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Deforestation and Malaria in sub-Saharan Africa: an overview

C Uneke

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Abstract

Malaria remains the most complex and overwhelming health problem in sub-Saharan Africa. The disease is compounded by the generally poor social, environmental and economic conditions in the region. Most sub-Saharan African countries are experiencing unprecedented rate of population growth which has led to uncontrolled and unsustainable exploitation of natural resources, especially the forests resources. Through the process of forest clearing, deforestation alters every element of local ecosystems such as microclimate, soil, and aquatic conditions, and most significantly, the ecology of local flora and fauna, including malaria vectors. Mosquitoes are highly sensitive to environmental changes because of deforestation: their survival, density, and distribution are dramatically influenced by small changes in environmental conditions, such as temperature, humidity, and the availability of suitable breeding sites. Changes in mosquito ecology and human behaviour patterns in deforested regions influence the transmission of malaria and deforestation has therefore been shown to increase the risk of malaria transmission in sub-Saharan. Because deforestation is a process that cannot be readily controlled for a variety of political and economic reasons, investigations and assessments of possible impacts of future deforestation will be crucial to minimize the ecological degradation caused by human activities and to control epidemics of malaria.

INTRODUCTION

Malaria remains the most complex and overwhelming health problem, facing humanity with 300 to 500 million cases and 2 to 3 million deaths per year [1] . About 90% of all malaria deaths in the world today occur in sub-Saharan Africa (Figure 1) and this is because majority of infections are caused by Plasmodium falciparum, the most dangerous of the four human malaria parasites (P. falciparum, P. ovale, P. vivax, P.malariae), accounting for an estimated 1.4 to 2.6 million deaths per year in this region [23] . In addition, the most effective malaria vector- the mosquito Anopheles gambiae is the widest spread in the region and the most difficult to control [2] . In some areas of sub-Saharan Africa people receive 200 to 300 infective bites per year [45] . The vector population in sub-Saharan Africa is uniquely effective, with the six species of the Anopheles gambiae complex being the most efficient vectors of human malaria in the region, and often considered the most important in the world. An. funestes is also capable of producing very high inoculation rates in a wide range of geographic, seasonal, and ecological conditions [6] . These vectors have proven effective in transmitting the malaria parasite to humans across the region, in rural and urban areas alike. An. pharoensis is also widely distributed in Africa, geographically and ecologically, and can maintain active transmission of malaria even in the absence of the main malaria vectors [7] . Malaria in sub-Saharan Africa is a problem of dimensions unlike those seen anywhere else in the world today. The magnitude of malaria in the region is affected by a variety of factors, none of which addressed alone is likely to effect a resolution. It is further compounded by the generally poor social, environmental and economic conditions in sub-Saharan Africa.

Most sub-Saharan African countries are experiencing unprecedented rate of population growth without any appreciable improvement in the socio-economic status of the populace. There is therefore a high level of poverty and underdevelopment in the region particularly in the rural areas. One major consequence of this situation is uncontrolled and unsustainable exploitation of natural resources, especially the forests resources, which has generated severe environmental, ecological and public health problems including increase in vector-borne diseases like malaria. Forests are among the world’s most important biomes in terms of the area of land surface they cover (approximately 30% of all land - over 3.8 billion hectares [8] , and the goods and services they provide, and the biodiversity they contain (approximately 90% of terrestrial biodiversity) [9] . More than 1 billion people depend on forests for their livelihoods to varying degrees and 60 million indigenous people are almost wholly dependent on forests, while around 350 million people living within or adjacent to dense forests depend on them to a high degree for subsistence and income, in developing countries, agro-forestry farming schemes support 1.2 billion people and help sustain agricultural productivity and the generation of income [10] . Forest industries provide employment for some 60 million people worldwide [9] .

Through the process of clearing, deforestation alters every element of local ecosystems such as microclimate, soil, and aquatic conditions, and most significantly, the ecology of local flora and fauna, including human disease vectors [11] . Of all the forest vector species that transmit diseases to humans, mosquitoes are among the most sensitive to environmental changes because of deforestation: their survival, density, and distribution are dramatically influenced by small changes in environmental conditions, such as temperature, humidity, and the availability of suitable breeding sites [12,13,14] . Changes in mosquito ecology and human behaviour patterns in deforested regions influence the transmission of mosquito-borne diseases such as malaria, Japanese encephalitis, and filariasis [15,16] . In particular, each incident of deforestation and land transformation has a different influence on the prevalence, incidence, and distribution of malaria directly and indirectly [15] . Numerous country and area studies have described the influence of deforestation and subsequent land use on the density of local mosquito vectors. Some of the studies were able to follow-up further and observe changes in local malaria incidence and prevalence due to the mosquito density change [11,15,16] . Thus malaria transmission (and also the control) has clear links to ecosystem changes that result from natural resource policies such as land tenure, road building, and agricultural subsidies; and deforestation is a major development policy concern which often heralds many other 'malaria-causing' land use changes [17] .

