RESEARCH ARTICLE

Impact of eliminating malaria by 2040 on poverty rates among agricultural households in Africa [version 1; peer review: 1 approved, 1 approved with reservations]

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Abstract

Background: Reaching the goal of eradicating malaria by 2040, if achieved, would have a profound effect on farmers' lives in sub-Saharan Africa. Our objective is to examine how achieving that goal would affect poverty rates of agricultural households.
Methods: We analyzed the potential impact of eliminating malaria by 2040 on poverty rates among agricultural households in malarious regions of sub-Saharan Africa. Our model used ten scenarios to examine how the impact of eliminating malaria by 2040 on households' income would affect the number of individuals living on less than $1.90 (2011 PPP) per day.
Results: We analyzed ten scenarios for malaria's impact on agricultural household income from 2018 to 2040 for the approximately 324 million individuals in agricultural households in malarious regions of sub-Saharan Africa in 2018. We found that approximately 53 million to 123 million individuals would escape poverty by 2040 if malaria were eliminated by that year. If the malaria burden in agricultural households remained at its current level through 2040, only 40 million individuals would escape poverty by 2040, a decrease of only 24%. Therefore, the impact of eliminating malaria by 2040, relative to the status quo scenario through 2040, is that approximately 13 million to 84 million individuals in agricultural households will escape poverty.
Conclusions: The modeling analysis presented here is meant to be a starting point for additional research into the potential impact of eliminating malaria on the incomes of agricultural households in sub-Saharan Africa. This study could be strengthened with the application of new methods to examine malaria's impact on the welfare of agricultural households. We recommend the collection and analysis of longitudinal data from agricultural households in future studies of malaria's impact on these households.

Keywords

malaria eradication, agricultural households, poverty, Africa, harvest value

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Introduction

International funding for anti-malaria initiatives has increased significantly since 2000 (World Health Organization, 2018) with a goal of eradicating malaria by 2040. Achieving and sustaining the elimination of malaria will require sustained funding. The most common cause of past failures to achieve or maintain elimination was a lack of sufficient funding (Cohen *et al*., 2012). Sustaining funding for anti-malaria programs over the next two decades will depend, in part, on maintaining political support for malaria elimination efforts (Lover *et al*., 2017; Whittaker *et al*., 2014). One means of maintaining political support for malaria elimination initiatives would be to illustrate how suppressing malaria over the next two decades would affect poverty (Mills *et al*., 2008).

Concurrent to the global goal of eradicating malaria by 2040, the international community has established goals for reducing poverty over the next two decades. There are approximately 783 million people living in poverty globally (UN-SDG). The United Nations' Sustainable Development Goals (SDGs) have established a target of reducing, by at least 50 percent, the number of individuals living in poverty (UN-SDG). In 2015, the World Bank established $1.90 (2011 PPP) as the International Poverty Line, an increase from the previous global line of $1.25 (World Bank). The $1.90 poverty line uses 2011 prices and is expressed in terms of purchasing power parity (PPP). PPP exchange rates enable identical quantities of goods and services to be priced across countries equivalently (World Bank). Comparisons of countries' income and consumption data are facilitated through the use of PPP (World Bank).

An extensive literature has examined malaria's impact on economic growth (Gallup & Sachs, 2001; McCarthy *et al*., 2000) as well as its economic burden on households (Asenso-Okyere & Dzator, 1997; Ettling *et al*., 1994; Guiguemde *et al*., 1994; Shepard *et al*., 1991; Sauerborn *et al*., 1991). However, no studies have attempted to estimate how suppressing malaria over the next two decades would affect poverty rates. The objective of this paper is to examine how eliminating malaria by 2040 would affect poverty rates among agricultural households in sub-Saharan Africa.

Methods

Terminology and dataset

Our definition of an *agricultural household* for this study is the same as that used in our previous study (Willis & Hamon, 2018) in which we used a definition provided by an agricultural census conducted in Ethiopia in 2010 for identifying the characteristics of an agricultural household:

> A household is considered an agricultural household when at least one member of the household is engaged in growing crops and/or raising livestock in private or in combination with others (Federal Democratic Republic, 2010/2011).

In a recent study (Willis & Hamon, 2018), we estimated that there are approximately 54 million agricultural households in malarious regions of sub-Saharan Africa farming less than 10 hectares. This study will focus on these households. Therefore, throughout this paper, the term "agricultural households" refers to agricultural households farming less than 10 hectares. The 35 countries in sub-Saharan Africa that are included in this analysis are: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Côte d'Ivoire, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

Short summary of methodology

Our analysis has two components.

First, we developed a model to analyze the impact of eliminating malaria by 2040 on the incomes of agricultural households in malarious regions of sub-Saharan Africa. Our analysis estimated malaria's impact on the daily income of individuals in agricultural households from 2018 through 2040 by using a Malaria Elimination Path and a Status Quo Path. The Malaria Elimination Path corresponds to the average daily incomes of individuals in agricultural households if elimination were achieved by 2040. The Status Quo Path refers to the average daily incomes of individuals in agricultural households if the malaria burden were to remain at its current levels through 2040. Using our model, we examined ten scenarios for the long-term impact of suppressing malaria from 2018 through 2040 on daily per capita incomes.

Second, we identified research topics that, if addressed by the research community, could facilitate more accurate estimates of the potential long-term impact of eliminating malaria on agricultural households' incomes.

Detailed summary of data and model

In this section, we provide a more detailed description of our methodology for modeling the potential impact of eliminating malaria by 2040 on daily per capita incomes of individuals in agricultural households.

Three steps were involved in developing and applying our model. First, we developed estimates of the number of agricultural households in each of our target countries and the average income per capita for these households. Next, we identified ten sets of parameter values for estimating malaria's impact on the income of agricultural households. Finally, we used a model to link the agricultural household data for each country with the ten sets of parameter values in order to estimate the impact the elimination of malaria by 2040 would have on incomes and poverty levels. Our estimates of malaria's impact on the incomes of agricultural households are the product of comparing the incomes of these households if the malaria burden were to remain at its current level through 2040 with incomes if malaria elimination were achieved by 2040.

