



RESEARCH ARTICLE

Potential relationship between malaria elimination and reducing stunting in children in sub-Saharan Africa [version 1; peer review: 1 not approved]

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Abstract

Background: The Sustainable Development Goals include goals to reduce malaria and stunting. Stunting is a result of childhood undernutrition. Our previous studies found that suppressing malaria could reduce poverty rates among agricultural households in Africa. The objective of this paper is to highlight how suppressing malaria could have the further effect of reducing stunting rates among children in agricultural households.

Methods: We estimated the burden of stunting among children in agricultural households in malarious regions of sub-Saharan Africa on the basis of our previous research and data from UNICEF. We also used an evaluation of the impact of a nutrition program in Peru to assess the potential for poverty reduction to reduce stunting.

Results: We estimated that there are approximately 21.5 million children suffering from stunting in agricultural households in malarious regions of sub-Saharan Africa. Poverty reduction was found to be a necessary condition to reduce stunting via a multisectoral nutrition program in Peru. The potential impact of suppressing malaria on the poverty rate of agricultural households could therefore play an important role in nutrition programs aiming to reduce stunting in Africa. Reducing the number of children with stunting in these households would improve their health and productivity as adults.

Conclusion: We have developed the first estimates of the burden of stunting in agricultural households in malarious regions of sub-Saharan Africa. Understanding how suppressing malaria affects stunting in these households could affect funding for anti-malaria programs. Future research should use longitudinal data to examine this impact at a finer spatial scale.

Keywords

malaria, agricultural households, Africa, stunting, Sustainable Development Goals

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Introduction

The Sustainable Development Goals (SDGs) include goals for suppressing malaria and improving nutrition. The relationship between malaria and malnutrition has been extensively studied. A large number of studies have examined how malaria affects the susceptibility of individuals to malnutrition (Bradley-Moore *et al.*, 1985; Man *et al.*, 1998; Mcgregor *et al.*, 1956; Rowland *et al.*, 1977). Malnutrition's impact on the susceptibility of individuals to malaria has also been studied (Bates *et al.*, 1993; el Samani *et al.*, 1987; Shankar, 2000), as has the impact of improving nutrition on the productivity of agricultural households (Basta *et al.*, 1979; Behrman *et al.*, 1997; Brooks *et al.*, 1979; Gilgen *et al.*, 2001; Pitt & Rosenzweig, 1986; Popkin, 1978; Scholz *et al.*, 1997; Strauss, 1986). However, no studies have examined how suppressing malaria could reduce the impact of malnutrition on households.

Developing more accurate estimates of how suppressing malaria would affect the welfare of malarious communities could inform decisions regarding funding for malaria elimination programs (Willis & Hamon, 2018a). A lack of funding has been identified as the primary cause of failures to achieve or maintain elimination during the first Global Malaria Eradication Campaign (1955–1969) (Cohen *et al.*, 2012).

Malnutrition is a disease category that includes both undernutrition and overnutrition (WHO, 2017). While overnutrition can lead to obesity, undernutrition is caused by deficiencies in micronutrients. The term malnutrition is often used as an alternative to undernutrition. Childhood stunting is the product of disease and undernutrition. Stunting in a child is defined as the child's height-for-age Z score (HAZ) being less than two standard deviations below the median score of a healthy reference population.

In sub-Saharan Africa, 30% of the 155 million children under the age of five experienced stunting in 2016 (Skoufias, 2018) and approximately 25% of the population experiences chronic undernourishment (Ehui, 2018). These figures are causally linked as chronic malnutrition is one of the prime factors leading to stunting (Gray *et al.*, 2006; Schwinger *et al.*, 2017). The rate of stunting among the under-five population in Africa was the highest in the world in 2016.

The number of children with stunted growth under the age of five is increasing in sub-Saharan Africa (Skoufias *et al.*, 2018), a trend not observed in any other region of the world. From 1990 to 2014, the number of stunted children under five increased by 23%, from 47 million to 58 million (UNICEF). In contrast, the number of children with stunting decreased by 52% in Asia, 55% in Latin America (including the Caribbean) and 38% globally (UNICEF).

One reason for this increase is the rapid rise in the child population of sub-Saharan Africa. From 2015 until the end of the century, sub-Saharan Africa will have a higher number of births than any other part of the world (UNICEF). Another reason, however, is that Africa has made slower progress towards

reducing the percentage of children with stunting than other regions of the world (UNICEF). From 1990 to 2014, the percentage of stunted children under five in Africa decreased by only 24%, while the percentage in Asia declined by 47%, in Latin America (including the Caribbean) by 52% and globally by 40% (UNICEF).