Despite the high rates of malaria and deforestation in sub-Saharan Africa, the relationships between both contextual challenges have not been comprehensively assessed. The objective of this report therefore is to evaluate the relationship between deforestation and malaria in sub-Saharan Africa with the view to providing information that has policy relevance as it concerns malaria control and sustainable forest resource exploitation in sub-Saharan Africa. To achieve this, a Medline Entrez-Pubmed search was performed and studies conducted in sub-Saharan Africa and reported in English which investigated deforestation and malaria were identified. Combinations of key words such as Malaria and Deforestation were used for the search which yielded 59 entries as of June 2008. Selected publications obtained from the Google search using the key words Malaria, Deforestation and sub-Saharan Africa were also included in the review. References from all the selected publications were used to identify additional relevant literature. Emphasis was placed on studies that reported the relationship between deforestation and all aspects of malaria including the epidemiology of the disease, anopheline mosquito ecology, economic burden and the public health in sub-Saharan Africa. The overall goal was to provide scientific information that would enhance understanding of the impact of deforestation on malaria in sub-Saharan Africa and other malarial regions of the world with similar settings.

THE BURDEN OF MALARIA IN SUB-SAHARAN AFRICA

Malaria threatens the lives of 40% of the world's population – over 2.2 billion people [18] . The World Health Organization and the World Bank rank malaria as the largest single component of the disease burden in Africa, causing an annual loss of 35 million future life-years from disability and premature mortality. In Africa, malaria is responsible for about 20-30% of hospital admissions and about 30-50% of outpatient consultations [18] . Sub-Saharan Africa still remains the most malaria endemic area in the world (Figure 1). The global impact of malaria is staggering, regardless of how it is measured. Biomedically, the burden of disease is a function of many things and various public health disciplines define it differently. Epidemiologists refer to burden in terms of morbidity and mortality, while economists refer to a quantification of the costs (direct and indirect), and effects on levels of productivity, national growth, and development [19] . The cost of malaria can be measured in lives lost, in time spent ill with fever, and in economic terms. Money spent on preventing and treating malaria, the indirect costs of lost wages, time home from school, and time spent caring for sick children, adds up at the personal level. In most countries in sub-Saharan Africa, in the public sector, large fractions of health sector budgets are spent on malaria control and treatment and at the macroeconomic level, a heavy national burden of malaria dampens economic development, sometimes subtly, but pervasively. All of these effects are recognized and accepted widely, but their magnitude has been poorly documented.

Figure 1

Figure 1. Map of Africa showing malaria endemic sub-Saharan African region. (Courtesy WHO, 2000)

In areas where malaria is highly endemic, a protective semi-immunity against P. falciparum is acquired during the first 10–15 years of life, and the majority of malaria-related morbidity and mortality happen in young children [20] . Thus, the impact of malaria on child health is enormous. In year 2000, it was estimated that approximately 100 million children lived in areas where malaria transmission occurs and that 803 620 (precision estimate: 705 821–901 418) children died from the direct effects of malaria and for all of sub-Saharan Africa, including populations not exposed to malaria, malaria accounted for 18.0% (precision estimate: 15.8–20.2%) of child deaths [21] . However, in contrast with low malaria prevalence in adults, pregnant women in endemic areas are highly susceptible to malaria, and both the frequency and the severity of disease are higher in pregnant than non-pregnant women [22] . Malaria during pregnancy is a serious problem in sub-Saharan Africa, affecting an estimated 24 million pregnant women [23] . Each year between 75,000 and 200,000 infant deaths are attributed to malaria infection in pregnancy globally [23] . Pregnancies in women living in malaria endemic regions particularly in sub-Saharan Africa are associated with a high frequency and density of P. falciparum parasitaemia, with high rates of maternal morbidity including fever and severe anaemia, with abortion and stillbirth, and with high rates of placental malaria and consequently low birth weight in newborns caused by both prematurity and intrauterine growth retardation [232425] .

