 shows the disparity of malaria incidence across age. Though all age groups were infected by malaria, children and youths are the most vulnerable groups of society and bear the highest burden. The vulnerability of this group has future implications on the economy. Malaria incidence declines across age this may be due to the awareness and capabilities of adults to protect themselves.

The second figure displays malaria incidence by livestock ownership. Livestock ownership believed to show the differences in economic status among the household. In the figure, most of the cases have occurred among the group with a low level of livestock ownership. Malaria is highly prevalent among individuals with low socioeconomic status. At the macroeconomic level: it is argued that malaria has a strong association with low socioeconomic status. Malaria endemic countries in the world are the poorest(Gallup and Sachs, 2001).

Table 4. 5: labor days per hectare and maize productivity by malaria sick and not sick

	Malaria sick	
	0	1
Labor days (Days/ha)		
Mean	150.77	172.10
Std.dev	164.42	156.50
Frequency	2,864	2,429
Maize productivity		
Mean	4085.02	4084.22
Std.dev	1705.56	1832.21
Frequency	2,864	2,429

Source: Author’s computation

The table above shows labor days per hectare and maize productivity between households who had at least one-member malaria sick by malaria and not sick by malaria. The mean for labor days per hectare in households with sick member is higher comparing with those households with no malaria sick member. Maize productivity is slightly higher among the household with no malaria sick.

Table 4. 6: Summary statistics- cross tabulation by malaria sick

Malaria sick		
	0	1
Eave of the house completely closed (1/0)		
Mean	0.57	0.54
Std.dev	0.49	0.49
Other diseases (1/0)		
Mean	0.009	0.43
Std.dev	0.09	0.49
Animals sheltered in the main house (1/0)		
Mean	0.41	0.413
Std.	0.49	0.492
All family sleeping under bed nets (1/0)		
Mean	0.15	0.12
Std.	0.36	0.33
Mobile ownership (1/0)		
Mean	0.46	0.49
Std.	0.49	0.50
Household size (1/0)		
Mean	5.78	5.56
Std.	1.83	1.94
Livestock ownership		
Mean	28754.59	27816.67
Std.	14228.58	15181.04
Education of head (secondary)		

Mean	0.06	0.07
Std.	0.25	0.25
Household food access insecurity scale (HFIAS)		
Mean	1.52	1.83
Std.	1.66	1.76

Source: Author's computation

In the above table variables that are included in malaria regression are tabulated by malaria sick. The mean value of households with completely closed is higher among those households with no sick member. The mean value of animals sheltered in the main house is higher among the households with at least one malaria sick member. The value of sleeping under bed nets is high with households that had at least one member with malaria sick. The average value of Food Access Insecurity Scale (HFAIS) shows food access problem is higher among the households with malaria sick member. A slight difference in livestock ownership comparing the two groups of households. Livestock ownership is slightly higher among households with no malaria sick member.

Table 4. 7: Treatment seeking behavior

The place malaria patients seek treatment	Freq.	Percent	Cum.
Village clinic	1502	72.98	72.98
Hospital	242	11.76	84.74
Traditional healer	33	1.60	86.35
Village clinic and hospital	92	4.47	90.82
Village clinic and traditional healer	6	0.78	91.59
Hospital and traditional healer	11	0.53	92.13
All	4	0.19	92.32
Did not seek treatment	158	7.68	100.00

Source: Author's computation

The assessment of treatment-seeking behavior was confined to malaria patients during the year 2018/2019. Among those patients, during the year 7.68% of them did not seek treatment at all. Of those who sought treatment, 72.98% of them went to the village clinic. 11.76% went to the hospital and 1.60% went to traditional healers. Among the individuals who were ill due to malaria sought treatment on average after 4 days of sickness ranging from those who sought treatment on the day of their illness to those who sought treatment after three months of sickness (see table 4.8). This shows the difference in the behavior of seeking treatment.

4.5 Outcomes of malaria

4.5.1 Out of pocket expenditure due to malaria

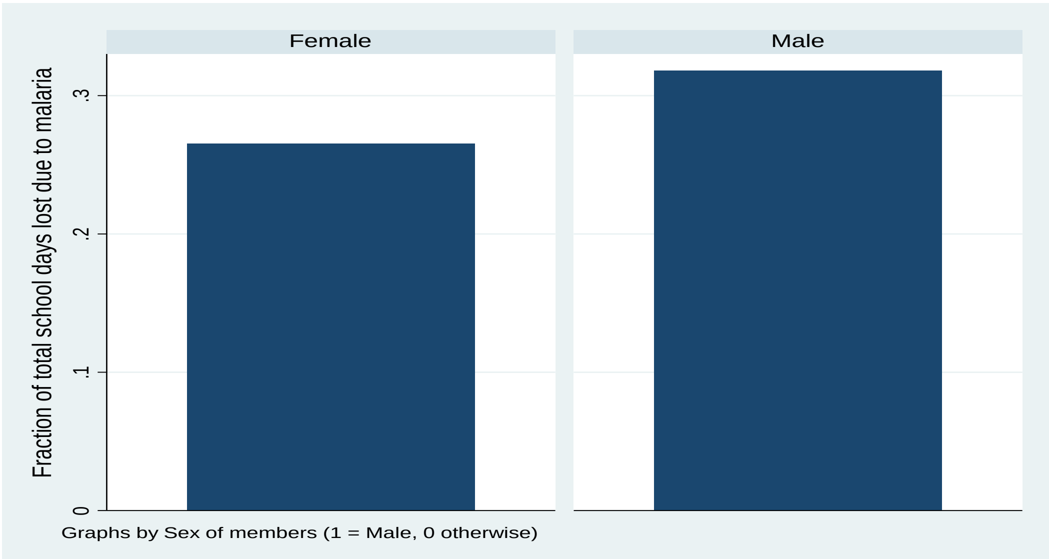
Table 4. 8: Out of pocket expenditure due to malaria

Variable	Obs	Mean	Std.Dev.	Min	Max
Person level out of pocket expenditure due to malaria	1,183	465.4099	820.0918	1	6300
Household level out of pocket exp (ETB)	843	653.1197	1054.132	1	8874
After how many days sought treat	1,809	3.907131	7.110941	0	90

Source: Author's computation

Table 4.8 shows the expenditure of individuals and households due to malaria. Malaria imposes a direct cost to individuals. On average an individual spent 465 ETB due to malaria annually. On average a household spent 653 ETB due to malaria annually. These costs include transportation costs, expenses for anti-malarial drugs, cost of diagnosis, and other related expenses. The expenses reduce the financial capacity of households when the incidence of malaria is serious.

4.5.2 The effect of malaria on children school days



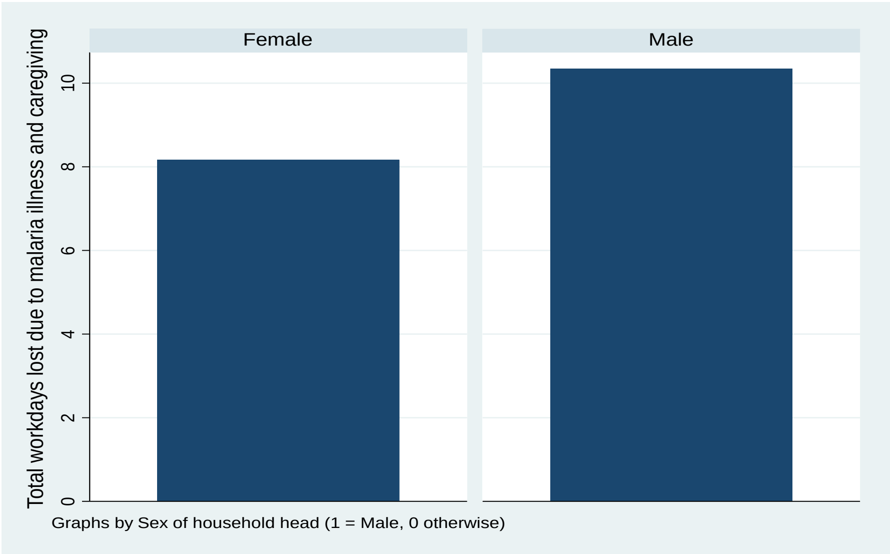
Source: Author's computation

Figure 4. 3: Total school days lost due to malaria illness and caregiving

This study explores the non-cognitive effect of malaria on education among children in the study area. The effect of malaria on schooling by sex of children is shown in figure 4.3. On average one child lost 29 school days due to malaria illness and/or caregiving per annum. The figure shows that males lost more school days (32 days) than females (27 days). This does not necessarily mean males are more vulnerable to malaria. This is maybe due to the number of males went to school is higher than that of females. This figure is in line with the result from Kenya: malaria accounted for 13% of school absenteeism(Leighton et al, 1993); the estimated annual school days lost due to malaria illness and related issues were 4-10 days(Nankabirwa et al., 2014).

The effect of malaria on school-age children does not only make students absent from school, moreover, it leads to poor school performance, and neurological impairment, which last longs in their lifetime. The study in Sri Lanka shows, other things remaining the same, consecutive malarial infections result in decreased language and mathematics scores by 15% relative to those who had not experienced malarial infections in the same period(Fernando et al., 2003). Not attending classes early in childhood has a long-term impact on children's future learning capacity. The result from Brazil shows that the return from literacy scores is decreasing with low attendance of school in early childhood. The literacy score is high among the students who attended class properly in their early childhood when compared with those who missed classes at an early age (de Felício et al., 2012). The effect of malaria on school days has a long-run impact constraining human capital formation.

