Original article

Review of the interplay between population dynamics and malaria transmission in Ethiopia

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Abstract

Background: The rapid growth of human population in malaria endemic areas has become a threat leading to the resurgence of the disease. Population growth and ecological changes in malarious areas have important implications for malaria control due to the adverse effects of the disease on the population.

Objective: To examine the relationship between different aspects of population dynamics and malaria transmission in Ethiopia.

Methods: Published and unpublished reports on the subject were reviewed. Internet sources, books and other relevant documents pertaining to the role of population changes and the magnitude of malaria were systematically reviewed.

Findings: Malaria is the number one public health problem in Ethiopia and a major cause of illness and death. Due to the high population pressure and depletion of agricultural land in highland areas, there has been a massive population movement to the lowlands, particularly in the last two decades. Most of the population movements are from malaria free or places of moderate endemicity to highly malarious areas. The number of people estimated to be residing in malarious areas of the country has shown a dramatic increase from 17.7 million in 1965 to more than 52.6 million in 2005, due to population growth and movement. High population movement and resettlement programs in malaria endemic areas have been identified as factors that exacerbate malaria transmission. As a result, more than half a million microscopically confirmed cases and 5-6 million clinical cases of malaria are reported annually from public health facilities in the country.

Conclusion: Movements into malarious areas, without substantial intervention, expose people to the risk of malaria, and further exacerbate the problem. Effective treatment of the disease with the right antimalarial drug is crucial. Thus, appropriate measures should be taken to address the consequences of developmental activities leading to ecological changes and population movements into malarious areas. [*Ethiop.J.Health Dev.* 2006;20(3):137-144]

Introduction

Malaria has been affecting human beings since the dawn of history (1). Currently, it is one of the major tropical diseases adversely affecting the health of the peoples and the economic development of many developing countries, particularly in sub-Saharan Africa (SSA). Each year, between 300 – 500 million malaria cases and up to three million deaths occur throughout the world, Africa accounting for more than 90% of the burden (2, 3). Over 80% of malaria deaths occur in Africa, while less than 15% of the deaths occur in Asia and Eastern Europe (4).

Although malaria eradication programs launched in the 1950s and 1960s had dramatically decreased the percentage of the world population at risk of the disease from 68% in 1946 to 52% in 1975, the absolute number of people at risk has increased from 2.1 billion in 1975 to about three billion in 2002 (5). The malaria eradication program had little success in many parts of Africa south of the Sahara. The number of people at risk of malaria in this Region grew to over 74% (about 600 million) at the end of the 20th century (1, 5). These upward demographic changes have important implications for malaria control since the proportion of the population residing in malarious areas is increasing through time.

Ethiopia, like other SSA countries, shares the intolerable burden of malaria, which has become a leading public health problem in the country. During the eradication program about 75% of the landmass of the country was estimated to be malarious (6, 7). However, recent information on the epidemiology of malaria indicates that the disease has encroached to areas that were free of malaria during the eradication period (8-11). Ethiopia is also characterized by a high population growth rate, which is currently estimated at 2.7%, with the projected population to reach 118 million in 2025, from the current estimate of 77 million (12). The population is growing at an average of 2 million annually between 2000 and 2005.

High population growth and ecological degradation in the highland and midland areas of Ethiopia have induced population mobility into lowland areas. This has led to increased exposure of people to communicable diseases like malaria, trypanosomiasis and other vector-borne diseases that are rampant in the lowland areas (13). With the current increase in population density in malarious areas of the country which are also endowed with untapped natural resources and a relatively fertile land that is conducive for agricultural opportunities, the number of malaria cases is expected to undoubtedly increase within the coming decades in the absence of effective interventions. Despite the importance of the relationship between population dynamics and malaria transmission in Ethiopia, less attention has been given to document their interactions. This paper presents an overview of some of the existing evidences on the relationship between population dynamics and malaria in the country, and highlights on areas that should be explored by further research.