In sub-Saharan Africa, malaria is currently known to enhance the susceptibility of infected individuals to other infectious agents. One outstanding instance is the co-infection of malaria with HIV infection. Concerning the global HIV epidemic, sub-Saharan Africa remains by far the worst-affected region with 25.4 million people living with HIV (Just under two thirds, i.e. 64% of all people living with HIV) [26] . Because of the high prevalence of malaria and HIV in sub-Saharan Africa, co-infections are common. Initial studies conducted among children and adults failed to show a consistent pattern of a biologic or clinical interaction between malaria and HIV infection [272829] , the two diseases were however, identified to critically intersect in pregnancy and have serious consequences in pregnant women, their fetuses, and infants [3031] . Approximately one million pregnancies per year are thought to be complicated by coinfection with malaria and HIV in sub-Saharan Africa [30] . P. falciparum malaria during pregnancy, can lead to parasite sequestration in the maternal placental vascular space, with consequent maternal anaemia, abortion, stillbirth, fetal distress, prematurity, low birthweight, congenital malaria and neonatal or maternal death [3233] . The risk of these adverse pregnancy outcomes is further increased with HIV co-infection [3134] . As a result, a considerable proportion of infants exposed in utero to both placental malaria and maternal HIV infection have an increased risk for postneonatal death three- to eightfold higher than infants born to mothers with either infection alone [353637] .

Beyond mortality, malaria causes morbidity through fever, weakness, malnutrition, anemia, spleen diseases and vulnerability to other diseases. The health consequences of malaria vary in terms of severity, but the global impact of malaria on human health, productivity, and general well-being is profound particularly in sub-Saharan Africa [38] . The joint mortality and morbidity impacts of malaria are estimated to be 45 million DALYs (disability adjusted life years) in 2000 or nearly 11% of all infectious diseases [39] . Malaria imposes substantive social and economic costs and impedes economic development through several channels, including but certainly not limited to, quality of life, fertility, population growth, saving and investment, worker productivity, premature mortality and medical costs in sub-Saharan Africa [3840] . Malaria is estimated to cause a decline in economic growth in the range of 0.25% to 1.3% of per capita GNP growth in tropical countries, even after accounting for initial endowments, overall life expectancy and geographic location [3940] . To the extent that slow economic growth limits funds for malaria control, there is a vicious cycle of poverty and malaria that diminishes economic opportunities for a large number of the world's inhabitants especially in sub-Saharan Africa [17] .

FOREST RESOURCES AND THEIR EXPLOITATION IN SUB-SAHARAN AFRICA

The malarious regions of the world are among the areas with the largest global forests. Although estimates of the global extent of humid tropical forest vary greatly, from 11.16 million to 15.71 million km ^{2} , the largest surviving areas of such forest are to be found in Latin America (6.53 million–7.80 million km ^{2}), chiefly in the Amazon region, followed by Africa (1.93 million– 5.19 million km ^{2}) and South–east Asia (2.70 million–2.72 million km ^{2}) [414243] . Both forest biodiversity, and the natural functioning of health forest ecosystems, contribute immensely to human health. Forest species contribute to balanced diets, and are a major component of traditional healthcare systems – which provide the primary healthcare for around two-thirds of the global population [44] . The medical needs of approximately one billion people depend on drugs derived from forest plants, many of which have been long been used in traditional medicine. In recognition of the importance of forest ecosystems and the services provided, the proportion of forest cover to total land area (excluding inland waters) has been adopted as an indicator measure for monitoring progress towards achieving the Millennium Development Goals (MDGs) adopted by the member states of the United Nations under the 2000/2002 Millennium Declaration [45] . It is already well established that the drastic modification of the environment as a result of overexploitation of natural resources particularly the forest resources, results to severe health, ecological and economic consequences especially among the rural populace in sub-Saharan Africa and other tropical regions [46474849] .

Deforestation in malarious areas is extensive, with global estimates of its rate ranging from 36,000–69,000 km2/year [50] . The estimated rates of global deforestation are astonishing. According to the World Resources Institute (http://pubs.wri.org/pubs_content.cfm?PubID=3018), more than 80 percent of the Earth's natural forests have already been destroyed (at a rate of about 40 million hectares per year). Up to 90 percent of West Africa's coastal rain forests have disappeared since 1900. Loss of habitats is among the obvious consequences of deforestation` (seventy percent of the Earth's biodiversity is present in forests). Rain forests help generate rainfall in drought-prone countries elsewhere. Studies have shown that destruction of rain forests in such West African countries as Nigeria, Ghana, and Côte d'Ivoire may have caused two decades of droughts in the interior of Africa. (http://pubs.wri.org/pubs_content.cfm?PubID=3018). Analysis of the Food and Agriculture Organization of the United Nations (FAO) report shows that developing countries in the tropics generally suffered the worst rates of forest loss between 2000 and 2005. Of the 10 countries with the highest deforestation rate during that period, all were considered "developing" and nine were tropical. Four of the top six were located in south or southeast Asia as follows; Nigeria 55.7%, Viet Nam 54.5%, Cambodia 29.4%, Sri Lanka 15.2%, Malawi 14.9%, Indonesia 12.9%, North Korea 9.3%, Nepal 9.1%, Panama 6.7%, Guatemala 6.4% [51] . Nigeria therefore, has the world's highest deforestation rate of primary forests according to the revised deforestation figures from the FAO and between 2000 and 2005 the country lost 55.7 percent of its primary forests -- defined as forests with no visible signs of past or present human activities [51] .