4.5.3 The effect of malaria on adult's workdays

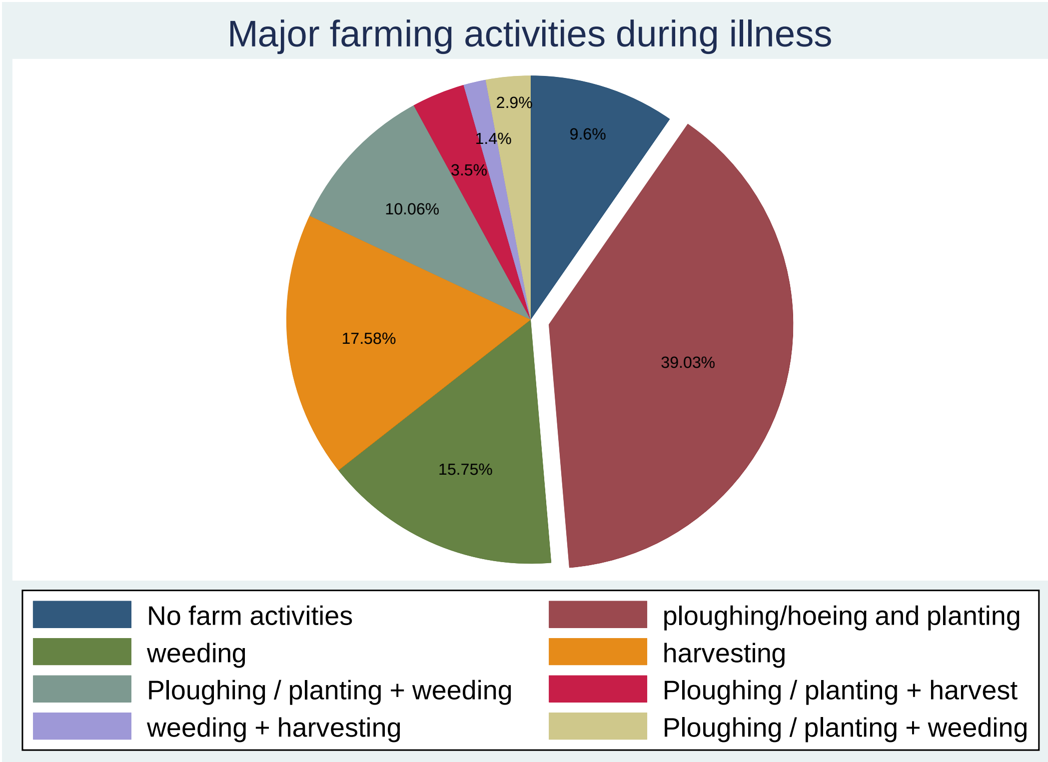


Source: Author's computation

Figure 4. 4: Mean of total workdays lost due to malaria illness and caregiving

The effect of malaria on workdays is illustrated in figure 4.4 above. On average one adult lost 10 workdays due to malaria illness and caregiving per annum. The figure shows the lost workdays due to malaria by the sex of the household. Male headed households lost around 8 workdays because of malaria. The female-headed households lost around 10 workdays due to malaria. The figure is higher among females may be due to females are the ones who are responsible for most caregiving activities in the family.

This result is consistent with the result from the estimation of the economic impact of malaria in Ghana, which suggests that on average 9 workdays lost by the working-age population(Asante and Asenso-Okyere, 2003). Other studies from Africa also show the same direction of results. The review of most studies that have investigated lost workdays of patients and caregivers in Africa suggests that 1 to 5 workdays were lost per malaria episode. This number depends upon the seriousness of infection and immunity of the individuals (Chima, et al., 2003).



Source: Author's computation

Figure 4. 5: Major farming activities during illness

The severity of malaria is different across the time of farming activities shown through workdays lost. The pie chart shows the major farming activities during malaria illness. The chart shows 39.03% of illness of malaria were during ploughing/hoeing and planting. The burden of malaria is intolerable since it overlaps with important farm activities. It is learned that the period of malaria endemicity and major farming activities overlap. A small proportion of malaria incidence occurred with a time of no farming activities.

4.6 Estimation framework

In this section, first, we check diagnostic tests, to identify which estimation approach suitable for the data and the model.

4.6.1 Test for multicollinearity

One of the basic assumptions of the classical linear regression model (CLRM) is independency among explanatory variables**.** If there is a high interdependency between regressors, it is called multicollinearity. Estimation of the dependent variable as a function collinear independent variables causes week statistical inferences and it is difficult to differentiate the effect of individual regressors on the dependent variable(Gujarati, 2012). To check whether there is collinearity among the regressors, we use the Variance Inflation Factor (VIF). Hence, the mean VIF of regressor is 2.11, which is less than the rule of thumb-10(see appendix 1B). The result suggests there is collinearity among variables but not a serious problem.

4.6.2 Test for Heteroskedasticity

The other basic assumption of CLRM is the constant variance of error terms across observations. Heteroskedasticity arises when the variance of error term varies across observations (Wooldridge,2004.). If there is heteroskedasticity, the coefficients from the estimation results would be inefficient(Gujarati, 2012). So, it is vital to check whether the error term has an unequal variance or not. We use the Breusch-Pagan test with the null hypothesis of homoscedastic variance among error terms against heteroscedastic variance. The probability (prob> chi2) = 0.0000(see appendix 2B), suggests to reject the constant variance (null hypothesis). This means there is a problem of heteroscedasticity. The need for robust standard errors since robust standard errors imposes homoscedasticity. In our estimation, we conduct a robust regression in all the equations. Regression without checking for robustness might bring inconsistent results in the presence of outliers. Robust regression helps (1) to fix outliers by conciliating the exclusion and inclusion of outliers (2) to consider the observations differently depending on how they behave. This helps to estimate a more efficient model.

4.7 Results from regression

4.7.1 Malaria incidence estimation

Table 4. 9: Factors contributing to malaria incidence

Variables	OLS	Random effect
Eave of the house completely closed (1/0)	-0.0137*	-0.0133
	(0.00822)	(0.00815)
Eave of the house partially closed (1/0)	-0.0111	-0.0104
	(0.00919)	(0.00925)
Animals sheltered in the main house (1/0)	0.0135**	0.0131**
	(0.00641)	(0.00650)
All family member sleep under bed nets (1/0)	-0.00937	-0.0102
	(0.00768)	(0.00768)

Households food access insecurity scale (HFAIS)	0.0103***	0.0105***
	(0.00185)	(0.00190)
Other diseases (1/0)	0.780***	0.782***
	(0.0138)	(0.0123)
R-squared	0.353	
N	2994	2,994

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively.

Definition of Eave: the overhanging lower edge of a roof.

Source: Author's computation

Table 4.9 demonstrates factors contributing to malaria incidence. This regression links malaria incidence with households' practices and other variables. Among these four variables are identified representing households' practices. These variables are eave of the house completely closed, partially closed, animals sheltered in the main house, and all the family members sleeping under bed nets. Completely closed eaves significantly and negatively related to malaria incidence. Having a house with a completely closed eave reduce the probability of infected by malaria by 0.01 compared to the house with completely open and partially closed eave since closed eaves reduce mosquitoes' entrance to the house.

Animals sheltered in the main house increase the probability of malaria incidence. All other things remaining the same, sheltering animals in the main house increase the probability of getting infected by mosquitoes by 0.01 since animal's urine attracts mosquitoes and fastens the growth of mosquitoes. This is evidenced by the laboratory experiment, which shows 1 to 7 days of animals' urine help mosquitoes to produce oviposition(Kweka et al., 2011). Malaria incidence decreases along with household size. The coefficient of sleeping under bed nets is not significant in both OLS and RE. This means it did not create a systematic difference in malaria incidence. ITNS may not be effective to reduce malaria due may be due to improper usage and/or the insecticide resistance of mosquitoes(Lindblade et al., 2015).

Household practices determine malaria incidence, which means people can choose to be sick or not. On contrary there are suggestions which magnify the exogenous nature of any disease "disease being an environmental factor is thought of as an exogenously given variable, i.e. farmers do not choose to be sick" Nur (1993) p.4.

Table 4.9 also shows the link between other variables and malaria incidence. In both models, we find that HFAIS significantly affects malaria incidence. The variable HFAIS shows the level of food insecurity. The coefficient is significant and positive, shows malaria incidence is high among households with high food access problems. This result is consistent with the study from Western Brazil, which suggests poor nutritional status is highly associated with malaria incidence(Alexandre et al., 2015).

Those who were infected by other diseases had a higher probability of being infected by malaria. The coefficient of other diseases become positive and significant in both models. Other things remaining the same, being infected by other diseases increases the probability of getting infected by malaria by 0.78 compared to being free from any other disease. This is because illness due to other diseases lessens immunity.

The coefficient of sex is positive and significant. All other things remaining the same, the probability of being infected by malaria of males is slightly higher than as compared to the probability of being infected by malaria of females. It implies being male had 0.008 more probability of getting infected than female. Malaria incidence also decreases along with household size. Other variables controlled in the regression are not significant to influence malaria.

4.7.2 Checking for the validity of instrument of 2SLS, G2SLS, and 3SLS

The basic assumption of instrument validity is there must be no correlation between the instrumental variables and the error term. Since it is impossible to test this criterion, we can only give an argument. The instruments that are identified do not have a direct relationship with the outcome variable. Eave of the house, animals sheltered in the main house, and sleeping under bed nets does not affect maize productivity directly. This means the instruments are not correlated with the other unobserved factors that affect maize productivity.

The other identification criteria for instrument validity in 2SLS is the instrumental variables must be at least jointly significant in explaining the variation in the endogenous explanatory variables. Our regression of 2SLS and G2SLS in table 4.11 and 4.12 below only shows the final result of the effect of malaria and total workdays lost due to malaria on maize productivity.

In the first stage of regression, malaria is estimated as a function of instruments and other controlled variables. The result from these regressions shows all the instruments are at least jointly significant in determining malaria incidence and workdays lost due to malaria having p-value (0.000) shown in table 4.10. This guarantees the validity of instruments for the estimation. In the second line of regression logarithm of maize productivity is estimated as a function of the predicted value of malaria and lost workdays due to malaria, and other controlled variables.

Table 4. 10: Joint significance of instruments

Variables	Malaria sick
Eave of the house completely closed (1/0)	-0.071 (3.75) **
Eave of the house partially closed (1/0)	-0.004 (0.20)
Animals sheltered in the main house (1/0)	0.011** (0.77)
All family member sleep under bed nets (1/0)	-0.085 (0.509)
Constant	(29.06) **
	0.01
Prob > F = 0.0000 Number of households 2994	

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively.

Source: Author’s computation

P-value of Prob > F = 0.0000 guarantees the joint significance of households’ practices to an instrument for malaria and total days lost due to malaria.