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Methods of review

A review of the available literature was made in order to examine the relationship between population dynamics and malaria transmission in Ethiopia. Internet sources were searched for articles and documents that reflect the effect of population dynamics on malaria transmission or the demographic effect of malaria. Published and unpublished literature from different sources including books were searched and systematically reviewed. The search terms included: "malaria and population dynamics", "malaria and demographic effect", "population movement and malaria", "population settlement and malaria", "irrigation and malaria", "dams and malaria", "land use and malaria" with "Ethiopia". Searches were also conducted for materials that may not have been contained in the internet sources using citation links and the reference lists of the identified literature. Overall, 27 peer-reviewed articles, four unpublished documents, six chapters in books, and 10 other materials were identified, reviewed and organized in this paper. However, in general, the paucity of resource materials on the subject was apparently noted.

Findings and Discussion

Population at risk through time

The Ethiopian population has shown a dramatic increase during the 20th century from approximately 26 million in 1965 to 77.4 million in 2005 (12). These demographic transitions have important implications pertaining to the number of people exposed to the risk of malaria. Based on the 68% population at risk of malaria, the number of people estimated to be residing in malarious areas of the country has increased from 17.7 million in 1965 to more than 52.6 million in 2005, basically due to sharp population growth (Table 1). With the current population growth rate, the Ethiopian population will reach 118 million by the year 2025, of which nearly 80 million will be at risk of acquiring malaria infection (12).

Table 1: **Ethiopian population living in areas at risk for malaria transmission compared to the total population, 1965 to 2005.**

Time(Year)	Total population (000)	Population at risk (68%) (000)
1965	26090	17741

1975	34114	23197
1985	43361	29485
1995	60007	40805
2005	77431	52653

Source: World population database, 2004 (12)
Central Statistical Authority (14, 15)

The estimates of the number of population at risk of malaria in Ethiopia are based on the two thirds (68%) of the total population being at risk, estimated during the malaria eradication service in the 1960s (6, 7). However, it has been assumed that the total population at risk of malaria could be more than those figures presented in Table 1 due to the high rate of in-migration, settlement and fast urbanization associated with developmental schemes in malarious areas. Evidences show that migration in the Ethiopian context is generally from northern to central and southwestern regions and from densely populated highlands to the sparsely settled lowland malarious areas of the country (13-16).

This increase in the number of the population in malaria endemic areas has major implications for the need to increase access to effective antimalarial treatment in the country. New and affordable drugs need to be identified to cope up with resistance problems.

Population movement, settlement and malaria

Traditionally the highland and midland areas of Ethiopia have been considered as quite salubrious to human habitation, while lowland or river valley areas have been avoided due to the risks of communicable disease hazards (13). Due to fear of malaria, most of the human settlements before the 20th century concentrated in malaria free areas of the country. Historically, some areas in Ethiopia had been considered as infamous due to the dreadful effects of malaria. Modjo, situated on the main highway from Addis Ababa to Adama, is a renowned
area for the legend "VÐ ›Ñ\ q"Ð _d ›ÃÖóU ŸÔÐ" meaning that "*Although Modjo is a beautiful place, every house has a dead body*." These days, Modjo has become a center of large scale agro-industrial activities due to improved control of malaria in the area. Although the above legend was documented for Modjo area, the effect of malaria is felt similar in other malarious areas of the country.

Fear of malaria acquisition in malaria endemic areas has been a major obstacle to population mobility and settlement in fertile lands. The distribution of malaria in Ethiopia has influenced human settlements. More than 80% of the Ethiopian population lived in the 54% of the land mass that lies above 1500 meters above sea level in 1984 (17). The lack of movement of people to work or settle in highly endemic areas because of fear of malaria has resulted in negative economic growth and development in many tropical and subtropical developing countries (18).