Most of Africa's deforestation is caused by slash-and-burn agriculture. Forests are rarely replanted as people move from depleted lands to clear new forest areas. Yet forests and trees make an essential contribution to rural life by providing firewood, dyes, fruits, nuts, and building materials. Firewood and charcoal represent more than half the energy consumption in sub-Saharan Africa [52] . The fight against deforestation is being lost in some countries. For example, Côte d'Ivoire once had the largest rainforest in West Africa. In 2000, deforestation reduced the coverage of forests to 22 percent of the country's area [53] . Hope comes from such countries as Gambia and Rwanda, which have been praised for their efforts to save and replant forests. In 2004, the World Bank approved a $40 million grant to help Madagascar preserve natural forests and protect biodiversity [54] .

Rapid growth in population and expansion in socio-economic development in sub-Saharan Africa, are imposing considerable pressures on the natural resources base and the environment in the region. There is a need to satisfy rapidly growing demands for agriculture, housing, and infrastructure development. This has led to environmental degradation manifested as deforestation, and loss of wildlife habitat, desertification, erosion, floods and general loss of the productive land base of the countries of sub-Saharan Africa. Deforestation is driven by a wide variety of human activities, including agricultural development, logging, transmigration programs, road construction, mining, and hydropower development [10] . Meanwhile health, poverty and forest degradation remain very closely intertwined, with many of the world's poorest people depending directly on a wide range of forest resources and services for their livelihoods [4649] . The effects of deforestation on ecosystems and human health are diverse and have taken place for many decades, though both the rate and geographic range have increased markedly over the last 30 years [15] . Severe forest disruption via over exploitation (deforestation), combined with evolution (of pathogens), globalization (in trade and travel) and changes in living patterns, can therefore lead – and have already led – to the loss of many forest goods and services, with profound implications for human health particularly the transmission of vector borne-diseases like malaria [1547] .

DEFORESTATION AND MALARIA: THE INTERCONNECTING LINK

Malaria is a major killer and factor in the burden of disease in and near forested areas in Africa. An interesting hypothesis, hotly debated in the current literature [555657] is that when Africans experienced a dramatic change in their environmental and behavioural practices 10,000 years ago, shifting from hunter-gatherers to farmers, malaria started to infect humans [58] . Forest clearing either for farming or other purposes has allowed populations to enter areas that malaria had previously rendered uninhabitable. The causal links between deforestation and incidence of malaria are difficult to distinguish. Some logging processes can lead to standing water and increases in mosquito breeding sites. Road building, tree felling, reduced shade and increased pooling of water have been shown to promote breeding and more rapid development of mosquito larvae [5960] . Of additional concern, a form of malaria previously found in non-human primates has recently been found in humans in Southeast Asia [6162] .

Massive clearing of forests has enormous impacts on local ecosystems and human disease pattern. It alters microclimates by reducing shade, altering rainfall patterns, augmenting air movement, and changing the humidity regime [63] . It also reduces biodiversity and increases surface water availability through the loss of topsoil and vegetation root systems that absorb rain water [64] . For anopheline species that breed in shaded water bodies, deforestation can reduce their breeding habitats, thus affecting their propagation. On the other hand, some environmental and climatic changes due to deforestation can facilitate the survival of other anopheline species, resulting in prolonged seasonal malaria transmission [16] . Deforestation and land transformation influence the malaria vector anophelines, especially larval survivorship, adult survivorship, reproduction and vectorial capacity, through changing environmental and microclimatic conditions such as temperature (average, variability), sunlight (amount, duration), humidity, water condition (distribution, temperature, quality, turbidity, current), soil condition, and vegetation [65] .