Average daily income for individuals in agricultural households. The first step in developing our model was estimating the average per capita income for agricultural households in each of our target countries. Our estimates of the number of agricultural

households in each of the 35 countries included in our analysis came from a recently published dataset (Willis, 2018).

We were unable to identify comprehensive estimates of agricultural household income for all 35 countries. As a result, we developed estimates of daily per capita income using the World Bank's PovcalNet data set, which includes data on the median of monthly household per capita income in 2011 Purchasing Power Parity (World Bank n.d.). These data are available for each of our target countries except Equatorial Guinea.

A World Bank report estimated that Equatorial Guinea's poverty rate in 2006 was 76.8 percent (Bassett *et al*., 2017). We assumed that this poverty rate reflects the poverty rate experienced by agricultural households in 2018. Using our model, we estimated that a median daily income of $1.35 would result in approximately 75 percent of individuals in agricultural households having daily incomes less than $1.90 (2011 PPP).

We assumed that these estimates provided in the PovcalNet data set for the median daily per capita income at the national level also reflect the daily per capita income of individuals in agricultural households. This is a conservative assumption given that poverty rates in rural areas are generally higher than in non-rural areas:

> Sub-Saharan Africa remains the last frontier in the fight to reduce poverty. Nearly half of the rural and one third of the urban population lived on less than $1.25 a day in 2008. For each poor person in an urban area, there were 2.4 as many in rural areas (World Bank & International Monetary Fund, 2013)

Table 1 summarizes the number of agricultural households and their median per capita daily income for each of our 35 countries.

Malaria's short-term impact on agricultural households' incomes. We defined malaria's short-term impact on the income of agricultural households as the impact over one year if there were an unexpected decrease in the malaria burden during that year relative to previous years. For example, if an agricultural household expected to experience malaria infections in 2018 but in fact did not, then the difference between the household's projected income with and without malaria infections would represent malaria's short-term impact on income.

Malaria could have a short-term impact on household income in two ways. The first would be the number of work days that would be lost by adults due to malaria morbidity or the provision of care for children within the household. The second would be the cost of seeking medical care.

The best evidence available to estimate the short-term impact of malaria on agricultural households' harvest values is a study conducted in Zambia in 2009, which found that households with access to a vector control intervention experienced an increase in harvest values of US$76 (Fink & Masiye, 2015). This increase in harvest values corresponded to an increase in yields of approximately 15% (Fink & Masiye, 2015). The authors attributed the higher harvest values to an increase in the number of people within agricultural households who could work as well as an increase in the number of hours those individuals could work (Fink & Masiye, 2015).

Fink and Masiye described the households enrolled in their study as follows:

> Average plot size was 4.15 ha (median 3.1) in 2009, and average harvest value in 2009 was US$577 (median US$463). With an average household size of close to six members, this implies average per-capita resources of approximately US$0.26 per day, placing the majority of these households well below the international US$1.25 dollars per day poverty threshold (Fink & Masiye, 2015)

Although Fink and Masiye assume that the households included in their study are representative of the average agricultural household in Zambia, they may not be representative of the average agricultural household in other countries. This creates uncertainty as to how to use the results from Fink and Masiye's study to inform the parameters in our model.

We therefore used a range of values in our model to address the uncertainty regarding malaria's short-term impact on agricultural households in our target countries in sub-Saharan Africa. Fink and Masiye found that harvest values were approximately 15% higher due to access to vector control interventions. Most scenarios in our model used a more conservative approach as we assumed that malaria's short-term impact on the income of agricultural households ranged from 3% to 21%.

Malaria's long-term impact on agricultural households' incomes. We defined malaria's long-term impact on the income of agricultural households as the impact over more than one year if the malaria burden would have remained suppressed. Malaria may affect the long-term income of agricultural households in many ways. For example, malaria may affect household decisions regarding which crops to plant and the amount of resources to devote to purchasing agricultural inputs. However, we lack longitudinal studies that examine malaria's impact on the incomes of agricultural households over long periods of time.

For the Status Quo Path, we assumed that the incomes of agricultural households will grow by 1% from 2018 through 2040. Our Elimination Path included ten scenarios for the annual growth in agricultural household income, with the growth rate ranging from 1.25% to 3.50%. Therefore, malaria's impact on the annual growth in agricultural household income ranged from 0.25% (Scenario 1) to 2.50% (Scenario 10). Malaria's long-term impact on agricultural households is the difference in household income from 2018 through 2040 between the Status Quo Path and the Elimination Path. Table 2 summarizes the parameter values used in our model for the Status Quo Path and for our ten Elimination Path scenarios.

We used Tanzania and Scenario 1 to provide a more detailed illustration of how our model was used to estimate

Table 1. **Country data for Number, Population, Median Daily Income and Poverty Levels of Agricultural Households.**