The high population density in malaria free areas has caused over-cultivation, over-population and severe environmental degradation, leading to extensive drought and recurrent famine in many mid- and highland areas. This increased population pressure and the need for natural resources particularly in fertile lowland areas, has forced people to move to highly endemic areas, which were earlier thought to be dreadful due to fear of malaria. Further, the effects of malaria eradication interventions particularly during the 1960s and 1970s reduced the fear of the disease and opened opportunities for development and expansion of agro-industrial schemes in malarious areas of the country (6).

Human factors in general and population movements in particular are also the main elements that increase the spread of diseases (19-23). Work opportunities and resettlement programs in malaria endemic areas can easily attract a huge number of people, making them vulnerable to the disease (24). As people move to malarious areas, they increase their risk of acquiring the disease. Migrants from malaria free areas do not have immunity and easily acquire the disease (25).

In Ethiopia, the 1980s and 1990s were characterized by the vast internal movements of the population (26). This increased population movement has led to greater concern about the relationship between mobility and malaria (23). These internal movements of the population, particularly from malaria free areas to malarious areas have also resulted in variations in the estimates of the population at risk of malaria. This variation has wide-ranging implications for policy, and updating national and regional maps of malaria endemicity with population at risk from the disease is essential for planning malaria control and estimating the burden of the disease in the country.

The state-sponsored resettlement programs have been one of the basic alternatives to settle people in fertile lowland malarious areas. During 1984/85, more than 600,000 people from drought and famine stricken areas of northern and central parts of the country settled in Gambella, Metekel (Pawie), Wellega and Keffa regions of the country (26, 27). However, the resettlement programs resulted in considerable health problems associated with population movements and settlement. Evidences from Metekel site, for example, indicate that the mortality rate was estimated at 24% mainly due to malaria and diarrhoea (27).

Before the major resettlement programs, the areas were characterized by stable malaria transmission and the problem among the indigenous population was not of major concern due to low prevalence of the disease (24). Following the resettlement programs, however, an unprecedented increase in the incidence of malaria was observed in those areas. As for instance, 150,027 microscopically confirmed malaria cases were reported in the Pawie Settlement Area during the three-year period of 1985 to 1988, which had never been observed before. Most settlers came from the malaria free highlands and unstable fringe areas, putting them at high morbidity and mortality risk from malaria (24, 26).

The stable characteristics of malaria transmission in the designated areas are disturbed due to the ecological and epidemiological changes introduced by non-immune settlers and extensive application of malaria control interventions, at the same time increasing the susceptibility of the indigenous population to malaria. Although not systematically documented, the number of deaths due to malaria among the settlers was high (24, 26, 27). In general, malaria and other vector-borne diseases such as trypanosomiasis and onchocerciasis were identified as immediate health hazards of the settlers (26).

The movement of infected people from malaria endemic areas to malaria receptive areas is as well implicated to lead to the resurgence of malaria (20). After the abandonment of the resettlement programs in the early 1990s, most of the settlers returned to their original places, particularly during the transition period of the current regime (28). As a result, the prevalence of malaria in the original areas where the returnees resettled increased due to the migration of malaria parasites with the people.

The period of 1991-1993 in Ethiopia was characterized with the demilitarization of about half a million soldiers of the previous Derg Regime and return of refugees. However, the impact of this movement on malaria was not documented. The most recent resettlement program started since 2003 has resulted in the subsequent influx of a huge number of non-immune compatriots into new resettlement sites in malaria endemic areas. However, no studies or reports related to the malaria situation in the current resettlement programs have come out so far. One of the most important aspects that should not be undermined about resettlement programs is that, strong and sustainable malaria control activities should be instituted along resettlement programs.

Population movement is also one of the factors that have been incriminated for the spread of antimalarial drug resistance (20). Drug resistance in *Plasmodium falciparum* in Ethiopia was first reported in 1985, along the Ethio-Sudan and Kenyan borders, and rapidly spread to other parts of the country (6, 29). This period was associated with the massive population movements ever encountered in the history of Ethiopia.