In the western Kenya highlands it was reported that Mosquitoes that were placed in houses in the deforested area showed a 64.8–79.5% higher fecundity than those in houses located in the forested area, but the median survival time was reduced by 5–7 days [66] . According to the report female mosquitoes in the deforested area showed a 38.5–40.6% increase in net reproductive rate and an 11.6–42.9% increase in intrinsic growth rate than those in the forested area; significant increases in net reproductive rate and intrinsic growth rate for mosquitoes in the deforested area suggest that deforestation enhances mosquito reproductive fitness, increasing mosquito population growth potential in the western Kenya highlands. The vectorial capacity of An. gambiae under study was estimated at least 106% and 29% higher in the deforested area than in the forested area in dry and rainy seasons, respectively [66] . Deforestation and cultivation of natural swamps increased larval survivorship and adult productivity of An. gambiae through their effects on water temperature and nutrients [67] . In Southern Cameroon, the increased density of An. gambiae near the area where massive deforestation took place in order to cite a new international airport combined with the low parity rates, indicated that deforestation favoured the breeding of this species. Malaria transmission was estimated at 106 and 68 infective bites per man per year in hamlets close to and far away from the airport zone respectively and An. gambiae accounted for 13% of the transmission in the hamlet adjoining the airport and 0% three kilometers off the airport [68] .

Many species of mosquitoes prefer to feed on animals rather than humans. Destruction of animal habitats, and a decline in the number of wild animals forces the mosquitoes to feed on domestic animals and humans [15] . The frequency of human feeding has a marked influence on malarial transmission. Consequently, in most places the clearing of land results in an increase in malaria. Anopheles mosquitoes that breed in partially shaded or sunlit water replace the forest-breeding mosquitoes. In some cases these mosquitoes are more efficient vectors than those replaced. Deforestation practice therefore can result in a massive increase in mosquito breeding sites. Dragging logs through the forest can cause water-filled furrows. Tire marks, hoof prints, and even human footprints, can provide ideal breeding places. Removal of growth along stream edges, slowing of water run off by debris, and impoundment for water supplies, accumulation of coconut shells, tins, tires, and other rubbish, and pooling of water in tree stumps, all increase the breeding potential [15] .

The relationship between malaria transmission, forest cover and deforestation is complex. Aspects related to microclimate and/or the chemical composition of soils can be important [69] . Ecological factors can regulate the species composition of the mosquito populations, and thus the numbers and types of malaria vector, by, for example, changes in host-preference and predation patterns [70] . Human population migrations to and from forests (usually driven by economic and social pressures) and the associated changes in land cover are often critical [15] . Such migrations often bring human populations closer to the forest. The direction of land-use that follows forest clearing— usually towards grasslands or crops — is also important but its influence will be mediated by the local ecology and vectors [16] . The replacement of forest with rice cultivation, for example, may provide more favourable conditions for Anopheles gambiae s.s. or An. albitarsis s.s. [717273] but can reduce transmission in areas where An. dirus is the main vector [16] . In contrast, An. dirus can find tree-crop plantations suitable for breeding since such plantations provide conditions that are similar to this vector's natural habitat [16] . As the result of such links, the effects of deforestation on malaria transmission are spatially variable and largely dependent on vector distribution, since the vector species have adapted to different types of land cover, including forests and near-forest habitats. This makes the effects of deforestation on malaria transmission regionally distinctive and even locally specific. A basic knowledge of vector bionomics leads to the generally accepted (though largely qualitative) opinion that deforestation increases the risk of malaria transmission in Africa and tropical America but decreases it in Asia [7475] .

A synthesis of the literature on forests and malaria proposes at least six pathways through which deforestation can affect malaria infection and disease [76] .

(i). Deforestation changes the ecology of a disease vector and its options for hosts. Whereas the forest floor in primary growth tends to be heavily shaded and littered with a thick layer of organic matter that absorbs water and renders it quite acidic, cleared lands are generally more sunlit and prone to the formation of puddles with more neutral pH which can favour specific anopheline larvae development [11] . Terrain affects the manner in which water collects in deforested areas – on steep inclines, streams are more common than large pools.

(ii). Deforestation can change local climate and thereby affect the spread of disease byreducing moisture held by the vegetation, and raising ground temperatures. Higher temperatures can increase the rate at which mosquitoes develop into adults, the frequency of their blood feeding, the rate at which parasites are acquired, and the incubation of the parasite within mosquitoes [15] . For example, deforestation and its related activities have produced new habitats for Anopheles darlingi mosquitoes and have caused malaria epidemics in South America [15] . The different species complexes in SE Asia (A. dirus, A. minimus, A balabacensis) have been affected in different ways by forest clearance with different impacts on malaria incidence.

(iii). Deforestation is often the beginning of a variety of land use changes. These changes may include agriculture and livestock, plantations, human settlement, increased use of regenerating forests, road construction, and water control systems (dams, canals, irrigation systems, reservoirs). These habitat changes may not only result in mosquito populations that have higher rates of malaria transmission, but they may also lead to increased human contact and transmission [77] . Networks of irrigation ditches, canals and impoundments, as well as puddles from road construction, can improve vector habitats. Livestock can change vectorial capacity. Rubber plantations in Malaysia encourage A. maculates, whereas erythrina (with their bromeliads) encouraged A. bellator in Trinidad [15] . Use of insecticide in follow-up agriculture can increase vector resistance [78] .