Interventions to reduce childhood stunting include nutrition-specific or nutrition-sensitive interventions. Nutrition-specific interventions include providing micronutrients and vitamins to mothers and promoting breastfeeding. Although the efficacy of these interventions is high, developing countries have found it challenging to scale-up these approaches in resource-constrained settings (Galasso *et al.*, 2016). These nutrition-sensitive interventions target the determinants of malnutrition rather than providing improved nutrition options directly to mothers. Nutrition-sensitive interventions include interventions that increase the productivity of agricultural households (Berti *et al.*, 2004; De Brauw *et al.*, 2015; Girard *et al.*, 2012; Masset *et al.*, 2012; Ruel *et al.*, 2013). Suppressing malaria could have a similar impact on stunting given that recent studies indicate that malaria suppression could increase productivity and reduce poverty in agricultural households (Willis & Hamon, 2018a; Willis & Hamon, 2018b). The objective of this study is to highlight how suppressing malaria could affect stunting rates among children in agricultural households in sub-Saharan Africa.

Methods

Figure 1 was developed in a recent study (Willis & Hamon, 2019) as a conceptual framework to illustrate how eradicating malaria could create a virtuous cycle that improves the welfare of agricultural households. In previous studies, we examined the links from “Malaria decreases” to “Household income increases” (Willis & Hamon, 2018a; Willis & Hamon, 2018b). In the current study we examine the evidence for the links in Figure 1 from “Household income increases” (due to suppressing malaria) to “Nutrition security improves.”

Estimation of stunting

First, we estimated the burden of stunting in agricultural households in malarious areas of sub-Saharan Africa, using the commonly used metric of the number of children under the age of five in such households with stunting. By combining recent estimates of the total relevant population (Willis & Hamon, 2018a; Willis & Hamon, 2018b) and demographic data (taken from Population Pyramid), we estimated the number of children under five in agricultural households in each of 35 sub-Saharan countries. We then used published estimates of the prevalence of stunting in the under-five population in each of these countries (UNICEF, 2018) to estimate the number of those children with stunting.

Assessing the link between reduction in poverty and reduction in stunting

Second, we explored the link between poverty reduction and a reduction in stunting on the basis of recent work in Peru (Levinson *et al.*, 2013; Skoufias *et al.*, 2018). Data from the World Bank were used to examine the change in poverty