4.7.3 Maize productivity estimation (kg/ha)

Table 4. 11: The effect of malaria on maize productivity

Variables	OLS	RE	2SLS	G2SLS
At least one member was malaria sick in the last 12 months (1/0)	-0.0370*	-0.0626***	0.205	0.295
	(0.0207)	(0.0212)	(0.239)	(0.289)
Fall armyworm (FAW) (1/0)	-0.130**	-0.108***	-0.166**	-0.136***
	(0.0524)	(0.0327)	(0.0647)	(0.0393)
Stem borers (SB) (1/0)	-0.164***	-0.139***	-0.184***	-0.156***
	(0.0403)	(0.0340)	(0.0464)	(0.0384)
FAW and SB (1/0)	-0.0650	-0.0812**	-0.0721	-0.0861**
	(0.0455)	(0.0369)	(0.0472)	(0.0387)
Striga (1/0)	-0.288*	-0.214***	-0.325**	-0.236***
	(0.151)	(0.0718)	(0.147)	(0.0721)
Other shocks (1/0)	-0.353***	-0.393***	-0.365***	-0.398***
	(0.0495)	(0.0504)	(0.0524)	(0.0516)
Log urea use per (ha)	0.0662**	0.0809***	0.0689**	0.0806***
	(0.0289)	(0.0217)	(0.0301)	(0.0220)
Battese urea (1/0)	0.132	0.189*	0.135	0.184*
	(0.132)	(0.0995)	(0.135)	(0.102)
Log of dap use per (ha)	0.106***	0.100***	0.102***	0.100***
	(0.0312)	(0.0240)	(0.0338)	(0.0245)
Battese dap (1/0)	0.373***	0.375***	0.371***	0.380***
	(0.126)	(0.1000)	(0.133)	(0.102)
Log seed per (ha)	0.0871***	0.137***	0.0749**	0.124***
	(0.0307)	(0.0294)	(0.0336)	(0.0310)
Log herb per (ha)	-0.0130	-0.00767	-0.0169	-0.0109
	(0.0176)	(0.0166)	(0.0190)	(0.0177)
Battese herb (1/0)	-0.0359	-0.0491*	-0.0235	-0.0417
	(0.0351)	(0.0267)	(0.0382)	(0.0277)
Log labor days per (ha)	0.0769***	0.134***	0.0639**	0.115***
	(0.0298)	(0.0308)	(0.0287)	(0.0290)
Manure per (ha)	0.0374*	0.0442***	0.0343*	0.0442***

Variables	OLS	RE	2SLS	G2SLS
	(0.0203)	(0.0167)	(0.0208)	(0.0170)
Irrigation (1/0)	-0.0692	-0.0430	-0.0800	-0.0509
	(0.0586)	(0.0370)	(0.0597)	(0.0390)
Log of farm size(ha)	-0.00336	-0.00214	0.000604	0.00357
	(0.0163)	(0.0176)	(0.0170)	(0.0188)
Intercropping (1/0)	-0.0499	-0.0961**	-0.0922	-0.129**
	(0.0669)	(0.0425)	(0.0784)	(0.0509)
Previous crop maize (1/0)	-0.0429**	-0.00960	-0.0393*	-0.00831
	(0.0204)	(0.0145)	(0.0202)	(0.0146)
Crop residue left (1/0)	-0.00363	-0.0199	0.00444	-0.0188
	(0.0398)	(0.0336)	(0.0411)	(0.0337)
Mobile (1/0)	0.0376*	0.0457*	0.0289	0.0355
	(0.0225)	(0.0238)	(0.0254)	(0.0276)
Household size	0.00160	0.00197	-0.00540	-0.00861
	(0.00521)	(0.00534)	(0.00904)	(0.0104)
Sex (1/0)	0.00551	0.0154	-0.00352	0.00158
	(0.0336)	(0.0363)	(0.0346)	(0.0386)
Age in years	-0.000845	-0.000878	-0.00173	-0.00204
	(0.000972)	(0.00104)	(0.00117)	(0.00128)
Head schooling primary school years (1/0)	0.0240 (0.0223)	0.0253 (0.0232)	0.0250 (0.0228)	0.0235 (0.0239)
Head schooling (secondary and above) (1/0)	0.0904*	0.0881*	0.0985*	0.0988**
	(0.0495)	(0.0468)	(0.0509)	(0.0503)
lnlivestock000 in ETB	0.0239*	0.0257**	0.0256**	0.0287**
	(0.0123)	(0.0118)	(0.0125)	(0.0123)
No livestock (1/0)	0.163	0.191*	0.187	0.226**
	(0.115)	(0.108)	(0.119)	(0.115)
Constant	6.529***	6.042***	6.583***	6.097***

Variables	OLS	RE	2SLS	G2SLS
	(0.217)	(0.218)	(0.222)	(0.221)
Number of plots	5,293	5,293	5,293	5,293
R-squared Number of hh_id	0.188	 2,994	0.156	2,994

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively. Kebele dummies are controlled in the regression.

Source: Author's computation

Table 4.11 reports the effect of malaria incidence on maize productivity on 5293 plots. The magnitude and sign of estimated coefficients vary across different specifications. The sign of malaria coefficient on maize productivity in plot *p* is negative on the first two estimation techniques, and positive in the last two estimation techniques. In all the above four specifications maize productivity is modeled as a function of malaria and other controlled variables in the regression. In the first two specifications: malaria has a significant effect on maize productivity while taking malaria as an exogenous variable. However, in the other two estimations, malaria has no significant effect on maize productivity while taking malaria as an endogenous variable.

The differences in the result might be because of the endogeneity of the incidence of malaria. The result from OLS and RE suggests, all other factors being equal, households with at least one malaria ill person had 3.7% and 6.26% less maize productivity in plot *p* than with those who had no member infected by malaria. Though there is a big difference in the magnitude of lost productivity, this result is in the same direction as the other estimates. Adebayo et al. (2015) suggest that when malaria prevalence increases by one unit, crop productivity reduced by 89%.

In the other two estimation techniques (2SLS and G2SLS): the results from the first equation shows that the validity of instruments (see table 4.8). In both 2SLS and G2SLS: the coefficient of malaria incidence is insignificant. The absence of a significant effect of malaria on maize productivity is evidenced by other studies. (Audibert, et al., 2009) suggests malaria has no significant effect on coffee and cocoa productivity. Nur (1993) also suggests malaria does not have a significant effect on economic outcomes. This may be attributed to (1) the substitution of an incapacitated person due to malaria with other healthy members (2) the substitution of ill labor by hired labor so the incidence did not affect productivity. Kebeles dummies controlled are not shown in the table rather it is shown in Appendix 1A.

4.7.4 The effect of total lost adult working days due to malaria on maize productivity.

Table 4. 12: The effect of total workdays lost due to malaria on maize productivity

Variables	OLS	RE	2SLS	G2SLS
Log total work days lost	-0.00252	-0.00441**	0.0262	0.0335
	(0.00178)	(0.00187)	(0.0194)	(0.0237)
FAW (1/0)	-0.130**	-0.108***	-0.194***	-0.150***
	(0.0525)	(0.0328)	(0.0716)	(0.0423)
SB (1/0)	-0.165***	-0.139***	-0.193***	-0.158***
	(0.0403)	(0.0340)	(0.0477)	(0.0387)
FAW and SB (1/0)	-0.0643	-0.0802**	-0.0850*	-0.0964**
	(0.0454)	(0.0369)	(0.0505)	(0.0406)
Striga (1/0)	-0.289*	-0.214***	-0.338**	-0.239***
	(0.151)	(0.0717)	(0.148)	(0.0715)
Other shocks (1/0)	-0.353***	-0.393***	-0.371***	-0.399***
	(0.0495)	(0.0504)	(0.0528)	(0.0517)
Log of urea per (ha)	0.0662**	0.0808***	0.0711**	0.0808***
	(0.0290)	(0.0217)	(0.0308)	(0.0220)
Battese urea (1/0)	0.132	0.189*	0.141	0.184*
	(0.132)	(0.0995)	(0.137)	(0.101)
Log of dap per(ha)	0.106***	0.100***	0.0993***	0.100***
	(0.0313)	(0.0240)	(0.0347)	(0.0245)
Battese dap (1/0)	0.373***	0.375***	0.366***	0.382***
	(0.126)	(0.100)	(0.137)	(0.102)
Log seed per(ha)	0.0864***	0.136***	0.0738**	0.125***
	(0.0307)	(0.0294)	(0.0331)	(0.0305)
Log herb per(ha)	-0.0131	-0.00783	-0.0185	-0.0108
	(0.0177)	(0.0168)	(0.0187)	(0.0172)
Battese herb (1/0)	-0.0358	-0.0493*	-0.0147	-0.0379

Variables	OLS	RE	2SLS	G2SLS
	(0.0353)	(0.0269)	(0.0389)	(0.0279)
Log labor days per (ha)	0.0767**	0.133***	0.0566*	0.112***
	(0.0298)	(0.0308)	(0.0291)	(0.0295)
Manure (1/0)	0.0376*	0.0443***	0.0302	0.0431**
	(0.0203)	(0.0167)	(0.0213)	(0.0171)
Irrigation (1/0)	-0.0702	-0.0436	-0.0779	-0.0495
	(0.0585)	(0.0369)	(0.0580)	(0.0377)
Log of farm size(ha)	-0.00287	-0.00132	-0.00153	0.000361
	(0.0163)	(0.0176)	(0.0170)	(0.0188)
Intercropping (1/0)	-0.0497	-0.0962**	-0.126	-0.146***
	(0.0669)	(0.0425)	(0.0871)	(0.0539)
Previous crop maize (1/0)	-0.0432**	-0.00981	-0.0335	-0.00501
	(0.0204)	(0.0145)	(0.0205)	(0.0146)
Crop residue (1/0)	-0.00367	-0.0200	0.0109	-0.0188
	(0.0397)	(0.0336)	(0.0425)	(0.0342)
Mobile (1/0)	0.0374*	0.0452*	0.0252	0.0338
	(0.0224)	(0.0237)	(0.0255)	(0.0275)
Household size	0.00123	0.00139	-0.00684	-0.00962
	(0.00521)	(0.00531)	(0.00791)	(0.00905)
Sex (1/0)	0.00514	0.0147	-0.00642	0.000117
	(0.0336)	(0.0363)	(0.0353)	(0.0392)
Age in years	-0.000853	-0.000888	-0.00231*	-0.00254*
	(0.000974)	(0.00105)	(0.00123)	(0.00133)
Head schooling- primary (1/0)	0.0246 (0.0224)	0.0261 (0.0232)	0.0190 (0.0237)	0.0165 (0.0247)
Head schooling- secondary or above (1/0)	0.0910*	0.0889*	0.0981*	0.0980*
	(0.0495)	(0.0469)	(0.0510)	(0.0501)
lnlivestock000 in ETB	0.0236*	0.0251**	0.0305**	0.0353***

Variables	OLS	RE	2SLS	G2SLS
	(0.0123)	(0.0118)	(0.0137)	(0.0137)
No livestock (1/0)	0.161	0.186*	0.227*	0.282**
	(0.115)	(0.108)	(0.129)	(0.128)
Constant	6.508***	6.006***	6.841***	6.374***
	(0.218)	(0.219)	(0.307)	(0.306)
Number of plots	5,293	5,293	5,293	5,293
R-squared	0.188	2,994	0.125	2,994

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively. Kebele dummies are controlled.