Table 1: Country Data for Number, Population, Median Daily Income and Poverty Levels of Agricultural Households				
Country	Number of agricultural households (less than 10 hectares)	Population of agricultural households (less than 10 hectares)	Median per capita daily income for individuals in agricultural households (2011 PPP)	Population in agricultural households in poverty (daily income less than $1.90) in 2018
Angola	791,492	4,748,952	$2.90	1,329,706
Benin	302,601	1,815,604	$1.95	871,490
Botswana	89,231	535,386	$4.54	74,954
Burkina Faso	657,559	3,945,355	$2.09	1,735,956
Burundi	1,156,946	6,941,676	$1.35	5,206,257
Cameroon	686,673	4,120,040	$3.64	824,008
Central African Republic	225,383	1,352,296	$1.35	1,014,222
Chad	271,790	1,630,738	$2.44	587,065
Republic of Congo	106,228	637,366	$2.54	216,704
Democratic Republic of Congo	3,322,215	19,933,288	$1.10	18,936,624
Equatorial Guinea	22,289	133,735	$1.35	100,301
Ethiopia	10,937,173	65,623,036	$2.79	19,686,911
Gabon	52,711	316,265	$7.70	9,487
Gambia	51,276	307,659	$3.87	55,378
Ghana	1,856,309	11,137,856	$4.61	1,447,921
Guinea	623,308	3,739,845	$2.37	1,383,743
Guinea Bissau	62,461	374,766	$1.41	269,831
Ivory Coast	828,898	4,973,386	$2.83	3,580,838
Kenya	2,039,498	12,236,986	$2.44	4,405,315
Liberia	90,290	541,740	$2.27	195,026
Madagascar	1,801,047	10,806,284	$1.10	10,265,970
Malawi	1,976,868	11,861,210	$1.26	9,726,192
Mali	597,158	3,582,946	$1.94	1,719,814
Mozambique	2,272,891	13,637,344	$1.50	9,137,021
Niger	496,398	2,978,388	$2.07	1,310,491
Nigeria	11,667,985	70,007,910	$1.80	37,804,272
Rwanda	1,242,001	7,452,009	$1.76	4,098,605
Senegal	324,121	1,944,724	$2.38	719,548
Sierra Leone	165,580	993,483	$1.86	516,611
South Sudan	773,131	4,638,788	$2.32	1,762,740
Tanzania	3,635,359	21,812,155	$1.95	10,469,834
Togo	318,556	1,911,337	$1.95	917,442
Uganda	2,926,297	17,557,780	$2.23	7,023,112
Zambia	1,311,962	7,871,771	$1.58	4,959,216
Zimbabwe	324,530	1,947,180	$3.42	428,380
TOTAL:	54,008,214	324,049,282	-	162,790,985

Table 2. Parameters for Status Quo Path and Elimination Path Scenarios.

Table 2: Parameters for Status Quo Path and Elimination Path Scenarios											
	Status Quo Path	Elimination Path Scenarios									
		Most Conservative Scenarios						Least Conservative Scenarios			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Malaria's Short-Term Impact on Agricultural Household Income in 2018	-	3%	5%	7%	9%	11%	13%	15%	17%	19%	21%
Malaria's Long-Term Impact on Annual Growth of Agricultural Household Income from 2018 through 2040	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%	3.00%	3.25%	3.50%

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malaria's impact on poverty levels. In 2015, the International Poverty Line was increased from $1.25 per day to $1.90 per day (2011 PPP). Our analysis of each country estimates the number of individuals who have an income greater than $1.90 per day in 2018 as well as the number who achieve an income greater than $1.90 per day by 2040 for each scenario.

We estimated that there are approximately 22 million people living in agricultural households in Tanzania and that the median per capita income is $1.95 (2011 PPP) (Table 1). Given that this is a median value, half of the individuals will have daily incomes greater than $1.95 and half will have incomes less than $1.95. To account for these differences in daily incomes among the individuals in Tanzania's agricultural households, we assumed a discrete uniform distribution with the lowest value being 20% of $1.95 and the largest value being 80% higher than $1.95.

We estimated that in 2018 there were approximately 11.3 million individuals in Tanzania's agricultural households with per capita incomes greater than $1.90 and approximately 10.5 million individuals with per capita incomes less than $1.90 (Table 1). For our Status Quo Path, we assumed that the annual growth rate in per capita income was 1%. Based on this assumption, our model estimated that in 2040 approximately 2.6 million individuals who had incomes less than $1.90 in 2018 would escape poverty.

For our Elimination Path Scenario 1, we assumed that the median income of individuals in Tanzania's agricultural households in 2018 was 3% higher (short-term impact) and that the annual growth rate of incomes through 2040 was 1.25% (0.25% higher than the Status Quo Path growth rate). These assumptions for Scenario 1 led to approximately 3.5 million individuals who had incomes less than $1.90 in 2018 escaping poverty (Table 4). The parameter values for Scenario 1, therefore, lead to an additional 872,486 individuals (3.5 million versus 2.7 million) escaping poverty relative to the Status Quo Path (Table 5).

Results

Modeling potential impact of suppressing malaria from 2018 to 2040

Table 3, Table 4 and Table 5 display the results of our analysis of the impact of eliminating malaria on poverty among individuals in agricultural households. Table 3 summarizes the impact of eliminating malaria on the number and percentage of individuals in poverty for all of the 35 countries included in our analysis.

Summary of poverty among agricultural households in 2018. Approximately 54 million agricultural households currently exist in malarious regions of sub-Saharan Africa. Using an estimate of 6 individuals per household, this yields a total population in these households of approximately 324 million (Table 1).

Using the dataset we developed with the median daily income of agricultural households in each country, we found that approximately 151 million individuals in agricultural households live in countries in which the median daily per capita income is less than $1.90 (2011 PPP). This population represents 47% of the total population of individuals in agricultural households. Approximately 154 million individuals, 48% of the total population, live in countries in which the median daily income of agricultural households is between $1.90 and $3.00 (2011 PPP). The remaining 5% of the population in agricultural households are in countries with a median daily per capita income greater than $4.00 (2011 PPP).

The total number of individuals in our study across all countries living in poverty in 2018 was approximately 163 million, which represented about 50% of the total population of all agricultural households. This percentage is consistent with estimates in other studies that approximately half of the rural population in sub-Saharan Africa lives in poverty (World Bank & International Monetary Fund, 2013).

Status Quo Path. The next step in our analysis involved examining how poverty levels in agricultural households would change from 2018 through 2040 with our Status Quo Path. The Status Quo Path assumed that the malaria burden among agricultural households would remain at its 2018 level through 2040 and that the annual real growth (growth in excess of inflation) in incomes among agricultural households would be 1% during that same period.

Based on this assumed annual growth in incomes, we found that the number of individuals in poverty decreased from approximately 163 million in 2018 to 126 million in 2040, a decrease of approximately 40 million individuals (Table 3). This represents a decrease from 50% of the total population living in poverty in 2018 to approximately 39% in 2040, a 24% decrease (Table 3).

In 2018, 13 countries had poverty rates in excess of 50% for their agricultural households. Assuming the Status Quo Path, nine of these countries would continue to experience poverty rates greater than 50% in 2040. The poverty rate was in excess of 30% in 20 countries.