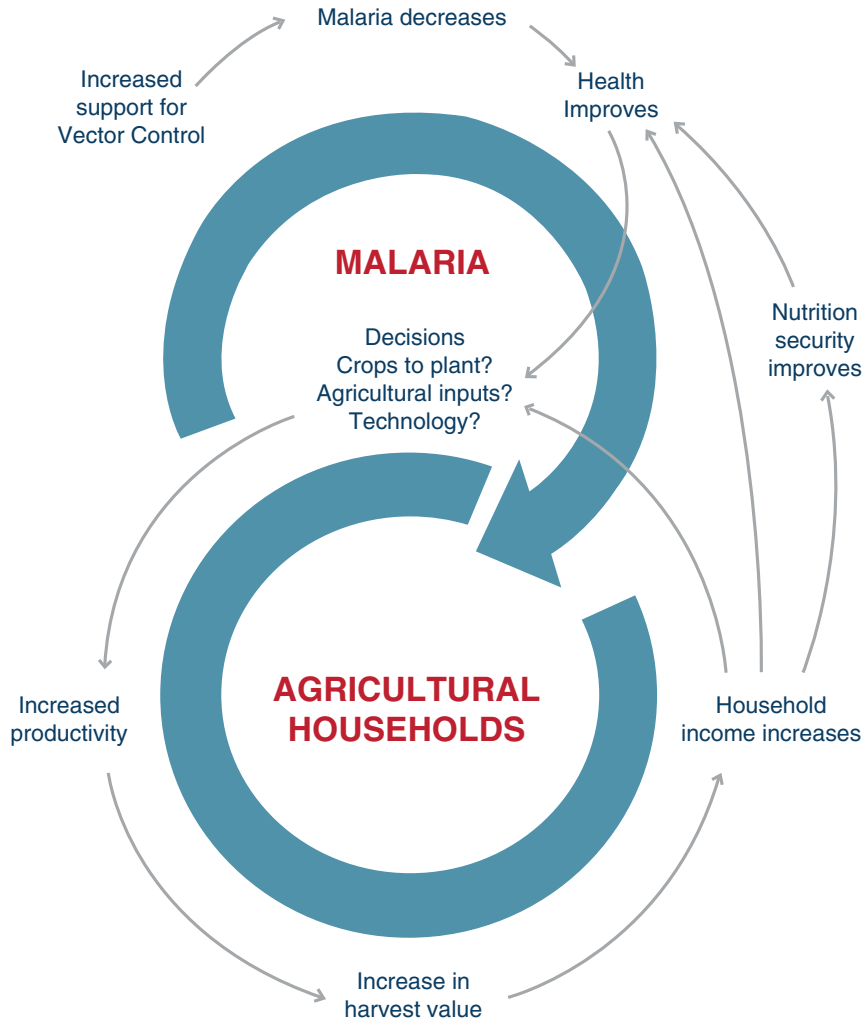


Figure 1. Conceptual framework for the long-term impact of malaria on the income of an agricultural household.

rates from 2004 to 2011, while Demographic and Health Survey data for stunting rates were used to analyze the change in this indicator from 2007 to 2012 (World Bank, 2012).

Results

The relevant Sustainable Development Goals (SDGs) for malaria and malnutrition are summarized in Table 1. The goal for stunting is to achieve a 40% reduction in stunting rates among children under five by 2025 using 2010 as a baseline (Hawkes & Fanzo, 2017).

Based on the current global progress toward reducing stunting, this goal will not be achieved (Hawkes & Fanzo, 2017). The number of stunted children under five globally is decreasing at a rate of 1.5% annually, which will lead to only a 20% reduction in stunting from 2010 to 2025 (Galasso et al., 2016). In order to reach the goal of a 40% reduction by 2025, the annual reduction in stunting will need to increase from 1.5 to 3.4% (Galasso et al., 2016).

Estimation of the burden of stunting among agricultural households in sub-Saharan Africa

In a recently published study, we estimated that there are approximately 54 million agricultural households in the malarious regions of 35 countries in sub-Saharan Africa (Willis & Hamon, 2018b). We defined an agricultural household as a household with a farming area of fewer than 10 hectares. Assuming that six individuals live in each household, we estimated that approximately 324 million individuals live in agricultural households in these regions.

The proportion of the total population of each country under the age of five ranged from 11.6 to 20% (Population Pyramid). Using these demographic data, we estimate that there are approximately 52.7 million individuals in the under-five population in agricultural households in malarious regions of sub-Saharan Africa.

The stunting rate in these 35 countries ranged from 20.2 to 58.8% (UNICEF, 2018). By linking the stunting rate estimates for

Table 1. Sustainable Development Goals for Malaria and Nutrition: impact of suppressing malaria among agricultural households in Africa on Sustainable Development Goals for Malaria and Nutrition.

Goal	Target for 2030
Good Health and Well-Being	Reduce the global maternal mortality ratio to less than 70 per 100,000 live births
	End preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least 12 per 1,000 live births and under-5 mortality to at least 25 per 1,000 live births
	End the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases
Zero Hunger	End hunger and ensure access for all to safe, nutritious and sufficient food all year round, particularly the poor and vulnerable, including infants
	End all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women, and older persons
	Double the agricultural productivity and incomes of small-scale food producers, particularly women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

each country with the under-five population estimates for each country, we estimate that approximately 21.5 million children suffered from stunting in agricultural households in malarious regions of sub-Saharan Africa in 2018. The number of children under five with stunting among agricultural households in each country is given in [Table 2](#).

Impact of poverty reduction on stunting in Peru

In [Table 3](#), we summarize the evidence for changes in poverty and stunting from a case study of Peru ([Levinson et al., 2013](#)). The top section of [Table 3](#) shows that from 2004 to 2011, the national poverty rate in Peru decreased by 31 percentage points, from 58.8% to 27.8% ([Skoufias et al., 2018](#)).