Source: Author's computation

In Table 4.12, we present results of the impact of workdays lost due to malaria on maize productivity in plot *p*. We run this regression in addition to the effect of malaria on productivity because of the effect of malaria on productivity may ignore the effect of workdays lost due to malaria on maize productivity. Similar to the previous regression of malaria incidence, this regression has four estimation techniques.

Under RE the coefficient of total workdays lost due to malaria illness and caregiving is significant and negatively affected maize productivity. The result shows, all other factors being equal, a 1% increase in total lost adult workdays due to malaria resulted in a 0.44% reduction in yield of maize productivity in plot *p*. In model 3 and 4 total lost adult working days has a positive coefficient, but not significant, which means the increase in total lost adult working days due to malaria does not affect the yield of maize per hectare. This may be attributed to (1) family labor substitution− other members of a family compensated more than the lost workdays (2) mutual aid− neighbors helped them in times of their sickness("debo"). Kebeles dummies controlled are not shown in the table rather it is shown in appendix 2B.

4.7.5 3SLS Estimation Results

Table 4. 13: Three-stage least square estimation of malaria incidence

	(1)	(2)	(3)
Variables	Malaria sick	Log of maize productivity	Log of labor supply

Malaria sick		0.245	1.035***
		(0.215)	(0.0959)
Log of labor supply		0.382***	
		(0.127)	
Number of plots	5,293	5,293	5,293
R-squared	0.088	0.073	0.138

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively.

Source: Author's computation

Furthermore, we estimate the three-stage least square estimation because of a need to further estimate labor supply as a function of malaria and workdays lost due to malaria. Malaria sick(malaria_sick), maize productivity (lnyield) and, labor supply (lnlabor_days_hec) are simultaneously estimated. We go further in addition to 2SLS, because of labor supply suspected to be endogenously determined in the second stage regression, so 2SLS could not capture such effects. Three equations are specified: in the first equation malaria incidence is estimated as a function of instruments and other controlled variables; in the second equation maize productivity is estimated as a function of malaria incidence and other possible determinants of yield productivity in the regression; in the third equation labor supply is estimated as a function of malaria. Malaria incidence has no significant effect on maize productivity, this result is the same with 2SLS and G2SLS estimations above.

However, malaria has a significant and positive effect on labor days per hectare. All other factors being equal, households who had at least one member infected by malaria had much more labor days per hectare than with those who were not infected. Malaria incidence increases labor days per hectare because the number of workdays among ill persons per hectare would be longer. This shows that the labor supply is endogenously determined by malaria. This result is in line with the self-reported 7.5% reduced capacity of individuals due to malaria (see appendix C), since malaria reduces individual's productivity, it will take longer days to perform their activities from normal days.

A 1% increase in labor days per hectare, increase maize productivity by 38.2%. We have already stated labor days per hectare increases along with the increase in malaria incidence. The more days take them per hectare means the longer the recovery period from the illness. Farmers decided to substitute hired and/or family. The increase in maize productivity may be due to the more effectiveness of substituted labor than the ill's productivity. Labor substitution helps to reduce the agricultural cost of malaria. This result may not be credible, because of the lack of instrumental variable for labor supply in the data set, but at least it shows the direction of the effect of malaria on labor productivity is through labor supply.

Table 4. 14: Three-stage least square estimation of total days lost due to malaria

	(1)	(2)	(3)
Variables	Log of total workdays lost due to malaria	Log of maize productivity	Log of labor supply
Log of total workdays lost due to malaria		0.0289	0.0631***
		(0.0167)	(0.00726)
Log of labor supply		0.415***	
		(0.129)	
Number of plots	5,293	5,293	5,293
R-squared	0.088	0.022	0.330

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.
***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively.
Source: Author's computation

We estimate another 3SLS for total workdays lost due to malaria. Total work days lost due to malaria has a significant and positive effect on labor days per hectare. Other things remaining the same a 1% increase in total labor days lost due to malaria increase labor days per hectare by 6.3%. 1% increases in labor days per hectare increase maize productivity by around 41.5%. This is maybe due to (1) the rise in the quantity of labor (members substitution and community corporation) (2) the rise in quality of labor (substituted labor may be more efficient than the efficiency of ill members that they would have been healthy). This result is opposite to the suggestions that hired labor might not be effective as the family labor (Asenso-Okyere et al., 2009).

Table 4. 15: The effect of malaria on hired labor

Variables	Log total hired labor per hectare
At least one member was malaria sick in the last 12 months (1/0)	0.204*** (0.0346)
Mobile (1/0)	-0.0219
	(0.0388)
Household size	-0.00137
	(0.0107)
Sex (1/0)	-0.0699
	(0.0596)
Age in years	0.000673
	(0.00128)
Education of head-schooling primary	0.0201
	(0.0391)
Education of head-schooling secondary and above	0.00703
	(0.0679)
lnlivestock000 in ETB	-0.0346**
	(0.0167)
No livestock (1/0)	-0.393***
	(0.151)
Constant	2.828***
	(0.176)
Number of Plots	5,293
Number of hh_id	2,994

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively.

Source: Author’s computation

Table 4. 16: The effect workdays lost due to malaria on hired labor

Variables	Log of total hired labor
Log of total days lost	0.0137***
	(0.00298)
Mobile (1/0)	-0.0116
	(0.0383)
Household (1/0)	-0.00220
	(0.0106)
Sex (1/0)	-0.0435
	(0.0679)
Age in years	0.00173
	(0.00142)
Education of head-schooling primary	0.0116
	(0.0389)
Education of head-schooling secondary and above	0.00547
	(0.0652)
lnlivestock000 in ETB	-0.0241
	(0.0178)
No livestock (1/0)	-0.317**
	(0.160)
Constant	2.807***
	(0.188)
Number of Plots	5,293
R-squared	0.055

Note: Robust standard errors in parentheses adjusted for 2,994 clusters in household id.

***, ** and *, shows statistically significant variables at 1%, 5% and 10% level of significance, respectively.

Source: Author's computation

In table 4.15, we estimate the effect of malaria on hired labor. The result suggests households who had at least one-member sick by malaria had a 20.4% higher probability to hire more labor. It is possible to link this result with the previous regressions of the effect of malaria on maize productivity taking malaria as an endogenous variable. The results from table 4.11 and 4.12 shows malaria does not explain the difference in maize productivity. Despite the productive time lost due to malaria, malaria did not lead to loss of productivity. Households use the rural labor market to compensate for lost labor days due to illness and/ or caregiving. The effect of malaria on farm productivity is not apparent through the loss of productivity though we cannot explore the problems arises with the substitution of labor in this study.

The result form table 4.16 shows hired labor increases along with an increase in total days lost due to malaria. Households who lost their working days due to malaria use more hired labor. All other things remaining the same, a 1% increase in total lost workdays increase the probability of hiring another labor by 1.4%. Since maize productivity was not hindered among households with malaria sick members, the hired labor was at least as effective as the substituted ill or caregiver members. From the two tables above, it is obvious that malaria leads to increased demand for hired labor. It was a good opportunity for laborers to work and earn. However, the social gain of hiring is not explored in this study.

CHAPTER FIVE: CONCLUSIONS AND POLICY IMPLICATIONS

In this study, we estimated the economic burden of malaria and factors contributing to the incidence of malaria among 2,994 rural households in North West Ethiopia. The findings of this study show several factors contribute to malaria incidence, among these eaves of the house, animals sheltered in the house, other diseases, sex, and HFIAS significantly affects malaria incidence. Closed eaves lessen the probability of infected by mosquitoes. In contrast, animals sheltered in the main house increase the likelihood of being infected. This shows the importance of household practices for the difference in the incidence of malaria. Sleeping under bed nets does not significantly determine malaria. This may be due to insecticide resistance of mosquitoes, and not using it properly. The coefficient of HFIAS shows that poor nutritional status in the household increases the probability of malaria incidence. This implies malaria the disease of the poor.

Malaria is one of the major health problems in the district. 13.6% of individuals were infected by malaria in 2018/2019. This figure is even higher than the total incidence of other diseases. Malaria is not only a mere health issue but also a developmental problem. The result from the descriptive statistics shows malaria is a cause for out of pocket expenditure at the individual and household levels, absenteeism from school among children, missing productive labor time, and reduced working capacity among adults. The effect of malaria on school days has an immense long-run impact on children's future learning capacity. This impedes the formation of human capital by reducing two major components (health and education) intern affect the economic growth of a country.

We estimated the impact of malaria on maize productivity by using five estimation techniques. Taking malaria as exogenous independent variables, results from OLS and RE shows malaria significantly affects maize productivity. It suggests households with at least one member infected by malaria had less maize productivity compared to the household with no sick member. Moreover, the effect of lost workdays due to malaria is negative under the RE specifications.