In addition to the state-sponsored resettlement programs involving drought and famine victims, spontaneous and seasonal migration is common in Ethiopia. Farm labor migrations to agro-industrial schemes situated in malaria endemic areas are also by far the most important factors that have influenced the epidemiology of malaria in Ethiopia (30). During the 1970s and 1980s, huge numbers of highland farm laborers migrated into the lowlands. In 1974, more than 100,000 of the 250,000 inhabitants in the Awash Valley were migrant farm laborers from the highlands (30).

Seasonal short-term and cyclical movements by subsistence farmers and unemployed people seeking land for cultivation and job opportunities for livelihood have also important implications for the changing pattern of malaria distribution (30). Many Ethiopians from the midhighland areas are away from their permanent homes during certain seasons of the year, particularly during the summer plantation and the following harvesting season. These seasons are part of the year when malaria peaks and mostly occurs in epidemic forms. Seasonal coffeepicking in the southwest, *teff* mowing in central Ethiopia, cotton and sugarcane plantations and harvest in the Awash Valley and Humera lowlands attract large number of farm laborers and unemployed people from different mid-highlands of Ethiopia. Most of the people involved in such movements are non-immune and are at high risk for malaria (26, 27).

People involved in other tasks such as government employees, developmental workers, military personnel, traders and tourists also frequently move into areas of endemic malaria in Ethiopia. As a result, their risk for malaria increases due to the absence of or low-level immunity against the disease, maintaining transmission of malaria at high levels. This indicates that many breadwinners and people seeking for job opportunities might have died of malaria through such movements, resulting in a high loss of permanent lifetime earnings due to premature death. Indeed, the introduction of nonindigenous, non-immune people into malaria endemic areas is accompanied by malaria epidemic (30). Internal displacement due to natural disasters, civil unrest and wars tend to favor malaria transmission (23, 31). As a result, large numbers of non-immunes enter into malaria endemic zones each year and have become victims of the disease. Appropriate measures to address the consequences of the disease on population movement and resettlement are critical for malaria control. Effective treatment of the disease with the right antimalarial drugs is desirable. People should be made aware of the risks of malaria and its prevention methods.

Ecological changes and malaria

The effects of land use comprising of water impoundment schemes, irrigation schemes, deforestation, agricultural development, road and hydro-electric power construction in malarious areas result in ecological disturbances that exert considerable influence on the proliferation of mosquito breeding sites, resulting in high malaria transmission (32-35). Changes in land use followed by variations in climatic conditions singly or in combination have been incriminated by increases in morbidity and mortality from a number of parasitic diseases like malaria and schistosomiasis (32-36).

Changes in government policies since the 1960s have emphasized on the exploitation of fertile, but sparsely populated lowlands, particularly for agricultural development. As a result, sugarcane, cotton and coffee plantations were extensively practiced in malarious areas of the country. Irrigation schemes and agricultural

developments launched in the Upper and Middle Awash valleys during the 1970s and 1980s resulted in major ecological changes (30). This brought a dramatic rise in the incidence of malaria and other vector-borne diseases in these areas particularly among the non-immune migrants. Similarly, state-sponsored resettlement programs conducted in western and southwestern parts of the country resulted in ecological disruption followed by high morbidity and mortality from malaria (26, 27).

In northern Ethiopia, construction of water dams accompanied by conditions suitable for the breeding of mosquitoes in the 1990s resulted in the rise of malaria prevalence (36). The study showed an increased risk of malaria among children in communities near microdams, indicating the effects of environmental changes on the epidemiology of malaria. While well-maintained canals and irrigation schemes do not favor the breeding of mosquitoes, small standing pools of water, seepage and improper maintenance can produce and sustain breeding opportunities in the dam areas. Most of the recent ecological disruption and environmental changes in Ethiopia have occurred in lowland areas favoring malaria transmission.