The lower part of [Table 3](#) summarizes the change in stunting rates at the national level and sub-national levels for rural districts, urban districts and districts that were targeted by the government's CRECER program. The CRECER program (the National Nutrition Strategy for Poverty Reduction and Economic Opportunities) was a multisectoral strategy to improve nutrition that included results-based incentives for local participation ([Levinson et al., 2013](#)). Most of the districts where the program was implemented were in rural areas. While the percentage point decrease in the rural and CRECER-targeted districts was 13.8% and 21.4%, respectively, there was only a 5.1% decrease in urban areas ([Levinson et al., 2013](#); [World Bank, 2012](#)). Nationally, Peru experienced a 10.4 percentage point decrease from the 2007/2008 baseline period to 2012 ([Skoufias et al., 2018](#)).

An evaluation of the impact of the CRECER program concluded that income growth played an important role in enabling multisectoral efforts to decrease undernutrition, although the declines in stunting could not be exclusively attributed to economic growth and poverty reduction ([Skoufias et al., 2018](#)).

There is increasing interest in implementing similar multisectoral nutrition programs in sub-Saharan Africa ([Hawkes & Fanzo, 2017](#); [Skoufias et al., 2018](#)):

“Although the declines in stunting cannot be exclusively attributed to economic growth and poverty reduction in Peru, it is important for policy makers in SSA countries to consider income growth and reduced income variability as necessary but not sufficient conditions for the reduction of child stunting” ([Skoufias et al., 2018](#)).

Discussion

Impact of eliminating malaria on poverty rates in sub-Saharan Africa

In a recent study, we found that eliminating malaria by 2040 would reduce the number of malaria cases experienced by agricultural households in sub-Saharan Africa by approximately 565 million to 1.1 billion cases from 2018 to 2040 as opposed to the number of cases for an unchanged malaria burden over that period ([Willis & Hamon, 2018b](#)). Eliminating malaria would enable adults in agricultural households to work an additional 3 billion days and children to attend 1.5 billion more days of school ([Willis & Hamon, 2018b](#)).

[Figure 1](#) illustrates how suppressing malaria could affect the income of an agricultural household. Suppressing malaria may lead the household to make different decisions than otherwise regarding which crops to plant and how much to invest in agricultural inputs. The suppression of malaria may also increase the productivity of agricultural households by reducing the number of work days missed due to malaria. Recent research ([Fink & Masiye, 2015](#)) suggests that increasing the number of days worked by an agricultural household could increase the value of its harvest. We would therefore expect the suppression of malaria over the next two decades to increase the income of an

Table 2. Country data for number, population, median daily income and poverty levels of agricultural households in malarious countries of sub-Saharan Africa.

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	Under-5 population in agricultural households	Stunting Rate	Number of children with stunting in under-5 population in agricultural households
Angola	791,492	4,748,952	\$2.90	1,329,706	878,556	45.7%	401,500
Benin	302,601	1,815,604	\$1.95	871,490	279,603	38.2%	106,808
Botswana	89,231	535,386	\$4.54	74,954	62,105	31.4%	19,501
Burkina Faso	657,559	3,945,355	\$2.09	1,735,956	670,710	27.3%	183,104
Burundi	1,156,946	6,941,676	\$1.35	5,206,257	1,270,327	58.8%	746,952
Cameroon	686,673	4,120,040	\$3.64	824,008	646,846	38.0%	245,802
Central African Republic	225,383	1,352,296	\$1.35	1,014,222	194,731	42.4%	82,566
Chad	271,790	1,630,738	\$2.44	587,065	301,686	41.6%	125,502
Republic of Congo	106,228	637,366	\$2.54	216,704	102,616	21.2%	21,755
Democratic Republic of Congo	3,322,215	19,933,288	\$1.10	18,936,624	3,528,192	47.0%	1,658,250
Equatorial Guinea	22,289	133,735	\$1.35	100,301	20,060	26.2%	5,256
Ethiopia	10,937,173	65,623,036	\$2.79	19,686,911	9,449,717	40.0%	3,779,887
Gabon	52,711	316,265	\$7.70	9,487	43,012	28.9%	12,431
Gambia	51,276	307,659	\$3.87	55,378	55,994	28.7%	16,070
Ghana	1,856,309	11,137,856	\$4.61	1,447,921	1,626,127	22.1%	359,374
Guinea	623,308	3,739,845	\$2.37	1,383,743	598,375	32.4%	193,874
Guinea Bissau	62,461	374,766	\$1.41	269,831	58,089	31.6%	18,356
Ivory Coast	828,898	4,973,386	\$2.83	3,580,838	800,715	21.6%	172,955
Kenya	2,039,498	12,236,986	\$2.44	4,405,315	1,847,785	29.2%	539,553
Liberia	90,290	541,740	\$2.27	195,026	82,886	33.6%	27,850
Madagascar	1,801,047	10,806,284	\$1.10	10,265,970	1,664,168	49.2%	818,771
Malawi	1,976,868	11,861,210	\$1.26	9,726,192	1,992,683	39.1%	779,139
Mali	597,158	3,582,946	\$1.94	1,719,814	648,513	33.8%	219,198
Mozambique	2,272,891	13,637,344	\$1.50	9,137,021	2,304,711	45.8%	1,055,558
Niger	496,398	2,978,388	\$2.07	1,310,491	595,678	42.2%	251,376
Nigeria	11,667,985	70,007,910	\$1.80	37,804,272	11,761,329	49.3%	5,798,335
Rwanda	1,242,001	7,452,009	\$1.76	4,098,605	1,035,829	36.7%	380,149
Senegal	324,121	1,944,724	\$2.38	719,548	330,603	20.2%	66,782
Sierra Leone	165,580	993,483	\$1.86	516,611	150,016	40.4%	60,606
South Sudan	773,131	4,638,788	\$2.32	1,762,740	728,290	32.0%	233,053
Tanzania	3,635,359	21,812,155	\$1.95	10,469,834	3,795,315	37.8%	1,434,629
Togo	318,556	1,911,337	\$1.95	917,442	296,257	33.3%	98,654
Uganda	2,926,297	17,557,780	\$2.23	7,023,112	3,213,074	30.2%	970,348
Zambia	1,311,962	7,871,771	\$1.58	4,959,216	1,361,816	42.1%	573,325
Zimbabwe	324,530	1,947,180	\$3.42	428,380	305,707	28.1%	85,904
TOTAL:	54,008,214	324,049,282	-	162,790,985	52,702,122	-	21,543,170