The Status Quo Path projects that only 7 countries (Angola, Botswana, Cameroon, Gabon, Gambia, Ghana and Zimbabwe) will have a poverty rate of less than 20% by 2040. The total 2018 population of these 7 countries represents 7.1% of the population of the 35 countries in our study (Table 4). The Status Quo Path projects that Gabon will be the only country to eliminate poverty among its agricultural households by 2040 (Table 4).

Elimination Path. We analyzed the impact of ten Elimination Path scenarios on poverty levels of agricultural households from 2018 to 2040. Each Elimination Path scenario assumed that malaria would be eliminated by 2040; the differences between the scenarios were the impact that malaria elimination would

Table 3. Impact of Eliminating Malaria by 2040 on Poverty Among Individuals in Agricultural Households.

Table 3: Impact of Eliminating Malaria by 2040 on Number of Individuals in Agricultural Households That Escape Poverty											
Population in agricultural households in poverty in 2018 (162,790,985)	Status Quo Path	Elimination Path Scenarios									
		Most Conservative Scenarios									Least Conservative Scenarios
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Population that escapes poverty by 2040:	39,644,493	52,875,047	62,525,694	72,197,774	81,304,973	90,051,323	97,437,776	104,758,504	110,759,700	116,501,077	122,890,026
Impact of eliminating malaria on population that escapes poverty by 2040:		13,230,554	22,881,201	32,553,281	41,660,480	50,406,830	57,793,283	65,114,011	71,115,207	76,856,584	83,245,533
Percentage of population that escapes poverty by 2040:	24.4%	32.5%	38.4%	44.3%	49.9%	55.3%	59.9%	64.4%	68.0%	71.6%	75.5%
Impact of eliminating malaria on percentage of population that escapes poverty by 2040:		33.4%	57.7%	82.1%	105.1%	127.1%	145.8%	164.2%	179.4%	193.9%	210.0%

Table 4. Number of Individuals in Agricultural Households in 2040 in Poverty – Status Quo Path versus Elimination Path Scenarios.

Table 4: Number of Individuals in Agricultural Households That Escape Poverty in 2040 - Status Quo Path versus Elimination Path Scenarios												
	Population in agricultural households in poverty (daily income less than $1.90) in 2018	Population in agricultural households that escapes poverty (daily income less than $1.90) in 2040										
		Status Quo Path	Elimination Path Scenarios									
			Most Conservative Scenarios Least Conservative Scenarios									
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Angola	1,329,706	379,916	474,895	569,874	664,853	759,832	854,811	902,301	997,280	1,044,769	1,092,259	1,139,748
Benin	871,490	217,872	290,497	344,965	399,433	435,745	490,213	526,525	562,837	599,149	635,461	671,773
Botswana	74,954	26,769	37,477	42,831	48,185	58,892	64,246	69,600	69,600	74,954	74,954	74,954
Burkina Faso	1,735,956	433,989	591,803	710,164	789,071	907,432	986,339	1,065,246	1,144,153	1,223,060	1,301,967	1,341,421
Burundi	5,206,257	1,110,668	1,527,169	1,943,669	2,221,336	2,499,003	2,707,254	2,915,504	3,123,754	3,332,004	3,540,255	3,679,088
Cameroon	824,008	247,202	329,603	412,004	453,204	535,605	576,806	618,006	659,206	700,407	741,607	782,808
Central African Republic	1,014,222	216,367	297,505	378,643	432,735	486,827	527,395	567,964	608,533	649,102	689,671	716,717
Chad	587,065	146,766	211,996	244,611	277,225	309,840	342,455	375,070	407,685	423,992	456,607	472,914
Republic of Congo	216,704	57,363	76,484	89,231	108,352	121,100	127,473	140,221	152,968	159,342	172,089	178,462
Democratic Republic of Congo	18,936,624	4,185,990	5,581,321	6,577,985	7,574,649	8,571,314	9,567,978	10,365,310	11,162,641	11,959,973	12,557,971	13,155,970
Equatorial Guinea	100,301	21,398	29,422	37,446	42,795	48,145	52,157	56,169	60,181	64,193	68,205	70,880
Ethiopia	19,686,911	5,249,843	7,218,534	8,530,995	9,843,455	11,155,916	12,468,377	13,124,607	14,437,068	15,093,298	15,749,529	17,061,989
Gabon	9,487	9,487	9,487	9,487	9,487	9,487	9,487	9,487	9,487	9,487	9,487	9,487
Gambia	55,378	18,460	24,613	27,689	33,842	36,919	39,996	43,072	46,149	49,225	52,302	55,379
Ghana	1,447,921	445,514	668,271	779,650	1,002,407	1,113,786	1,225,164	1,336,543	1,447,921	1,447,921	1,447,921	1,447,921
Guinea	1,383,743	336,586	448,781	560,977	635,774	747,969	822,766	897,563	934,961	1,009,758	1,047,157	1,121,954
Guinea Bissau	269,831	59,963	86,196	101,187	116,177	131,168	142,411	153,654	164,897	176,140	183,635	194,878
Ivory Coast	3,580,838	795,742	1,143,879	1,342,814	1,541,750	1,740,685	1,889,887	2,039,088	2,188,290	2,337,491	2,436,959	2,586,161
Kenya	4,405,315	1,101,329	1,590,808	1,835,548	2,080,288	2,325,027	2,569,767	2,814,507	3,059,247	3,181,616	3,426,356	3,548,726
Liberia	195,026	48,757	70,426	81,261	92,096	102,931	113,765	124,600	135,435	140,852	151,687	157,105
Madagascar	10,265,970	2,269,320	3,025,760	3,566,074	4,106,388	4,646,702	5,187,016	5,619,268	6,051,519	6,483,770	6,807,959	7,132,147
Malawi	9,726,192	2,253,630	2,965,303	3,439,751	4,151,424	4,625,872	5,100,320	5,456,157	5,930,605	6,286,441	6,523,666	6,879,502
Mali	1,719,814	429,954	537,442	680,760	752,419	859,907	967,395	1,039,054	1,110,713	1,182,372	1,254,031	1,289,861
Mozambique	9,137,021	2,045,602	2,863,842	3,409,336	3,954,830	4,500,324	4,909,444	5,318,564	5,727,684	6,000,431	6,273,178	6,682,299
Niger	1,310,491	327,623	416,974	506,326	595,678	655,245	744,597	804,165	863,733	923,300	953,084	1,012,652