(iv). Deforestation is accompanied by migration that may enhance the spread of malaria. As shown in the case of gold miners in the Brazilian Amazon, migrants typically have little previous exposure and therefore lower natural immunity [79] . Moreover, migrants introduce the additional complication associated with administering health services to transient populations—inadequate medical follow up and possible side effects. Although incomplete treatment can relieve fever, the underlying malarial infection persists as the migrant moves and potentially transmits the disease to other locations, presumably on the deforestation frontier.

(v). Deforestation has several putative climate impacts via the role of trees in the carbon cycle and regional weather patterns. Where the scale of deforestation is large, e.g. the Amazon basis, the effects on temperature and moisture and therefore on vector habitats can be quite significant [49] . By changing temperature, humidity, availability of standing water, and vegetation, open forests can enhance malarial transmission [80, 81] .

(vi). Ecosystem change such as deforestation can play a role in antimalarial resistance that has become a major concern for several plasmodium species [78] . Resistance evolves through fundamental principles of natural selection and evolution, including diverse factors such as extent of treatment, nature and site of antibiotic action, or genomic complexity of the parasite. Greater virulence results from genetic changes that occur by chance mutation, drift, or selection. While ecological change permeates the process, it is difficult to delineate the roles of specific forms of change such as deforestation.

In the process of deforestation and subsequent land transformations, improved surveillance and monitoring are necessary to detect changes in the environment, vector density, human migration and behaviour, and malaria incidence to prevent further deterioration of malaria status in the region.

PUBLIC HEALTH CONSIDERATION

Malaria is a major threat to public health and economic development in Africa. It is a disease of poverty and under-development and in sub-Saharan Africa malaria disproportionately affects the poorest of the poor populations including the forest communities which are often excluded from development processes. Reaching the poorest of the poor with malaria control interventions poses great challenges, not solely because of financial barriers to accessing care and prevention services but also because the poorest populations often live in the most remote areas and are socially or culturally marginalized [82] . Because forests, almost by definition, have lower population densities than urban areas, people living in forest and rural areas under threat of deforestation tend to be disregarded in formal health care systems including systematic malaria interventions. In most parts of the sub-Saharan Africa, these areas are often difficult to reach, and remote forested areas may have difficulty attracting doctors, nurses and health system administrators. There are ethical and practical reasons for reversing this trend.

In the global development community, concerns that public health interventions may not be reaching poor and marginalized populations have led investigators to examine the differences in the burden of disease and the coverage and impact of public health interventions among persons with differing socioeconomic status [83] . If extra efforts are not made to reach the poorest of the poor with effective malaria control interventions, it is very likely that the Roll Back Malaria (RBM) target of reducing the global malaria burden by 50% by the year 2010 will not be reached particularly in sub-Saharan Africa. Interventions, therefore, must be designed to ensure that a large percentage of the most poor are using effective treatment, insecticide-treated bed nets (ITNs), and other essential malaria control interventions [82] .

Because deforestation is a process that cannot be readily controlled for a variety of political and economic reasons, investigations and assessments of possible impacts of future deforestation will be crucial to minimize the ecological degradation caused by human activities and to prevent epidemics of malaria and other vector-borne diseases [65] . Another challenge of deforestation to malaria control is loss of plants that could provide new treatments for malaria and other diseases. It was demonstrated in Ekiti State, Nigeria how botanicals used by local populations for treating malaria are becoming rarer [84] . The problem arises because of a land tenure system that pushes the boundaries of farms into the forests. In looking at the economic burden of malaria we talked about the need to integrate malaria control and development planning. Now we can see that environmental management must also be a strong part of that picture [78] .

An additional challenge with malaria is that it has developed resistance to some antimalarial drugs. Also, newer and more effective antimalarial drugs are expensive. A 2003 survey in 28 African countries showed that only 42 percent of children with malaria were treated with antimalarial drugs. Most were treated with less effective drugs because they were less expensive. In Tanzania, the cost of malaria treatment was the largest household expenditure. Only in five countries, Botswana, Djibouti, Namibia, South Africa, and Swaziland, is malaria treatment free [85] . In 1997, the WHO, the World Bank, and other international agencies launched the Multilateral Initiative on Malaria. This program seeks to promote research and develop strategies to control the disease. Its main focus has been on Africa. In 1999, the trial use of insecticide-treated bed netting (ITNs) in Burkina Faso, Gambia, Ghana, and Kenya reduced malaria deaths of children there by 25 to 40 percent [86] . Since then, other African countries have made an effort to provide people with

ITNs. However, at the end of 2004, fewer than 5 percent of African children were sleeping under an insecticide-treated net. Many poor households cannot afford the net, which costs between $2 and $5 [87] .