2SLS and G2SLS estimated the impact of malaria and workdays lost due to malaria on maize productivity by exploiting the endogenous nature of malaria. Malaria and workdays lost due to malaria do not have a significant effect on maize productivity in both models. This does not mean malaria did not affect an individual’s productivity. This is evidenced by the self-reported reduced working capacity (on average an individual lost 7.5% of their working capacity due to malaria illness) (see appendix C). Workdays lost due to malaria did not impede maize productivity due to the substitution of lost labor time.

The results from 3SLS estimation also suggest malaria incidence increases labor days per hectare since an ill person cannot accomplish a given task in a given period. So, it took him/her more days to finish a given task on the plot. The insignificancy of malaria on maize productivity may be attributed to the use of the rural labor market to replace the lost labor time due to malaria and also the substitution of lost labor time by another healthy family member. The insignificant coefficient of malaria on maize productivity in most of the specifications is because (1) the use of endogenous nature of malaria (2) since it limits healthy workdays the productivity must depend upon the substituted family and/or hired labor efficiency.

Furthermore, workdays lost due to malaria positively affects labor days per hectare, which means the more the lost workdays, the more the labor took more days to accomplish a task in a given plot, and the more the chance to hire labor.

From the result of the study, it is learned that systematic difference in household’s health-seeking behavior affects malaria incidence. Specifically, indoor self-protection mechanisms like closing eaves and sheltering animals outside the main house helped to protect households from malaria. Emphasizing is up to individuals to choose whether to be sick or not.

Because of the substitution of lost labor time, the impact of malaria on agricultural productivity does not necessarily lead to immediate economic deprivation. The economic impact of malaria shown in the lost workdays, school days, and reduced working capacity. The possible effect on schooling goes beyond absenteeism, it may impair children learning capacity even after recovery.

Therefore, any interventions to reduce malaria should consider the differences in the household’s behavior. An improved thought of association between mosquitoes and agriculture will help the interventions to control malaria because the incidence coincided with the major farming. Policies intended to reduce the burden of malaria should not only consider the short-run economic losses, rather emphasize on its impact on an individual’s capacity.

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Appendix

Appendix A: Tables of maize productivity regressions

Table 1A. The impact of malaria on maize productivity

Variables	(1) OLS	(2) RE	(3) 2SLS	(4) G2SLS
At least one member was malaria sick in the last 12 months (1/0)	-0.0370*	-0.0626***	0.205	0.295
	(0.0207)	(0.0212)	(0.239)	(0.289)
Fall armyworm (FAW)	-0.130**	-0.108***	-0.166**	-0.136***
	(0.0524)	(0.0327)	(0.0647)	(0.0393)
Stem borers (SB)	-0.164***	-0.139***	-0.184***	-0.156***
	(0.0403)	(0.0340)	(0.0464)	(0.0384)
FAW and SB	-0.0650	-0.0812**	-0.0721	-0.0861**
	(0.0455)	(0.0369)	(0.0472)	(0.0387)
Striga	-0.288*	-0.214***	-0.325**	-0.236***
	(0.151)	(0.0718)	(0.147)	(0.0721)
Other shocks	-0.353***	-0.393***	-0.365***	-0.398***
	(0.0495)	(0.0504)	(0.0524)	(0.0516)
Log urea use per (ha)	0.0662**	0.0809***	0.0689**	0.0806***
	(0.0289)	(0.0217)	(0.0301)	(0.0220)
Battese urea	0.132	0.189*	0.135	0.184*
	(0.132)	(0.0995)	(0.135)	(0.102)
Log of dap use per (ha)	0.106***	0.100***	0.102***	0.100***
	(0.0312)	(0.0240)	(0.0338)	(0.0245)
Battese dap	0.373***	0.375***	0.371***	0.380***
	(0.126)	(0.1000)	(0.133)	(0.102)
Log seed per (ha)	0.0871***	0.137***	0.0749**	0.124***
	(0.0307)	(0.0294)	(0.0336)	(0.0310)

Log herb per (ha)	-0.0130	-0.00767	-0.0169	-0.0109
	(0.0176)	(0.0166)	(0.0190)	(0.0177)
Batteses herb	-0.0359	-0.0491*	-0.0235	-0.0417
	(0.0351)	(0.0267)	(0.0382)	(0.0277)
Log labor days per (ha)	0.0769***	0.134***	0.0639**	0.115***
	(0.0298)	(0.0308)	(0.0287)	(0.0290)
Manure per (ha)	0.0374*	0.0442***	0.0343*	0.0442***
	(0.0203)	(0.0167)	(0.0208)	(0.0170)
irrigation	-0.0692	-0.0430	-0.0800	-0.0509
	(0.0586)	(0.0370)	(0.0597)	(0.0390)
Log of farm size(ha)	-0.00336	-0.00214	0.000604	0.00357
	(0.0163)	(0.0176)	(0.0170)	(0.0188)
intercropping	-0.0499	-0.0961**	-0.0922	-0.129**
	(0.0669)	(0.0425)	(0.0784)	(0.0509)
Previous crop maize	-0.0429**	-0.00960	-0.0393*	-0.00831
	(0.0204)	(0.0145)	(0.0202)	(0.0146)
Crop residue left	-0.00363	-0.0199	0.00444	-0.0188
	(0.0398)	(0.0336)	(0.0411)	(0.0337)
mobile	0.0376*	0.0457*	0.0289	0.0355
	(0.0225)	(0.0238)	(0.0254)	(0.0276)
hhldsize	0.00160	0.00197	-0.00540	-0.00861
	(0.00521)	(0.00534)	(0.00904)	(0.0104)
sex	0.00551	0.0154	-0.00352	0.00158
	(0.0336)	(0.0363)	(0.0346)	(0.0386)
age	-0.000845	-0.000878	-0.00173	-0.00204
	(0.000972)	(0.00104)	(0.00117)	(0.00128)
Head schooling primary	0.0240	0.0253	0.0250	0.0235
years	(0.0223)	(0.0232)	(0.0228)	(0.0239)
Head schooling secondary and above	0.0904*	0.0881*	0.0985*	0.0988**

	(0.0495)	(0.0468)	(0.0509)	(0.0503)
lnlivestock000	0.0239*	0.0257**	0.0256**	0.0287**
	(0.0123)	(0.0118)	(0.0125)	(0.0123)
no_liv	0.163	0.191*	0.187	0.226**
	(0.115)	(0.108)	(0.119)	(0.115)
kebele2	0.248***	0.296***	0.275***	0.320***
	(0.0741)	(0.0862)	(0.0790)	(0.0898)
kebele3	0.176**	0.239***	0.180**	0.235**
	(0.0850)	(0.0908)	(0.0877)	(0.0969)
kebele4	-0.0136	-0.0428	-0.0244	-0.0720
	(0.112)	(0.141)	(0.115)	(0.152)
kebele5	0.141**	0.213***	0.134**	0.196**
	(0.0628)	(0.0756)	(0.0645)	(0.0817)
kebele6	-0.0957	-0.112	-0.0816	-0.0969
	(0.0664)	(0.0825)	(0.0696)	(0.0862)
kebele7	0.0633	0.124	0.0547	0.0906
	(0.0735)	(0.0831)	(0.0754)	(0.0937)
kebele8	-0.198**	-0.181**	-0.187**	-0.171**
	(0.0816)	(0.0853)	(0.0770)	(0.0847)
kebele9	0.222***	0.238***	0.281***	0.306***
	(0.0775)	(0.0881)	(0.0950)	(0.103)
kebele10	0.286***	0.311***	0.335***	0.373***
	(0.0810)	(0.0880)	(0.0841)	(0.0930)
kebele11	0.0754	0.0735	0.0892	0.0888
	(0.0687)	(0.0791)	(0.0696)	(0.0831)
kebele12	0.178***	0.184**	0.153**	0.138
	(0.0617)	(0.0752)	(0.0677)	(0.0887)
kebele13	-0.0202	-0.00739	0.0194	0.0358
	(0.0634)	(0.0732)	(0.0717)	(0.0805)
kebele14	-0.0597	0.0344	-0.0581	0.0164
	(0.112)	(0.102)	(0.110)	(0.107)

kebele15	-0.0699	-0.0373	0.0177	0.0885
	(0.0845)	(0.0975)	(0.121)	(0.138)
kebele16	-0.0623	-0.0404	-0.0790	-0.0674
	(0.108)	(0.115)	(0.111)	(0.122)
kebele17	0.174***	0.217***	0.186***	0.231***
	(0.0651)	(0.0737)	(0.0655)	(0.0769)
kebele18	-0.214***	-0.184**	-0.216***	-0.198**
	(0.0678)	(0.0768)	(0.0689)	(0.0815)
kebele19	0.0456	0.120	0.0744	0.155
	(0.0984)	(0.0981)	(0.0979)	(0.103)
kebele20	-0.163**	-0.131	-0.184**	-0.176
	(0.0802)	(0.0910)	(0.0868)	(0.107)
kebele21	-0.223***	-0.283***	-0.183**	-0.236***
	(0.0751)	(0.0819)	(0.0823)	(0.0879)
kebele22	0.0617	0.101	0.0634	0.0864
	(0.0679)	(0.0773)	(0.0704)	(0.0836)
kebele23	0.226***	0.196**	0.284***	0.270***
	(0.0757)	(0.0803)	(0.0916)	(0.0930)
kebele24	-0.0486	-0.0538	-0.0190	-0.0236
	(0.0621)	(0.0747)	(0.0640)	(0.0763)
kebele25	-0.141*	-0.124	-0.0863	-0.0697
	(0.0754)	(0.0865)	(0.0854)	(0.0907)
kebele26	-0.221***	-0.206***	-0.209***	-0.187**
	(0.0675)	(0.0764)	(0.0695)	(0.0810)
kebele27	-0.0996	-0.108	-0.0601	-0.0617
	(0.127)	(0.140)	(0.136)	(0.148)
kebele28	0.00921	0.0305	0.0422	0.0617
	(0.0651)	(0.0789)	(0.0732)	(0.0856)
kebele29	-0.135**	-0.190**	-0.0488	-0.0843
	(0.0676)	(0.0783)	(0.0988)	(0.104)
kebele30	-0.259***	-0.228***	-0.253***	-0.232***