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Table 4: Number of Individuals in Agricultural Households That Escape Poverty in 2040 - Status Quo Path versus Elimination Path Scenarios												
	Population in agricultural households in poverty (daily income less than $1.90) in 2018	Population in agricultural households that escapes poverty (daily income less than $1.90) in 2040										
		Status Quo Path	Elimination Path Scenarios									
			Most Conservative Scenarios Least Conservative Scenarios									
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Nigeria	37,804,272	9,801,107	12,601,424	14,701,661	16,801,898	18,902,136	21,002,373	23,102,610	24,502,769	25,902,927	27,303,085	28,703,243
Rwanda	4,098,605	1,043,281	1,341,362	1,564,922	1,863,002	2,086,563	2,235,603	2,459,163	2,608,203	2,757,243	2,906,284	3,055,324
Senegal	719,548	175,025	252,814	291,709	350,050	388,945	427,839	466,734	486,181	525,075	544,523	583,417
Sierra Leone	516,611	129,153	178,827	208,631	238,436	268,240	288,110	317,915	337,784	357,654	377,524	387,458
South Sudan	1,762,740	417,491	603,042	695,818	834,982	927,758	1,020,533	1,113,309	1,206,085	1,252,473	1,345,249	1,391,636
Tanzania	10,469,834	2,617,459	3,489,945	4,144,309	4,798,674	5,234,917	5,889,282	6,325,525	6,761,768	7,198,011	7,634,254	8,070,497
Togo	917,442	229,360	305,814	363,154	420,494	458,721	516,061	554,288	592,514	630,741	668,968	707,195
Uganda	7,023,112	1,755,778	2,282,511	2,809,245	3,160,400	3,687,134	4,038,289	4,389,445	4,740,601	4,916,178	5,267,334	5,618,490
Zambia	4,959,216	1,259,483	1,574,354	1,889,225	2,204,096	2,440,249	2,676,402	2,912,555	3,069,991	3,306,144	3,463,579	3,621,015
Zimbabwe	428,380	116,831	175,246	194,718	233,662	272,605	292,077	311,549	331,021	369,964	389,436	408,908
Total:	162,790,985	39,644,492	52,875,046	62,525,693	72,197,773	81,304,972	90,051,322	97,437,775	104,758,503	110,759,699	116,501,076	122,890,025

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Table 5. Impact of Eliminating Malaria by 2040 on Number of Individuals That Escape Poverty.

Table 5: Impact of Eliminating Malaria by 2040 on Number of Individuals That Escape Poverty											
	Population in agricultural households in poverty (daily income less than $1.90) in 2018	Population in agricultural households that escapes poverty (daily income less than $1.90) in 2040									
		Elimination Path Scenarios									
		Most Conservative Scenarios						Least Conservative Scenarios			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Angola	1,329,706	94,979	189,958	284,937	379,916	474,895	522,385	617,364	664,853	712,343	759,832
Benin	871,490	72,625	127,093	181,561	217,873	272,341	308,653	344,965	381,277	417,589	453,901
Botswana	74,954	10,708	16,062	21,416	32,123	37,477	42,831	42,831	48,185	48,185	48,185
Burkina Faso	1,735,956	157,814	276,175	355,082	473,443	552,350	631,257	710,164	789,071	867,978	907,432
Burundi	5,206,257	416,501	833,001	1,110,668	1,388,335	1,596,586	1,804,836	2,013,086	2,221,336	2,429,587	2,568,420
Cameroon	824,008	82,401	164,802	206,002	288,403	329,604	370,804	412,004	453,205	494,405	535,606
Central African Republic	1,014,222	81,138	162,276	216,368	270,460	311,028	351,597	392,166	432,735	473,304	500,350
Chad	587,065	65,230	97,845	130,459	163,074	195,689	228,304	260,919	277,226	309,841	326,148
Republic of Congo	216,704	19,121	31,868	50,989	63,737	70,110	82,858	95,605	101,979	114,726	121,099
Democratic Republic of Congo	18,936,624	1,395,331	2,391,995	3,388,659	4,385,324	5,381,988	6,179,320	6,976,651	7,773,983	8,371,981	8,969,980
Equatorial Guinea	100,301	8,024	16,048	21,397	26,747	30,759	34,771	38,783	42,795	46,807	49,482
Ethiopia	19,686,911	1,968,691	3,281,152	4,593,612	5,906,073	7,218,534	7,874,764	9,187,225	9,843,455	10,499,686	11,812,146
Gabon	9,487	0	0	0	0	0	0	0	0	0	0
Gambia	55,378	6,153	9,229	15,382	18,459	21,536	24,612	27,689	30,765	33,842	36,919
Ghana	1,447,921	222,757	334,136	556,893	668,272	779,650	891,029	1,002,407	1,002,407	1,002,407	1,002,407
Guinea	1,383,743	112,195	224,391	299,188	411,383	486,180	560,977	598,375	673,172	710,571	785,368
Guinea Bissau	269,831	26,233	41,224	56,214	71,205	82,448	93,691	104,934	116,177	123,672	134,915
Ivory Coast	3,580,838	348,137	547,072	746,008	944,943	1,094,145	1,243,346	1,392,548	1,541,749	1,641,217	1,790,419
Kenya	4,405,315	489,479	734,219	978,959	1,223,698	1,468,438	1,713,178	1,957,918	2,080,287	2,325,027	2,447,397
Liberia	195,026	21,669	32,504	43,339	54,174	65,008	75,843	86,678	92,095	102,930	108,348
Madagascar	10,265,970	756,440	1,296,754	1,837,068	2,377,382	2,917,696	3,349,948	3,782,199	4,214,450	4,538,639	4,862,827
Malawi	9,726,192	711,673	1,186,121	1,897,794	2,372,242	2,846,690	3,202,527	3,676,975	4,032,811	4,270,036	4,625,872
Mali	1,719,814	107,488	250,806	322,465	429,953	537,441	609,100	680,759	752,418	824,077	859,907