Table 3. Reduction in poverty and stunting in Peru (2004 to 2012). Data from Levinson & Balarajan, 'Addressing Malnutrition Multisectorally: What have we learned from recent international experience?' (2013).

Variable		National	Rural	Urban	CRECER-targeted districts
Poverty (percentage point decrease):	Poverty Rate in 2004:	58.8%			
	Poverty Rate in 2011:	27.8%			
	Percentage point decrease in poverty:	31.0%			
Stunting (percentage point decrease among under-5 population):	Stunting Rate in 2007-2008:	28.5%	45.7%	15.6%	54.7%
	Stunting rate in 2012:	18.1%	31.9%	10.5%	33.3%
	Percentage point decrease in stunting:	10.4%	13.8%	5.1%	21.4%

agricultural household by increasing the value of agricultural harvests while also decreasing the household's expenditures on anti-malaria interventions (Willis & Hamon, 2019).

We have previously found that eliminating malaria by 2040 would allow between 53 million and 123 million individuals in agricultural households to escape poverty, a 6.3–37.9% decrease (Willis & Hamon, 2018a). In contrast, only 40 million individuals among these same households would escape poverty by 2040 if the malaria burden were to remain at its 2018 level through 2040 (Willis & Hamon, 2018a). There is a strong relationship between poverty and stunting rates in sub-Saharan Africa. The average difference between stunting rates in the richest quintile and poorest quintile from 2009 to 2013 among the southern, central, western and eastern regions of sub-Saharan Africa was 23% (UNICEF). In western Africa, stunting rates were 47% over that period in the poorest quintile but only 18% in the richest quintile (UNICEF). If no workers in sub-Saharan Africa today had experienced stunting in childhood, per capita income today would be 9–10% higher (Galasso *et al.*, 2016).

In Peru, a 31 percentage point decrease in the national poverty rate coincided with a 13.8 percentage point decrease in stunting in rural areas and a 21.4 percentage point decrease in districts targeted by a multisectoral initiative to improve nutrition (Skoufias *et al.*, 2018). Given our estimate that there are approximately 21.5 million children under the age of five with stunting in agricultural households in malarious regions of sub-Saharan Africa and the increased interest in implementing nutrition-improvement initiatives similar to that in Peru in sub-Saharan Africa, the international donor community should consider how the reduction in poverty due to malaria elimination initiatives could play a role in increasing the impact of such programs.