	(0.0781)	(0.0859)	(0.0764)	(0.0874)
kebele31	0.340***	0.255***	0.341***	0.252***
	(0.0851)	(0.0907)	(0.0837)	(0.0940)
kebele32	0.0242	0.0348	0.0672	0.0851
	(0.0670)	(0.0762)	(0.0766)	(0.0849)
kebele33	0.213**	0.196*	0.236***	0.216**
	(0.0833)	(0.102)	(0.0826)	(0.101)
kebele34	-0.0882	-0.0612	-0.0481	-0.0109
	(0.0635)	(0.0733)	(0.0710)	(0.0814)
kebele35	-0.0692	-0.0458	-0.0851	-0.0849
	(0.0935)	(0.105)	(0.0990)	(0.118)
kebele36	-0.0647	-0.00148	-0.0776	-0.0239
	(0.170)	(0.158)	(0.171)	(0.166)
kebele37	0.125	0.165*	0.0788	0.0903
	(0.0763)	(0.0857)	(0.0934)	(0.112)
kebele38	-0.00929	-0.0395	0.0433	0.0384
	(0.0738)	(0.0944)	(0.0862)	(0.107)
Constant	6.529***	6.042***	6.583***	6.097***
	(0.217)	(0.218)	(0.222)	(0.221)
Observations	5,293	5,293	5,293	5,293
R-squared	0.188		0.156	2,994
Number of hh_id		2,994		

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2A. the impact of workdays lost due to malaria on maize productivity

	(1)	(2)	(3)	(4)
Variables	OLS	RE	2SLS	G2SLS

Log total days lost	-0.00252	-0.00441**	0.0262	0.0335
	(0.00178)	(0.00187)	(0.0194)	(0.0237)
FAW	-0.130**	-0.108***	-0.194***	-0.150***
	(0.0525)	(0.0328)	(0.0716)	(0.0423)
SB	-0.165***	-0.139***	-0.193***	-0.158***
	(0.0403)	(0.0340)	(0.0477)	(0.0387)
FAW and SB	-0.0643	-0.0802**	-0.0850*	-0.0964**
	(0.0454)	(0.0369)	(0.0505)	(0.0406)
Striga	-0.289*	-0.214***	-0.338**	-0.239***
	(0.151)	(0.0717)	(0.148)	(0.0715)
Other shocks	-0.353***	-0.393***	-0.371***	-0.399***
	(0.0495)	(0.0504)	(0.0528)	(0.0517)
Log of urea per (ha)	0.0662**	0.0808***	0.0711**	0.0808***
	(0.0290)	(0.0217)	(0.0308)	(0.0220)
Battese urea	0.132	0.189*	0.141	0.184*
	(0.132)	(0.0995)	(0.137)	(0.101)
Log of dap per(ha)	0.106***	0.100***	0.0993***	0.100***
	(0.0313)	(0.0240)	(0.0347)	(0.0245)
Battese dap	0.373***	0.375***	0.366***	0.382***
	(0.126)	(0.100)	(0.137)	(0.102)
Log seed per(ha)	0.0864***	0.136***	0.0738**	0.125***
	(0.0307)	(0.0294)	(0.0331)	(0.0305)
Log herb per(ha)	-0.0131	-0.00783	-0.0185	-0.0108
	(0.0177)	(0.0168)	(0.0187)	(0.0172)
Battese herb	-0.0358	-0.0493*	-0.0147	-0.0379
	(0.0353)	(0.0269)	(0.0389)	(0.0279)
Log labor days per (ha)	0.0767**	0.133***	0.0566*	0.112***
	(0.0298)	(0.0308)	(0.0291)	(0.0295)
manure	0.0376*	0.0443***	0.0302	0.0431**
	(0.0203)	(0.0167)	(0.0213)	(0.0171)
irrigation	-0.0702	-0.0436	-0.0779	-0.0495

	(0.0585)	(0.0369)	(0.0580)	(0.0377)
Log of farm size(ha)	-0.00287	-0.00132	-0.00153	0.000361
	(0.0163)	(0.0176)	(0.0170)	(0.0188)
intercropping	-0.0497	-0.0962**	-0.126	-0.146***
	(0.0669)	(0.0425)	(0.0871)	(0.0539)
Previous crop	-0.0432**	-0.00981	-0.0335	-0.00501
	(0.0204)	(0.0145)	(0.0205)	(0.0146)
Crop residue	-0.00367	-0.0200	0.0109	-0.0188
	(0.0397)	(0.0336)	(0.0425)	(0.0342)
mobile	0.0374*	0.0452*	0.0252	0.0338
	(0.0224)	(0.0237)	(0.0255)	(0.0275)
hhldsize	0.00123	0.00139	-0.00684	-0.00962
	(0.00521)	(0.00531)	(0.00791)	(0.00905)
sex	0.00514	0.0147	-0.00642	0.000117
	(0.0336)	(0.0363)	(0.0353)	(0.0392)
age	-0.000853	-0.000888	-0.00231*	-0.00254*
	(0.000974)	(0.00105)	(0.00123)	(0.00133)
Head schooling primary	0.0246	0.0261	0.0190	0.0165
years	(0.0224)	(0.0232)	(0.0237)	(0.0247)
Head schooling secondary and above	0.0910*	0.0889*	0.0981*	0.0980*
	(0.0495)	(0.0469)	(0.0510)	(0.0501)
lnlivestock000	0.0236*	0.0251**	0.0305**	0.0353***
	(0.0123)	(0.0118)	(0.0137)	(0.0137)
no_liv	0.161	0.186*	0.227*	0.282**
	(0.115)	(0.108)	(0.129)	(0.128)
kebele2	0.251***	0.300***	0.264***	0.300***
	(0.0741)	(0.0863)	(0.0795)	(0.0924)
kebele3	0.176**	0.238***	0.185**	0.238**
	(0.0851)	(0.0909)	(0.0901)	(0.0985)

kebele4	-0.0105	-0.0387	-0.0648	-0.118
	(0.112)	(0.142)	(0.124)	(0.162)
kebele5	0.143**	0.216***	0.107	0.167*
	(0.0628)	(0.0758)	(0.0725)	(0.0911)
kebele6	-0.0929	-0.108	-0.100	-0.117
	(0.0665)	(0.0827)	(0.0730)	(0.0903)
kebele7	0.0661	0.128	0.0191	0.0460
	(0.0736)	(0.0834)	(0.0853)	(0.108)
kebele8	-0.193**	-0.174**	-0.228***	-0.221**
	(0.0816)	(0.0855)	(0.0852)	(0.0976)
kebele9	0.226***	0.243***	0.282***	0.300***
	(0.0769)	(0.0878)	(0.0840)	(0.0963)
kebele10	0.291***	0.317***	0.325***	0.357***
	(0.0809)	(0.0879)	(0.0802)	(0.0903)
kebele11	0.0790	0.0783	0.0621	0.0581
	(0.0688)	(0.0793)	(0.0763)	(0.0916)
kebele12	0.181***	0.188**	0.103	0.0871
	(0.0620)	(0.0756)	(0.0849)	(0.107)
kebele13	-0.0152	-0.000796	-0.00330	0.00743
	(0.0634)	(0.0734)	(0.0664)	(0.0798)
kebele14	-0.0566	0.0385	-0.0895	-0.0226
	(0.112)	(0.102)	(0.116)	(0.118)
kebele15	-0.0634	-0.0278	0.0155	0.0813
	(0.0843)	(0.0975)	(0.104)	(0.121)
kebele16	-0.0619	-0.0420	-0.0956	-0.0692
	(0.108)	(0.115)	(0.116)	(0.125)
kebele17	0.177***	0.220***	0.170**	0.214***
	(0.0651)	(0.0740)	(0.0681)	(0.0804)
kebele18	-0.212***	-0.180**	-0.247***	-0.236**
	(0.0678)	(0.0770)	(0.0769)	(0.0932)
kebele19	0.0498	0.126	0.0516	0.130

	(0.0985)	(0.0983)	(0.0982)	(0.105)
kebele20	-0.160**	-0.127	-0.229**	-0.228*
	(0.0802)	(0.0913)	(0.103)	(0.126)
kebele21	-0.218***	-0.276***	-0.208**	-0.272***
	(0.0751)	(0.0822)	(0.0811)	(0.0916)
kebele22	0.0646	0.104	0.0351	0.0577
	(0.0679)	(0.0773)	(0.0780)	(0.0929)
kebele23	0.231***	0.204**	0.274***	0.247***
	(0.0760)	(0.0807)	(0.0823)	(0.0875)
kebele24	-0.0444	-0.0489	-0.0407	-0.0470
	(0.0619)	(0.0748)	(0.0633)	(0.0790)
kebele25	-0.134*	-0.115	-0.117	-0.108
	(0.0751)	(0.0865)	(0.0756)	(0.0896)
kebele26	-0.218***	-0.203***	-0.233***	-0.204**
	(0.0675)	(0.0764)	(0.0744)	(0.0862)
kebele27	-0.0968	-0.105	-0.0593	-0.0641
	(0.127)	(0.140)	(0.134)	(0.147)
kebele28	0.0140	0.0370	0.0173	0.0283
	(0.0652)	(0.0791)	(0.0685)	(0.0860)
kebele29	-0.129*	-0.182**	-0.0503	-0.0977
	(0.0673)	(0.0783)	(0.0799)	(0.0902)
kebele30	-0.253***	-0.221**	-0.303***	-0.289***
	(0.0782)	(0.0862)	(0.0884)	(0.104)
kebele31	0.344***	0.259***	0.307***	0.209*
	(0.0849)	(0.0909)	(0.0926)	(0.107)
kebele32	0.0291	0.0417	0.0483	0.0578
	(0.0669)	(0.0765)	(0.0680)	(0.0812)
kebele33	0.217***	0.201**	0.215**	0.187*
	(0.0830)	(0.102)	(0.0847)	(0.109)
kebele34	-0.0836	-0.0549	-0.0662	-0.0336
	(0.0633)	(0.0734)	(0.0656)	(0.0795)

kebele35	-0.0677	-0.0451	-0.113	-0.110
	(0.0936)	(0.105)	(0.107)	(0.125)
kebele36	-0.0633	0.000714	-0.101	-0.0512
	(0.170)	(0.158)	(0.175)	(0.171)
kebele37	0.125	0.163*	0.0473	0.0626
	(0.0764)	(0.0859)	(0.0988)	(0.115)
kebele38	-0.00527	-0.0335	0.0406	0.0310
	(0.0736)	(0.0944)	(0.0800)	(0.102)
Constant	6.508***	6.006***	6.841***	6.374***
	(0.218)	(0.219)	(0.307)	(0.306)
Observations	5,293	5,293	5,293	5,293
R-squared	0.188	2,994	0.125	2,994