Urbanization and malaria

Ethiopia and other countries in the SSA are characterized by rapid urban population increase particularly in areas where the highest rates of *Plasmodium falciparum* are common (37, 38). There are two possible explanations about malaria transmission in urban areas. The first explanation argues that urban areas seem to have lower rates of malaria transmission probably due to the effects of pollution on mosquito breeding habits and reduction of man-vector contact through the use of vector control measures such as house screening, insecticides and mosquito nets (38). The second explanation stems from the idea that urban environment may influence malaria transmission often by providing ample mosquito breeding habitats like broken or blocked water drains, new construction activities, irrigation schemes and new water collection reservoirs (37, 38). As a result, the importance of urban malaria has been recently recognized as one of the major health problems for the urban community.

The urban population of Ethiopia has remained significantly low. In 1965 and 2005, about 7% and 16% of the Ethiopian population lived in urban areas, respectively (12). The total number of people living in urban areas has increased from 1.9 million in 1965 to 12.5 million in 2005. Urban population growth is partly fuelled by internal migration. Migration from rural to urban areas increased during the 1980s and 1990s (14, 15). Most of the significant increase in the number of the population in urban areas in Ethiopia occurs in lowland areas where the risk of malaria infection is very high. Some of the fastest growing towns in malarious areas of the country include Adama, Awasa, Bahir Dar, Arba Minch, Dire Dawa, Kombolcha, Jijiga, Zeway, Anger Gutin and Metema (Shehedi) (14, 15, 18). Similar to most urban settlements in SSA, Ethiopian towns are also characterized by poor housing, lack of proper sanitation, poor drainage of surface water, weak health services and widespread economic disparity (37). All these factors, independently or together, facilitate urban malaria transmission.

Anopheles gambiae and *Anopheles arabiensis*, the main vectors for malaria transmission in SSA including in Ethiopia, are also the most important anopheline species to maintain urban malaria transmission (37, 38). Malaria transmission in urban areas results in large variations in malaria prevalence in different parts of the towns. A 5.3% prevalence of malaria, of which 74% due to falciparum malaria, was reported mainly among people living near mosquito breeding sites in Gondar Town in 2004 (39). In Adama, an overall parasite rate of 2.8% was observed among 3890 individuals examined, with a much higher prevalence in the peripheral areas, and these differences were reflected in the abundance of mosquito density (40). Therefore, understanding urban factors that facilitate or inhibit malaria transmission is important for planning malaria control interventions in urban areas.

Malaria and human fertility

Aside from the direct demographic consequences of malaria morbidity and mortality, there are also significant indirect effects due to the disease. In highly endemic areas, malaria mortality mainly occurs among children under the age of five, and has effects on the age structure of these populations. Evidences show that high infant and child mortality rates are associated with high fertility rates. This phenomenon was particularly exemplified and attested when malaria eradication efforts in the 1940s and 1950s in Sri Lanka resulted in an immediate decline in all-causes of mortality and triggered a rapid population explosion, where decline in mortality was attributed to malaria control (41, 42).

Since malaria is a killing disease and rampant in highly endemic areas, parents desire to have more children to replace the ones they lose, or to guarantee at least one surviving heir or one surviving child into the parents' old age (18). Based on these assumptions, it is possible to predict a disproportionately high fertility rate accompanied with high population growth rate in epidemic-prone and intense malaria transmission areas. This warrants appropriate population growth control measures due to the fact that economic growth following the eradication of diseases like malaria may only be feasible when it is not offset by increases in population growth rates. However, there is no documented evidence about the impact of malaria on birth rates in Ethiopia.

Trends of malaria prevalence in Ethiopia

Literature review reveals that malaria is the number one public health problem in Ethiopia and accounts for the major cause of illness and hospitalization (43). The incidence of the disease has been significantly increased since the 1980s. Specific data on the number of malaria cases in Ethiopia is available only since the end of 1980s

(7, 43, 44) as presented in Figure 1. There has been a noticeable increase in the number of cases in the country over time, except for 1999/00 and 2000/01 years. The latter years were characterized by the low incidence of malaria due to the non-occurrence of severe malaria epidemics. *Plasmodium falciparum* and *Plasmodium vivax* are the most commonly encountered human malaria parasites in Ethiopia. *Plasmodium malariae* (<1%) is found sporadically in some areas, while there has been no report about the occurrence of *Plasmodium ovale* in the country.