Additional mechanisms by which suppressing malaria would affect stunting

Although our findings indicate that the effect of suppressing malaria on poverty rates could reduce the stunting burden in

sub-Saharan Africa, malaria suppression may also make children less susceptible to the health impacts of malnutrition more directly. A study of children in Nigeria found that the weekly administration of a malaria prophylaxis (chloroquine) was correlated with a decrease in the number of deaths due to malnutrition as well as with less severe malnutrition (Bradley-Moore *et al.*, 1985). Some evidence also indicates that reducing malaria may increase weight gain in children (Man *et al.*, 1998), and recurrent episodes of malaria have also been found to have a negative effect on weight gain (Marsden, 1964; Mcgregor *et al.*, 1956; Rowland *et al.*, 1977).

Effect of improving nutrition (reducing stunting) on malaria burden

Policies that improve the nutrition of households in malarious regions would also affect the malaria burden on these households, as improved nutrition may decrease the probability that a malaria inoculation will lead to a symptomatic case of malaria or death. Vitamin A supplements were found to be efficacious in reducing symptomatic malaria cases, splenomegaly and mean parasite density in children in Papua New Guinea (Shankar, 2000), and some studies have found that zinc supplementation decreases the number of children admitted to health centers for malaria (Bates *et al.*, 1993; Shankar, 2000). An analysis of children in the Sudan found that a lower nutritional status led to an increased relative risk for malaria (el Samani *et al.*, 1987). A WHO report notes that improved nutrition enables people to lessen the severity of malaria cases (World Health Organization, 2016).

Several studies have identified a link between better nutrition and increased farmer productivity in Sierra Leone, Indonesia and Pakistan (Behrman *et al.*, 1997; Pitt & Rosenzweig, 1986; Strauss, 1986). There is evidence that anemia and malnutrition in adults reduce their productivity. More sick days and absenteeism from work have been associated with anemia and malnutrition, along with overall reduced levels of productivity (Basta *et al.*, 1979; Brooks *et al.*, 1979; Gilgen *et al.*, 2001; Popkin, 1978; Scholz *et al.*, 1997). Increasing the productivity of an agricultural household may increase its income and lower its malaria burden.

Sustainable development goals for malaria and malnutrition

Global progress to reduce malnutrition is insufficient to meet its SDG (Table 1) (Hawkes & Fanzo, 2017). Achieving the SDG for malnutrition will require more than nutrition-specific interventions. Stunting would be reduced by only 20% globally if all 10 interventions that target stunting directly were implemented (Bhutta *et al.*, 2013). The 2017 *Global Nutrition Report* noted that better nutrition can contribute to progress toward a range of SDGs, namely, sustainable food production, strong infrastructure, health systems, equity and inclusion, and peace and stability (Hawkes & Fanzo, 2017).

Equity and inclusion is closely related to poverty, as 46% of all stunting cases globally occur among the 767 million people living in extreme poverty (Hawkes & Fanzo, 2017). In this study, we highlight how progress in three of these core areas can impact stunting: suppressing malaria leads to higher productivity among agricultural households, which leads to less poverty and, based on the evidence from Peru, less stunting. Just as we should not look at the challenges to improving nutrition in isolation, ignoring the relationship with other SDGs, we should not consider the links between nutrition and the other SDGs as independent, bidirectional relationships.

Multisectoral strategies to reduce stunting in sub-Saharan Africa

Recommendations have been made for multisectoral programs to improve nutrition in sub-Saharan Africa (Movement, 2018; Skoufias *et al.*, 2018). These strategies focus on food security, care, water, sanitation and hygiene, and health (Skoufias *et al.*, 2018). An analysis of Demographic and Health Survey (DHS) data from 33 countries in sub-Saharan Africa provides a blueprint for designing and implementing multisectoral strategies to reduce stunting. All but five of the countries that were included in our analysis were among these 33 countries. The use of data to inform the decisions of each sector on how to allocate resources provides an opportunity for this initiative to reduce stunting to succeed, in contrast to previous multisectoral initiatives in Africa (Levinson *et al.*, 2013). Senegal's Nutrition Enhancement Program (NEP) is an example of such a successful strategy (Skoufias *et al.*, 2018). The NEP was initiated in 2000, and stunting rates have decreased from more than 30% in 2000 to less than 19% in 2016 (Galasso *et al.*, 2016).