Since societal response to malaria is important and essentially consists of preventive (control) and curative (treatment) approaches; a recent study noted that the efficacy of both is affected by the mediating role of ecological and behavioural factors at the individual, community, and regional levels [17] . The main form of prevention is vector control, that is, destroying mosquito habitat and mosquitoes themselves at various stages of their life cycle by clearing vegetation, modifying river boundaries, draining swamps, applying oil to open water bodies, screening houses, and spaying insecticides (e.g. DDT). Individuals can also engage in preventive behaviours by using insecticide treated bednets and minimizing exposure by controlling activities in the early morning and evening hours [17] . The report of a WHO study group on malaria vector control and personal protection in 2006 [88] , emphasized the need for the following: (i). To sensitize the general public and the local authorities about the ravages of malaria on the health of native forest populations and the need to collaborate in the preservation of their environment, while ensuring accessibility to health care and education facilities; (ii). To strengthen and diffuse mechanisms of public information about the existence of health care posts open to everybody, in order to reach population groups who may be reluctant to use public health services; (iii). To ensure that malaria workers and other health staff recognize the importance of information about new economic activities in their areas of responsibility, as well as population movements and occurrences of fever outbreaks, which should require immediate reporting and investigation; (iv). To promote and support epidemiological and entomological research into the ways of penetration, attraction factors and mechanisms of adaptation of forest vectors to human hosts and shelters, as well as the colonization of forest fringe tree plantations by forest vectors, such as An. dirus, in order to devise more effective preventive measures.

Some researchers have made a compelling argument for an integrated approach to malaria control that relies on environmental management at its core [89] . The researchers argue that although society is engaged in a wide variety of efforts to combat malaria, including new drugs, engineered malaria-resistant mosquitoes and vaccines, these efforts will take time and are not guaranteed to deliver especially in sub-Saharan Africa with its current high level of poverty. In the interim, the best option appears to lie in environmental management for vector control, including vegetation clearance, management of water bodies (e.g., modification of river boundaries, drainage of swamps, reduction of standing water, application of oil to open water bodies), and use of screens and bed nets [17] .

Since the resources required for the accelerated expansion of health facilities and services to the rural areas in sub-Saharan Africa where the malaria burden is greatest are beyond the financial capacities of most countries, it is necessary that many interventions be undertaken by the communities themselves. This is already happening. A large number (12-82%) of all malaria episodes in sub-Saharan Africa are now managed outside the official health sector [9091] . The private sector now accounts for 40-60% of all antimalarial drugs distributed, with unofficial sources, such as street sellers and market stalls, accounting for as much as 25% [92] . One of the principles of the RBM movement is that it is driven by community priorities, in particular the protection and care of women and children. Studies have shown that ITN use has a protective efficacy of 17%, saves about six lives each year for every 1000 children protected, and reduces the incidence of mild malaria episodes by 48% [93] . Community-based malaria projects have been shown to be both efficacious and feasible. A number of small-scale projects have demonstrated that community-based interventions based on training of caregivers (e.g. mothers) to provide early diagnosis and treatment has great potential [94] .

It is pertinent to state that deforestation is an integral part of the life of forest communities in rural sub-Saharan African countries, therefore any malaria control effort that ignores the role of deforestation and its associated ecological and behavioural dimensions may suffer from serious setbacks. Conservation policies aimed at slowing deforestation will impact malaria as observed in a number of previous studies [154995] . Sustainable forest management is an important element of local development policies, as donor agencies and local policy makers seek to take a more integrative view of people in the natural landscape and the resulting changes in land cover, as well as changes in how people interact with the forest, these have implications for malaria [17] .

Just as effective community participation is imperative for the success of malaria intervention, so it is in the evolution and implementation of forest conservation and management policies. The role of forestry communities in forest management is presently almost non-existent in most parts of Africa. In some states of southern Nigeria particularly Cross River and Edo States, communities are now involved in forest management following the evolution of new forestry sector strategies. In these States, Forest Management Committees from the local communities are involved in the management of plantations and natural forests in both reserve and off-reserve areas. The communities living in the immediate vicinity of the forest resources in these States have a higher motivation to assure a sustainable management if their future rights to the resources are legally secured. Likewise, these local communities can assure a cheaper and more effective control and monitoring of a sustainable management system than can be achieved by the government [96] . If implemented in sub-Saharan Africa, the strategy has the long term objective of assuring the conservation and rational utilization of the forest resources through improved protection and management and the sustainable exploitation of both timber and non-timber products. At the same time, the socio-economic benefits that the local people would derive from the forest will be increased and secured. This would minimize unsustainable and uncontrolled forest exploitation which would go a long way to reducing the increasing incidence of deforestation-dependent malaria epidemics.