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Table 5: Impact of Eliminating Malaria by 2040 on Number of Individuals That Escape Poverty											
	Population in agricultural households in poverty (daily income less than $1.90) in 2018	Population in agricultural households that escapes poverty (daily income less than $1.90) in 2040									
		Elimination Path Scenarios									
		Most Conservative Scenarios						Least Conservative Scenarios			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Mozambique	9,137,021	818,240	1,363,734	1,909,228	2,454,722	2,863,842	3,272,962	3,682,082	3,954,829	4,227,576	4,636,697
Niger	1,310,491	89,351	178,703	268,055	327,622	416,974	476,542	536,110	595,677	625,461	685,029
Nigeria	37,804,272	2,800,317	4,900,554	7,000,791	9,101,029	11,201,266	13,301,503	14,701,662	16,101,820	17,501,978	18,902,136
Rwanda	4,098,605	298,081	521,641	819,721	1,043,282	1,192,322	1,415,882	1,564,922	1,713,962	1,863,003	2,012,043
Senegal	719,548	77,789	116,684	175,025	213,920	252,814	291,709	311,156	350,050	369,498	408,392
Sierra Leone	516,611	49,674	79,478	109,283	139,087	158,957	188,762	208,631	228,501	248,371	258,305
South Sudan	1,762,740	185,551	278,327	417,491	510,267	603,042	695,818	788,594	834,982	927,758	974,145
Tanzania	10,469,834	872,486	1,526,850	2,181,215	2,617,458	3,271,823	3,708,066	4,144,309	4,580,552	5,016,795	5,453,038
Togo	917,442	76,454	133,794	191,134	229,361	286,701	324,928	363,154	401,381	439,608	477,835
Uganda	7,023,112	526,733	1,053,467	1,404,622	1,931,356	2,282,511	2,633,667	2,984,823	3,160,400	3,511,556	3,862,712
Zambia	4,959,216	314,871	629,742	944,613	1,180,766	1,416,919	1,653,072	1,810,508	2,046,661	2,204,096	2,361,532
Zimbabwe	428,380	58,415	77,887	116,831	155,774	175,246	194,718	214,190	253,133	272,605	292,077
Total:	162,790,985	13,342,749	23,105,592	32,852,469	42,071,863	50,893,010	58,354,260	65,712,386	71,788,379	77,567,155	84,030,901

have on the incomes of agricultural households. Scenario 1 represents our most conservative estimate of the impact of suppressing malaria on the incomes of agricultural households while Scenario 10 represents our least conservative estimate (Table 2).

Our analysis of the Elimination Path scenarios found that the number of individuals in poverty decreased from 2018 to 2040 by 53 million (Scenario 1) to 123 million (Scenario 10). These decreases in poverty represented a 33% and 76% reduction, respectively, in poverty rates as compared to 2018 (Table 3). In contrast, only 40 million individuals escaped poverty by 2040 with the Status Quo Path, a 24% reduction in poverty rates.

While the Status Quo Path resulted in 9 countries with poverty rates greater than 50% in 2040, Scenarios 5 through 10 for the Elimination Path led to no countries having poverty rates greater than 50%. Six countries had poverty rates of more than 50% for Scenario 1 while the result was 3 countries for Scenario 2. Scenarios 3 and 4 each led to 2 countries having poverty rates of more than 50%.

The Status Quo Path led to twenty countries having poverty rates in excess of 30% in 2040. The number of countries with poverty rates of more than 30% for our Elimination Path scenarios varied from 18 for Scenario 1 to zero for Scenario 10.

Discussion

This study examined the potential impact of eliminating malaria by 2040 on poverty levels of agricultural households in sub-Saharan Africa from 2018 through 2040.

Summary of main findings from this study

Our analysis found that between 53 million and 123 million individuals in agricultural households would escape poverty by 2040 if malaria were eliminated by that year. This decrease in poverty represents a 33% to 76% decrease in the percentage of individuals in poverty relative to 2018 levels. In contrast, if the malaria burden were to remain at its current level in sub-Saharan Africa through 2040, we expect that only 40 million individuals in agricultural households would escape poverty by 2040, a decrease of only 24%. The impact, therefore, of eliminating malaria by 2040 is that approximately 13 million to 83 million individuals in agricultural households will escape poverty.

Policy implications of this research

Our findings of malaria's impact on the incomes of agricultural households should be interpreted as the difference between the incomes of these households if the malaria burden were to remain at its current level from 2018 through 2040 (the Status Quo Path) and incomes if malaria were suppressed over this same period of time (Elimination Path). Numerous factors could affect the incomes of agricultural households in sub-Saharan Africa over the next two decades, including macroeconomic risk, political risk and climate change. Progress towards eliminating malaria by 2040 in sub-Saharan Africa does not guarantee that incomes among agricultural households will increase and poverty rates will decline. For example, even if Ethiopia achieves significant progress towards eliminating malaria by 2040, the incomes of agricultural households in Ethiopia may not increase if climate change decreases crop yields. Therefore, it would not be appropriate to use the findings from this study to make claims that "if we eliminate malaria by 2040 we would also decrease poverty rates." It would be more appropriate to use these findings to make more measured statements along the lines of the following "based on the best available evidence, suppressing malaria over the next two decades may facilitate a trend, assuming other conditions that affect agricultural productivity remain favorable, in which the growth rate of agricultural households' incomes increase and poverty rates decline."

Impact estimates are conservative

Our estimates of the impact of eliminating malaria on poverty rates are conservative for two reasons.

First, our estimates of each country's daily per capita income in 2018 likely overestimate the actual daily income of individuals in agricultural households. Our methodology for developing estimates of the daily per capita income of individuals in agricultural households assumed that the median per capita income for all individuals in a country reflected the per capita income for individuals in agricultural households. This assumption likely leads to an overestimation of the actual daily per capita income of individuals in agricultural households.