Conclusions

In this study, we examine a third component of the cycle (Figure 1) of the impact of malaria on the welfare of agricultural households in sub-Saharan Africa: the impact of poverty reduction on stunting. This builds on our work showing the potential impact of eliminating malaria on the productivity and incomes of such households (Willis & Hamon, 2018a; Willis & Hamon, 2018b; Willis & Hamon, 2019).

We have developed new estimates indicating that there were approximately 21.5 million children with stunting in agricultural households in malarious regions of sub-Saharan Africa in 2018. We further identify a link between poverty reduction and a reduction in stunting on the basis of recent evidence from a nutrition program in Peru (Skoufias *et al.*, 2018).

As our previous work has shown that eliminating malaria by 2040 would lead to a 6.3–37.9% decrease in poverty in agricultural households in malarious sub-Saharan Africa, we propose that malaria elimination efforts should be seen as having the additional benefit of mitigating the major health challenge of stunting. This has implications for funding for malaria elimination initiatives. As most rural populations in sub-Saharan Africa experience high rates of both malaria transmission and stunting, the international development community should not consider these two problems as isolated challenges: policies that successfully suppress one will also affect the other.

Figure 1 contains a link from 'Nutrition security improves' to 'Health Improves.' Many of the long-term physical, social and cognitive impacts of stunting are irreversible. Undernourishment not only leads to stunting but also inhibits cognitive development. Individuals who experience stunting in childhood are at higher risk of non-communicable diseases as adults and often have reduced socioemotional skills. Reducing stunting leads not only to improved health as an adult but may also increase productivity, as childhood stunting is associated with delayed schooling and lower incomes as adults (Black *et al.*, 2013; Galasso *et al.*, 2016; Hoddinott *et al.*, 2013; Victora *et al.*, 2016).

In addition to developing a vision for eradicating malaria by 2040 (Gates & Chambers, 2015), the Bill and Melinda Gates Foundation has recognized the importance of eliminating malnutrition. Bill Gates specifically stated in a 2018 interview (with *Business Insider*) that this would be his target were he to have a magic wand.

One potential limitation to our study is that the relationship between poverty rates and stunting may be distinctly different in Peru than in sub-Saharan Africa. A decrease in poverty rates among agricultural households in sub-Saharan Africa may have a larger or smaller impact on stunting rates than was observed in Peru.

Future research should examine how improvements in income, education levels and gender equality due to suppressing malaria among agricultural households in sub-Saharan Africa would affect malnutrition and stunting. To address this research question, we recommend the collection of longitudinal data from households in Africa from a range of agro-ecosystems. Collecting longitudinal data of this type would help generate knowledge regarding heterogeneities in the impact of suppressing

malaria on malnutrition and stunting across communities and over time.

Data availability

The dataset for this research, Malaria among agricultural households in 2018 in sub-Saharan Africa - July 2018, has been deposited in CSV format with Harvard Dataverse. DOI: <https://doi.org/10.7910/DVN/ZFJ3XT> (Willis, 2018).

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

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The authors state that “Suppressing malaria could have a similar impact on stunting given that recent studies indicate that malaria suppression could increase productivity and reduce poverty in agricultural households”. The objective of this study is to highlight how suppressing malaria could affect stunting rates among children in agricultural households in sub-Saharan Africa.

The authors write: “However, no studies have examined how suppressing malaria could reduce the impact of malnutrition on households”. There are numerous studies on the effect of malaria on malnutrition, and the authors need to present and discuss these studies. This is a research area with conflicting results. Recent cohort studies suggest that malaria can increase wasting, but not stunting. On the other hand, neither wasting nor stunting increases the risk for malaria.

It seems that the mechanism the authors wish to study is an indirect one where reduction of malaria reduces poverty, and then poverty reduces stunting. This is an interesting and probable hypothesis. However, and to my knowledge, no such study has been done, probably because there are no long-term studies (over years) that have tested this hypothesis. Such studies would demand longitudinal data for many years.

A major weakness of this paper is that the authors based their findings on studies from South America and make their conclusions on African populations. Although they aim to make conclusions about stunting at the household level, they aggregate data on country levels from Africa. Although poverty and stunting may have decreased, recent data suggest that malaria has increased. These types of ecological studies have some severe limitations (ecological fallacy), and the authors do not discuss these limitations.

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?

No

If applicable, is the statistical analysis and its interpretation appropriate?

No

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

Partly

Are the conclusions drawn adequately supported by the results?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Infectious disease epidemiology, malaria, malnutrition, global health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.