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3A. 3SLS estimation of malaria and labor supply on maize productivity

Variables	(1) Malaria sick	(2) Log of maize productivity	(3) Log of labor days per hectare
At least one member was malaria sick in the last 12 months (1/0)		0.245	1.035***
		(0.215)	(0.0959)
FAW		-0.139***	
		(0.0487)	
SB		-0.177***	
		(0.0334)	
FAW and SB		-0.0555	
		(0.0369)	

Striga	-0.296***
	(0.0718)
Other shocks	-0.357***
	(0.0312)
Log of urea per(ha)	0.0610**
	(0.0245)
Battese urea	0.108
	(0.109)
Log of dap per(ha)	0.102***
	(0.0245)
Battese dap	0.354***
	(0.110)
Log of seed per(ha)	0.0717**
	(0.0338)
Log herb per(ha)	-0.0160
	(0.0161)
Battese herb	-0.0411
	(0.0283)
Log of labor days per ha	0.382***
	(0.127)
manure	0.0297
	(0.0229)
irrigation	-0.0697*
	(0.0402)
Log farm size(ha)	-2.05e-05
	(0.0138)
intercropping	-0.0722
	(0.0743)
Previous crop	-0.0424**
	(0.0178)

Crop residue		-0.00559	
		(0.0339)	
mobile	0.0405***	0.0260	-0.0358*
	(0.0150)	(0.0211)	(0.0187)
hhldsize	0.0301***	-0.0118	-0.0159***
	(0.00385)	(0.00840)	(0.00558)
sex	0.0481**	-0.00839	-0.0442
	(0.0246)	(0.0326)	(0.0306)
age	0.00343***	-0.00206*	-0.00292***
	(0.000575)	(0.00113)	(0.000780)
Head schooling- primary	0.00109	0.0326*	-0.0219
	(0.0148)	(0.0194)	(0.0181)
Head schooling-secondary and above	-0.0161	0.0921**	0.0384
	(0.0283)	(0.0371)	(0.0348)
lnlivestock000	-0.00344	0.0316***	-0.0106
	(0.00888)	(0.0118)	(0.0109)
no_liv	-0.0581	0.278**	-0.173*
	(0.0854)	(0.116)	(0.104)
kebele2	-0.0596	0.200**	0.312***
	(0.0646)	(0.0894)	(0.0797)
kebele3	0.0297	0.164**	0.0238
	(0.0625)	(0.0818)	(0.0766)
kebele4	0.0494	-0.0369	-0.0214
	(0.0574)	(0.0744)	(0.0708)
kebele5	0.0229	0.173**	-0.140**
	(0.0522)	(0.0677)	(0.0639)
kebele6	-0.0411	-0.241**	0.566***
	(0.0537)	(0.0940)	(0.0661)
kebele7	0.0630	-0.0270	0.140*

	(0.0632)	(0.0877)	(0.0780)
kebele8	-0.0296	-0.322***	0.465***
	(0.0634)	(0.0983)	(0.0780)
kebele9	-0.214***	0.260***	0.299***
	(0.0454)	(0.0800)	(0.0600)
kebele10	-0.113**	0.179*	0.580***
	(0.0511)	(0.0954)	(0.0638)
kebele11	-0.0125	-0.229	1.036***
	(0.0602)	(0.148)	(0.0741)
kebele12	0.118**	0.0225	0.268***
	(0.0536)	(0.0931)	(0.0667)
kebele13	-0.138**	-0.0533	0.392***
	(0.0575)	(0.0852)	(0.0720)
kebele14	0.0231	-0.0761	0.0290
	(0.0508)	(0.0670)	(0.0624)
kebele15	-0.386***	0.0437	0.370***
	(0.0788)	(0.128)	(0.104)
kebele16	0.0705	-0.153*	0.154**
	(0.0595)	(0.0838)	(0.0736)
kebele17	-0.0297	0.0830	0.375***
	(0.0507)	(0.0787)	(0.0625)
kebele18	0.0354	-0.271***	0.149**
	(0.0490)	(0.0668)	(0.0603)
kebele19	-0.122**	0.105	0.0428
	(0.0620)	(0.0842)	(0.0773)
kebele20	0.0955*	-0.260***	0.139**
	(0.0506)	(0.0769)	(0.0625)
kebele21	-0.0848	-0.582***	1.385***
	(0.0607)	(0.176)	(0.0751)
kebele22	-0.0193	0.0245	0.135*
	(0.0621)	(0.0818)	(0.0764)

kebele23	-0.136**	0.0104	0.990***
	(0.0564)	(0.134)	(0.0707)
kebele24	-0.110**	-0.175*	0.643***
	(0.0537)	(0.0964)	(0.0668)
kebele25	-0.229***	-0.226*	0.713***
	(0.0709)	(0.116)	(0.0899)
kebele26	-0.0613	-0.315***	0.399***
	(0.0646)	(0.0947)	(0.0795)
kebele27	-0.111*	-0.141	0.393***
	(0.0626)	(0.0923)	(0.0777)
kebele28	-0.144***	0.0574	0.102
	(0.0515)	(0.0734)	(0.0643)
kebele29	-0.301***	-0.366**	1.347***
	(0.0521)	(0.153)	(0.0701)
kebele30	-0.00886	-0.325***	0.229***
	(0.0635)	(0.0885)	(0.0781)
kebele31	0.112**	-0.313	1.933***
	(0.0452)	(0.274)	(0.0561)
kebele32	-0.156***	0.0164	0.320***
	(0.0518)	(0.0792)	(0.0654)
kebele33	-0.0269	0.210***	0.0698
	(0.0517)	(0.0712)	(0.0633)
kebele34	-0.152***	-0.168*	0.563***
	(0.0529)	(0.0913)	(0.0669)
kebele35	0.0882	-0.142*	0.0450
	(0.0553)	(0.0750)	(0.0685)
kebele36	0.0603	-0.171*	0.216***
	(0.0609)	(0.0892)	(0.0752)
kebele37	0.209***	-0.0102	0.0487
	(0.0638)	(0.101)	(0.0805)
kebele38	-0.224***	0.0202	0.349***

	(0.0632)	(0.0932)	(0.0808)
Eave completely closed	0.0101		
	(0.0169)		
Eave partially closed	0.0672***		
	(0.0191)		
Animals shelter in the main house	0.0360***		
	(0.0137)		
All family sleep under net	-0.0332**		
	(0.0163)		
Constant	0.127	5.232***	4.260***
	(0.0977)	(0.433)	(0.118)
Observations	5,293	5,293	5,293
R-squared	0.088	0.073	0.138

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4A. 3SLS estimation of the impact of workdays lost and labor supply on maize productivity

	(1)	(2)	(3)
Variables	Log of workdays lost	Log of maize productivity	Log of labor days per hectare
Log of total days lost		0.0289*	0.0631***
		(0.0167)	(0.00726)
FAW		-0.137***	
		(0.0522)	
SB		-0.178***	
		(0.0323)	

FAW and SB	-0.0552
	(0.0379)
Striga	-0.293***
	(0.0703)
Other shocks	-0.356***
	(0.0309)
Log of urea per(ha)	0.0584**
	(0.0246)
Battese urea	0.0973
	(0.109)
Log dap per(ha)	0.102***
	(0.0245)
Battese dap	0.348***
	(0.110)
lnq_seed_hec	0.0680**
	(0.0324)
Log of herb(ha)	-0.0164
	(0.0160)
Battese herb	-0.0437
	(0.0289)
Log labor days per(ha)	0.415***
	(0.129)
manure	0.0276
	(0.0232)
irrigation	-0.0692*
	(0.0392)
Log of farm size(ha)	-0.000955
	(0.0133)
intercropping	-0.0757
	(0.0778)

Previous crop		-0.0428**	
		(0.0184)	
Crop residue		-0.00610	
		(0.0342)	
mobile	0.476***	0.0217	-0.0270
	(0.177)	(0.0211)	(0.0179)
hhldsize	0.309***	-0.0136*	-0.00371
	(0.0453)	(0.00731)	(0.00506)
sex	0.515*	-0.0117	-0.0278
	(0.289)	(0.0328)	(0.0291)
age	0.0500***	-0.00267**	-0.00256***
	(0.00677)	(0.00118)	(0.000768)
Head schooling- primary	0.247	0.0263	-0.0386**
	(0.174)	(0.0199)	(0.0174)
Head schooling- secondary and above	-0.0439	0.0893**	0.0231
	(0.333)	(0.0373)	(0.0332)
lnlivestock000	-0.190*	0.0372***	-0.00352
	(0.105)	(0.0127)	(0.0105)
no_liv	-1.773*	0.329***	-0.135
	(1.007)	(0.123)	(0.101)
kebele2	0.235	0.172*	0.229***
	(0.761)	(0.0890)	(0.0758)
kebele3	0.203	0.165**	0.0344
	(0.736)	(0.0833)	(0.0731)
kebele4	1.861***	-0.0793	-0.0835
	(0.677)	(0.0814)	(0.0689)
kebele5	1.216**	0.148**	-0.196***
	(0.615)	(0.0716)	(0.0615)
kebele6	0.387	-0.278***	0.500***
	(0.633)	(0.0970)	(0.0630)

kebele7	1.904**	-0.0777	0.0902
	(0.745)	(0.0940)	(0.0758)
kebele8	1.397*	-0.384***	0.345***
	(0.747)	(0.105)	(0.0751)
kebele9	-1.511***	0.248***	0.166***
	(0.535)	(0.0712)	(0.0546)
kebele10	-0.0430	0.135	0.461***
	(0.602)	(0.0925)	(0.0600)
kebele11	1.133	-0.297*	0.950***
	(0.709)	(0.154)	(0.0712)
kebele12	2.864***	-0.0453	0.207***
	(0.632)	(0.104)	(0.0662)
kebele13	-0.102	-0.0904	0.259***
	(0.678)	(0.0818)	(0.0675)
kebele14	1.532**	-0.116	-0.0459
	(0.599)	(0.0712)	(0.0604)
kebele15	-3.056***	0.0374	0.165*
	(0.928)	(0.113)	(0.0951)
kebele16	1.136	-0.175**	0.156**
	(0.700)	(0.0864)	(0.0704)
kebele17	0.406	0.0533	0.313***
	(0.597)	(0.0810)	(0.0596)
kebele18	1.605***	-0.313***	0.0788
	(0.578)	(0.0721)	(0.0584)
kebele19	-0.133	0.0815	-0.0761
	(0.731)	(0.0814)	(0.0729)
kebele20	2.423***	-0.316***	0.0781
	(0.596)	(0.0872)	(0.0616)
kebele21	0.607	-0.659***	1.257***
	(0.715)	(0.181)	(0.0711)
kebele22	0.831	-0.00952	0.0661