For example, our methodology led to an estimate of US$1.58 (2011 PPP) for the median per capita income of individuals in agricultural households in Zambia. In comparison, Fink and Masiye estimated a median per capita daily income for agricultural households in Zambia of US$0.26 based on median harvest values of US$463 per households and an average of six individuals per household (Fink & Masiye, 2015).

Another study presented estimates of the mean annual per capita household income for Kenya, Ethiopia, Rwanda, Mozambique and Zambia based on surveys conducted in the 1990s and 2000s (Jayne *et al.*, 2003). Based on the annual per capita estimate of US$57.70 for agricultural households in Zambia in 2000, the daily per capita income of these households would be US$0.19 in 2018 if we assume growth in incomes of 1% per year. This estimate of US$0.19 for the daily per capita income of agricultural households in Zambia is consistent with the estimate of US$0.26 provided by Fink and Masiye but well below our estimate of $1.58 (2011 PPP). Using a similar approach for converting household income estimates in Jayne *et al.* to 2018 US dollars, we developed the following estimates for average daily per capita household income: Kenya (US$1.14), Ethiopia (US$0.25), Rwanda (US$0.28) and Mozambique (US$0.15). Our estimates for median daily per capita household income for the same four countries are five to ten times greater: Kenya (US$2.44), Ethiopia (US$2.79), Rwanda (US$1.76) and Mozambique (US$1.50).

As a result of using higher estimates of per capita income in 2018 for individuals in agricultural households, we are likely underestimating the number of these individuals who have incomes less than the poverty levels of $1.90 (2011 PPP). By underestimating the number of individuals in agricultural households who are in poverty in 2018, we are reducing the pool of individuals who can potentially escape poverty by 2040. We would, therefore, expect that our estimates of the number of individuals in agricultural households who escape poverty by 2040 for each scenario are conservative.

The second reason why we would expect our impact estimates to be conservative is the parameter values we used for estimating malaria's impact on incomes in 2018. Fink and Masiye found that access to subsidized bed nets led to a 14.7% increase in the harvest value of agricultural households (Fink & Masiye, 2015). Fink and Masiye did not attempt to quantify the cost of households seeking treatment for malaria infections experienced by household members. Therefore, we would expect that the actual cost of malaria to the household was greater than malaria's impact on harvest values. Most of the parameter values we used in our Elimination Path scenarios for estimating malaria's impact on household income in 2018 were below the 14.7% finding from Fink and Masiye. Our parameter values for malaria's impact in 2018 ranged from 3% to 21%. If the Fink and Masiye study had accounted for additional means by which malaria affects the incomes of agricultural households in the short term (e.g., household expenditures on treatment for malaria), the total impact of malaria on incomes could have been greater than 21%. We can therefore assume that our parameter estimates for malaria's impact on 2018 household income are likely conservative.

Limitations of this research

As with any study that attempts to estimate the impact of a disease on a large population over several decades, predicting with certainty how the population will response to an improvement in health is difficult.

For example, simply estimating the number of agricultural households annually in sub-Saharan Africa through 2040 is complex. We would expect that the population growth rate of rural areas of sub-Saharan Africa to gradually decrease from 2018 through 2040 due to the rapid urbanization that is projected for the region over that period. However, the suppression of malaria over that period and achieving malaria eradication in 2040 could make the quality of life in rural areas of Africa more attractive than if malaria remained at its current level. Increases in the expected quality of life in rural areas could, therefore, play a role in decreasing urbanization rates and increasing population growth in rural areas compared to malaria remaining at its current levels through 2040.

The objective in this study was to develop the most accurate projections possible of the potential long-term impact of eliminating malaria on agricultural households' incomes in Africa given the data available. It is our hope that researchers will use the knowledge gaps identified in this study to inform future research questions in order to develop better projections of how the elimination of malaria could affect the incomes of agricultural households.

Recommendations for new research agenda research of long-term impact of suppressing malaria on agricultural households' income

This study highlighted the need for research into how suppressing malaria over the next two decades would affect the incomes of agricultural households in sub-Saharan Africa. For our analysis, we assumed that the annual growth rate in incomes of agricultural households would be 0.25% to 2.50% higher for our Elimination Path scenarios relative to our Status Quo Path. In order to develop more precise estimates of the impact of the Elimination Path on income growth rates, we recommend that researchers focus on five channels through which malaria may affect agricultural households. The first channel is the impact of suppressing malaria on work days, caregiving days and gender equality among adults in agricultural households. The second channel is malaria's impact on education levels attained by children in agricultural households. The long-term impact of suppressing malaria on agricultural households' harvest values is the third channel. The fourth channel is the long-term impact of suppressing malaria on households' decisions regarding the level of resources to devote to purchasing anti-malaria interventions to prevent and treat malaria cases. The final channel is the decisions of agricultural households concerning which crops to plant and how much to invest in agricultural inputs if households expect a decrease in risk of malaria infections.

We recommend the use of longitudinal data from agricultural households in sub-Saharan Africa to examine these five channels. There are two potential advantages of using longitudinal data to examine the long-term impact of suppressing malaria on agricultural households' incomes. First, using longitudinal data to examine all five channels in a community would enable researchers to understand the interactions between these channels. For example, a household's decision to increase the level of resources devoted to purchasing agricultural inputs may depend, in part, on the household's decision to devote less resources to purchasing anti-malaria interventions to prevent malaria infections. Second, we would expect that there would be significant heterogeneities in the impact of suppressing malaria on agricultural households' income across communities and over time. Using longitudinal data from a range of agro-ecological zones in sub-Saharan Africa would enable researchers to examine how the five channels contribute to heterogeneities in growth rates of household income from the suppression of malaria.