During the late 1980s malaria prevalence in the country was very high because of high population movements from highlands to lowland malarious areas (7, 24). The impact of the disease was also extremely severe during the second half of the 1990s. Between April and December 2003, large-scale malaria epidemics flared up in many parts of the country resulting in over four million cases and 3,000 deaths (10).

It is estimated that each year between 5-6 million episodes of clinical malaria are reported from public health facilities in Ethiopia (43-47). However, there is a considerable variation between the number of malaria cases reported in "Health and Health Related Indicators" issued by the Ministry of Health (43) and other sources of malaria data (45, 46). "Health and Health Related Indicators" are likely to under-estimate the actual magnitude of malaria in the country, since these reports might have excluded malaria patients treated at health stations, health posts, by community health workers, nongovernmental organizations' health facilities and private health care providers (43, 45).

In general, the trend of malaria in Ethiopia over the last two decades has been increasing. The high influx of nonimmune people into malaria endemic areas for social and economic reasons such as resettlement and search for alternative income, and the expansion of agricultural and industrial developments in malarious areas of the country could be some of the reasons for the observed rise in the number of malaria cases during these periods (7, 24, 47). Intervention strategies such as scaling-up of mosquito net implementation, community mobilization for elimination of mosquito breeding sites and proper targeting of indoor residual spraying of houses are critical in reducing the consequences of malaria.

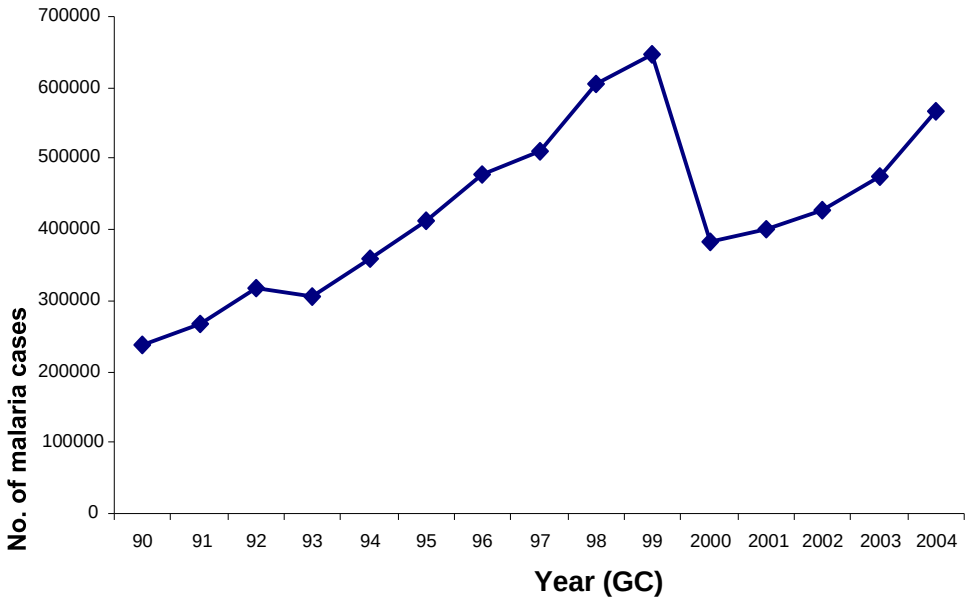

Figure 1: **Trends for annual number of microscopically confirmed cases of malaria in Ethiopia (1990-2004). Reporting is from July to June annual cycle. The year 90, for example, represents from July 1989 to June 1990, and so on. Source: Health and health related indicators, Ministry of Health (44, 44)**

Conceptual framework

While demographic studies on the impact of malaria on human population, or vice versa, are very limited in scope and space in Ethiopia, the relationship between population variables (human, environmental, social, and economic) that interact to create conducive factors for malaria transmission; (b) highlights human factors that influence malaria transmission; and (c) unveils the effect of malaria

dynamics and malaria can be easily appreciated using existing evidences. In this review, we propose a framework which: (a) distinguishes a series of on morbidity, population movement, land use and settlement (Figure 2).