	(0.731)	(0.0858)	(0.0733)
kebele23	-0.200	-0.0464	0.859***
	(0.664)	(0.133)	(0.0663)
kebele24	-0.0820	-0.217**	0.527***
	(0.632)	(0.0979)	(0.0628)
kebele25	-0.570	-0.281**	0.513***
	(0.835)	(0.113)	(0.0834)
kebele26	0.281	-0.352***	0.320***
	(0.761)	(0.0980)	(0.0758)
kebele27	-0.952	-0.152*	0.322***
	(0.738)	(0.0909)	(0.0735)
kebele28	-0.272	0.0297	-0.0242
	(0.607)	(0.0679)	(0.0603)
kebele29	-2.111***	-0.413***	1.171***
	(0.614)	(0.149)	(0.0630)
kebele30	1.877**	-0.389***	0.103
	(0.747)	(0.0967)	(0.0757)
kebele31	2.658***	-0.430	1.879***
	(0.532)	(0.282)	(0.0559)
kebele32	-0.410	-0.0173	0.185***
	(0.611)	(0.0737)	(0.0609)
kebele33	0.934	0.173**	-0.0177
	(0.609)	(0.0702)	(0.0607)
kebele34	-0.358	-0.206**	0.429***
	(0.623)	(0.0898)	(0.0623)
kebele35	1.727***	-0.178**	0.0308
	(0.652)	(0.0799)	(0.0662)
kebele36	1.331*	-0.206**	0.193***
	(0.717)	(0.0933)	(0.0723)
kebele37	2.947***	-0.0506	0.0797
	(0.752)	(0.104)	(0.0773)

kebele38	-1.724**	0.0122	0.226***
	(0.744)	(0.0873)	(0.0754)
Eave completely closed	-0.312		
	(0.210)		
Eave partially closed	0.613***		
	(0.235)		
Animals sheltered in the main house	0.433***		
	(0.164)		
All family sleep under bed nets	-0.225		
	(0.195)		
Constant	-7.730***	5.377***	4.923***
	(1.153)	(0.454)	(0.123)
Observations	5,293	5,293	5,293
R-squared	0.088	0.022	0.330

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix B: Diagnostic tests

Table 1B. test for multicollinearity by using Variance Inflation Factor(VIF)

Variable	VIF	1/VIF
Log livestock	8.46	0.118226
Log dap per(ha)	7.83	0.1277
no_liv	7.68	0.130175
Log ureaper(ha)	7.53	0.132817
Battese dap	5.91	0.169116
Battese urea	5.84	0.171369
kebele9	3.19	0.313189
kebele14	2.29	0.43595
kebele18	2.25	0.445266

kebele10	2.22	0.451436
kebele33	2.18	0.458084
kebele20	2.16	0.463631
kebele17	2.13	0.470408
kebele32	2.05	0.487202
kebele5	2.03	0.49198
kebele28	2.03	0.492577
kebele34	1.97	0.50766
kebele24	1.94	0.515514
kebele12	1.94	0.516249
kebele35	1.83	0.545965
kebele13	1.73	0.577026
kebele4	1.7	0.589124
kebele3	1.63	0.614958
kebele27	1.62	0.618935
kebele16	1.61	0.621968
kebele36	1.58	0.631141
kebele7	1.58	0.633658
kebele37	1.55	0.644475
kebele19	1.54	0.651394
kebele22	1.53	0.651999
kebele8	1.53	0.652832
kebele2	1.53	0.655537
kebele30	1.52	0.656174
kebele38	1.51	0.66289
kebele26	1.49	0.672293
Battese herb	1.49	0.672685
kebele25	1.39	0.718573
mobile	1.33	0.750045
hhldsize	1.33	0.750305
age	1.33	0.75173

sex	1.33	0.752975
Log herb per(ha)	1.31	0.76563
kebele15	1.3	0.768515
lnfarmsize	1.29	0.772748
educ3	1.26	0.796744
educ2	1.24	0.807327
manure	1.23	0.814588
Previous crop	1.21	0.825489
Log labor days per(ha)	1.18	0.845403
SB	1.18	0.846714
Log seed per(ha)	1.18	0.847081
Other shock	1.15	0.870914
Crop residue	1.13	0.885462
Malaria sick	1.12	0.895878
intercropping	1.11	0.901797
FAW and SB	1.09	0.91495
irrigation	1.09	0.915419
FAW	1.09	0.916395
Striga dummy	1.08	0.92176
Mean VIF	2.11	

Table 2B. test for heteroscedasticity using Breusch-Pagan test for heteroskedasticity

Estat
hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant

variance

Variables: fitted values of uhat square

chi2(1) = 1279.22
Prob > chi2 = 0.0000

Appendix C: summary of working capacity reduced because of malaria

Variable	Obs	Mean	Std.Dev.	Min	Max
Working capacity reduced because of malaria	2429	7.543	9.8	0	100

Appendix D: tables of the impact of malaria on hired labor and the impact of hired labor on maize productivity

Table 1D. The impact of malaria on hired labor

	(1)
Variables	Log total hired labor per hectare
At least one member was malaria sick	0.204***
in the last 12 months (1/0)	(0.0346)
mobile	-0.0219
	(0.0388)
hhldsize	-0.00137
	(0.0107)
sex	-0.0699
	(0.0596)
age	0.000673
	(0.00128)
educ2	0.0201
	(0.0391)

educ3	0.00703
	(0.0679)
lnlivestock000	-0.0346**
	(0.0167)
no_liv	-0.393***
	(0.151)
kebele2	0.163
	(0.215)
kebele3	0.0546
	(0.145)
kebele4	0.0505
	(0.107)
kebele5	-0.182
	(0.135)
kebele6	0.220
	(0.135)
kebele7	-0.0221
	(0.121)
kebele8	0.293***
	(0.107)
kebele9	0.336***
	(0.0985)
kebele10	0.402***
	(0.115)
kebele11	0.546***
	(0.129)
kebele12	0.196
	(0.166)
kebele13	0.248*
	(0.143)
kebele14	0.0283

	(0.119)
kebele15	-0.0332
	(0.106)
kebele16	0.272**
	(0.108)
kebele17	0.191*
	(0.111)
kebele18	-0.166
	(0.167)
kebele19	-0.0575
	(0.154)
kebele20	-0.117
	(0.181)
kebele21	-0.106
	(0.174)
kebele22	0.111
	(0.108)
kebele23	0.546***
	(0.109)
kebele24	0.515***
	(0.104)
kebele25	0.402***
	(0.128)
kebele26	0.298**
	(0.146)
kebele27	0.207*
	(0.107)
kebele28	-0.0962
	(0.110)
kebele29	0.273***
	(0.0977)

kebele30	0.291***
	(0.102)
kebele31	-0.177
	(0.115)
kebele32	0.0365
	(0.0984)
kebele33	0.0873
	(0.144)
kebele34	0.292***
	(0.108)
kebele35	0.0256
	(0.104)
kebele36	0.170
	(0.112)
kebele37	0.317***
	(0.114)
kebele38	0.0575
	(0.0989)
Constant	2.828***
	(0.176)
Observations	5,293
Number of hh_id	2,994

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2D. The impact of total work days lost due to malaria on hired labor

	(1)

Variables	Log of total hired labor
Log of total days lost	0.0137***
	(0.00298)
mobile	-0.0116
	(0.0383)
hhldsize	-0.00220
	(0.0106)
sex	-0.0435
	(0.0679)
age	0.00173
	(0.00142)
educ2	0.0116
	(0.0389)
educ3	0.00547
	(0.0652)
lnlivestock000	-0.0241
	(0.0178)
no_liv	-0.317**
	(0.160)
kebele2	-0.0280
	(0.370)
kebele3	0.151
	(0.163)
kebele4	0.0398
	(0.108)
kebele5	-0.0543
	(0.134)
kebele6	0.273**
	(0.130)
kebele7	0.0191

	(0.121)
kebele8	0.262**
	(0.107)
kebele9	0.341***
	(0.0968)
kebele10	0.483***
	(0.119)
kebele11	0.552***
	(0.119)
kebele12	0.251
	(0.166)
kebele13	0.322**
	(0.128)
kebele14	0.0422
	(0.128)
kebele15	-0.0307
	(0.103)
kebele16	0.281**
	(0.109)
kebele17	0.232**
	(0.107)
kebele18	-0.143
	(0.171)
kebele19	0.0235
	(0.143)
kebele20	-0.0127
	(0.151)
kebele21	0.0767
	(0.153)
kebele22	0.105
	(0.105)

kebele23	0.537***
	(0.101)
kebele24	0.540***
	(0.107)
kebele25	0.468***
	(0.127)
kebele26	0.285*
	(0.160)
kebele27	0.208**
	(0.103)
kebele28	-0.0669
	(0.108)
kebele29	0.267***
	(0.0958)
kebele30	0.278***
	(0.107)
kebele31	-0.187
	(0.118)
kebele32	0.000350
	(0.0984)
kebele33	0.161
	(0.122)
kebele34	0.302***
	(0.115)
kebele35	0.0409
	(0.107)
kebele36	0.149
	(0.109)
kebele37	0.340***
	(0.116)
kebele38	0.0446

	(0.0971)
Constant	2.807***
	(0.188)
Observations	5,293
R-squared	0.055

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1