Future research of the impact of suppressing malaria on long-term growth rates in agricultural household income should proceed in two stages. First, we recommend an analysis of our level of knowledge about each of the five channels through which

suppressing malaria may affect long-term growth rates in income among agricultural households. There is more than 100 years of evidence from studies around the world of malaria's impact on the welfare of agricultural households. An analysis of the evidence related to the five channels we have identified will enable researchers to determine which channels should be prioritized for additional research using longitudinal data. The second stage of this research initiative should be to identify opportunities to collect data for these five channels using existing frameworks that are collecting longitudinal malaria data. Two examples of existing frameworks that are collecting longitudinal malaria data are the INDEPTH health and demographic surveillance systems and the International Centers of Excellence for Malaria Research progam.

Data availability

The dataset for this research has been deposited in CSV format with Harvard Dataverse.

Harvard Dataverse: Dataset 1 V2. Willis - dataset - malaria among agricultural households in 2018 in sub-Saharan Africa - July 2018. https://doi.org/10.7910/DVN/ZFJ3XT (Willis, 2018)

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Introduction
Page 3:
"The most common cause of past failures to achieve or maintain elimination was a lack of sufficient funding (Cohen et al., 2012)".

Please restructure and add information on:
a. Past and current target for malaria elimination
b. Cause of failure in meting target
c. The importance of funding in meeting target

"The $1.90 poverty line uses 2011 prices and is expressed in terms of purchasing power parity (PPP). PPP exchange rates enable identical quantities of goods and services to be priced across countries equivalently (World Bank)."
a. Please add figures on percentage of farmers living below the poverty line in each of the selected countries.

"The 35 countries in sub-Saharan Africa that are included in this analysis are: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Côte d'Ivoire, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe"
a. How were the 35 countries in sub-Saharan Africa countries selected for this study? Purposively or by randomisation? Give reasons for the option used.

Methods
Page 4:

"A household is considered an agricultural household when at least one member of the household is engaged in growing crops and/or raising livestock in private or in combination with others (Federal Democratic Republic, 2010/2011). In a recent study (Willis & Hamon, 2018), we estimated that there are approximately 54 million agricultural households in malicious regions of sub-Saharan Africa farming less than 10 hectares. This study will focus on these households"

a. Were households raising livestock in private or in combination with others excluded in this study since the issue of 10 hectares is not applicable to this group?
b. What is the rationale for defining Agricultural households as farming having less than 10 hectares in light of your earlier definition of Agricultural households that was provided based on the definition of Agricultural census in Ethiopia, 2010.

"World Bank report estimated that Equatorial Guinea's poverty rate in 2006 was 76.8 percent (Bassett et al., 2017). We assumed that this poverty rate reflects the poverty rate experienced by agricultural households in 2018"

a. Why would Equatorial Guinea's poverty rate in 2006 estimated at 76.8 percent be used to compute for the 324 million individuals in agricultural households in malarious regions of sub-Saharan Africa in 2018 in this study?
b. What percentage of people living in Equatorial Guinea are farmers? This will give a stronger support to this premise.
c. Are local studies not available in most of these countries to provide proximate estimates?

Sub-Saharan Africa remains the last frontier in the fight to reduce poverty. Nearly half of the rural and one third of the urban population lived on less than $1.25 a day in 2008. For each poor person in an urban area, there were 2.4 as many in rural areas (World Bank & International Monetary Fund, 2013)
a. Please synthesize this statement into the body of your argument.

……hours those individuals could work (Fink & Masiye, 2015).
a. What of the cost of treating malaria on income? Please account for this extra cost. This should also vary by country.

…..will grow by 1% from 2018 through 2040.
a. What premise is this based on? Please look through trends of GDP over years in Sub-Saharan Africa and its impact on purchasing power. Use this to formulate a figure for income growth.

Page 7:
……poverty in 2018 was approximately 163 million,
a. What is the impact of the population growth rate on this figure in 2040? You need to account for this in your model.

Page 9:
There are two "Table 4"
The First Table 4:
a. Suggested Title: "Country overview of agricultural households in poverty in 2040....."

The second table 4
a. Has no title: Please give table a title like previous tables

The authors should have identified comprehensive estimates of household malaria infections and estimated expenditures on malaria treatment in rural household expenditures in each country or sub-regions in calculating short and long term impact of malaria rather than the guessed estimates used. Such data is available.
All the countries are treated as similar yet they are very dissimilar.

Page 14
The several limitations in the study seem to suggest that the authors did not seek enough information from the past study to guide methodological decisions.

Reviewer's Conclusion:
Although the analysing the potential impact of eliminating malaria by 2040 on poverty rates among agricultural households in malarious regions of sub-Saharan Africa is key to advocating for sustained malaria control and increased funding, the paper is predicated on several guesswork. In-country data is available but unused. Methodological flaw includes input data in the model failing to account for inter-country differences in respect of population growth rate, malaria endemicity, treatment cost and agricultural practices therefore jeopardizing result validity and diminishing added value of the paper.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
No

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Infectious disease epidemiology, public health policy

We have read this submission. We believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

Reviewer Report 20 December 2018

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I have reviewed the paper "Impact of eliminating malaria by 2040 on poverty rates among agricultural households in Africa" and have found the information given here interesting and could be strengthened with the application of new methods to examine malaria's impact on the welfare of agricultural households. The objective and overall goal of the study reported in this manuscript is rather noble and lofty. I am not sure that the authors can definitively determine the impact of eliminating malaria by 2040 on household's income on the number of individuals living on less than $1.90. But, the results are quite interesting. I suggest that the authors should recognize that their results are rather limited (using possible scenarios) and only imply the impact of eliminating malaria by 2040 on household's income on the number of individuals living on less than $1.90. Is there any analysis or comparison to determine significance of these impacts?

The references are sufficient, the results are clear, and the discussion is sufficient. However, more details should be added in methodology section: I recommend adding a map of Africa and fixing the 35 studied countries. Authors should justify the choice of the 10 scenarios and the 35 countries. They should also explain for the first time when using unusual words, for example PovcalNet, 2011 PPP. I would suggest the authors to have the opinion of a modeling scientist in data analysis. Additionally, a couple of tables (mainly table 2) should be changed to figures in order to make the manuscript more readable and expressive.

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Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Parasitology and Medical Entomology

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.