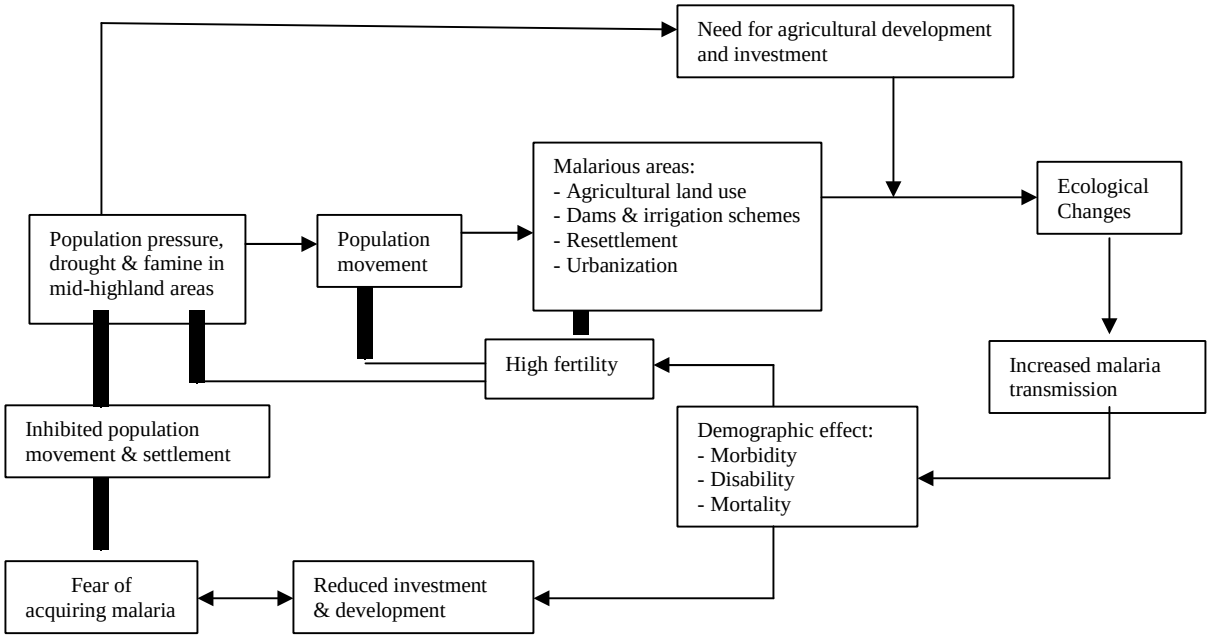

Figure 2: **Conceptual framework showing the relationship between different aspects of population dynamics and malaria transmission in Ethiopia.**

This framework is designed to facilitate the understanding of the relationships between population dynamics and malaria transmission by recognizing the importance of multiple interrelated factors between the disease and population. We recognize that there are several factors beyond the vector and the parasite to explain why malaria shows significant rise under the current Ethiopian context, and understanding the specific factors underlying the interactive role between population dynamics and malaria is necessary to plan and implement effective malaria control strategies.

Conclusion

Malaria continues to be a major cause of ill-health in Ethiopia. High population pressure in mid-highland areas of Ethiopia and the need for agricultural developments have resulted in ecological changes favoring malaria transmission. Seasonal or state-sponsored population movements for a number of reasons such as resettlement, economic necessity, civil unrest and natural disasters are some of the factors contributing to the resurgence of malaria. Most of the population movements are from malaria free or of moderate endemicity to highly malarious areas. These demographic changes result in an increase in the total population exposed to malaria risk, and exacerbate the problem. The review also identified important areas that deserve further research for a good understanding of how malaria and population dynamics affect one another.

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