References

1. Expert committee on malaria. WHO Tech Rep Ser 2000; No. 892: i-v.
2. World malaria situation in 1990. WHO Weekly Epidemiol Rec 1992; 67: 161-7.
3. World malaria situation in 1994. WHO Weekly Epidemiol Rec 1997; 72: 285-90.
4. Beier JC, Perkins PV, Onyango FK. Characterization of malaria transmission by Anopheles (Diptera: Culicadae) in western Kenya in preparation for malaria vaccine trials. J Med Entomol 1990; 27: 570-7.
5. Molineaux L, Gramicia G. The Garki Project. Geneva: World Health Organization. 1980.
6. Coluzzi M. Heterogeneities of the malaria vectorial system in tropical Africa and their significance in malaria epidemiology and control. Bull World Health Organ 1984; 62 (Suppl.), 107-113.
7. Janssens P, Wery M. Malaria in Africa south of the Sahara. Ann Trop Med Parasitol 1987; 81(5): 487-98.
8. State of the World's Forests. Food and Agriculture Organisation FAO, Rome.2003.
9. The Economic, Social and Ecological Value of Ecosystem Services: A Literature Review. Economics for the Environment Consultancy (EFTEC). 16 Percy St, London W1T 1DT. 2005; 47p.
10. A Revised Forestry Strategy for the World Bank Group. World Bank, 2001.
11. Patz JA, Graczyk TK, Gellera N, Vittor AY. Effects of environmental change on emerging parasitic diseases. Int J Parasitol 2000,30: 1395–405.
12. Martens P. Health and Climate Change: Modeling the Impacts of Global Warming and Ozone Depletion. London: Earthscan. 1998.
13. Molyneux DH. Vector-borne parasitic diseases – an overview of recent changes. Int J Parasitol 1998; 28:927-34.
14. Grillet ME. Factors associated with distribution of Anopheles aquasalis and Anopheles oswaldoi (Diptera: Culicidae) in a malarious area, northeastern Venezuela. J Med Entomol 2000; 37:231-238.
15. Walsh JF, Molyneux DH, Birley MH, Deforestation: effects on vector-borne disease. Parasitol 1993; 106 (Suppl): 55–75.
16. Kondrashin AV, Jung RK, Akiyama J. Ecological aspects of forest malaria in Southeast Asia. Sharma VP, Kondrashin AV, eds. Forest Malaria in Southeast Asia. New Delhi: World Health Organization/Medical Research Council, 1–28. 1991.
17. Pattanayak SK, Dickinson K, Corey C, Sills EO, Murray BC, Kramer R. Deforestation, Malaria, and Poverty: A Call for Transdisciplinary Research to Design Cross- Sectoral Policies Sustainability: Sci, Pract Policy 2006; 2(2): 1-12
18. The Global Malaria Burden. The Prescriber, UNICEF, Programme Division, 3 UN Plaza, New York 10017. UNICEF 2000; 16p.
19. Jones COH, Williams HA. The Social Burden Of Malaria: What Are We Measuring? Am J Trop Med Hyg 2004;71(Suppl 2): 156–61.
20. Riley EM, Hvii L, Theander TG. Malaria. In: Kierszenbaum F, editor. Parasitic Infections and the Immune System. NewYork; Academic Press 1994; p.119-143.
21. Rowe AK, Rowe SY, Snow RW, Korenromp EL, Armstrong-Schellenberg JRM, Stein C, Nahlen BL, Bryce J, Black RE, Steketee RW. The burden of malaria mortality among African children in the year 2000. International Journal of Epidemiology 2006;35:691–704
22. Brabin BJ. An analysis of malaria in pregnancy in Africa. Bull World Health Organ 1983; 61:1005-16.
23. Steketee RW, Nahlen BL, Parise ME, Menendez, C. The burden of malaria in pregnancy in malaria-endemic areas. Am J Trop Med Hyg 2001; 64:28-35.
24. Bouvier P, Breslow N, Doumbo O, Robert CF, Picquet M, Mauris A, Dolo A, Dembele HK, Delley V, Rougement A. Seasonality, malaria, and impact of pophylaxis in a West African village II. Effect on birthweight. Am J Trop Med Hyg 1997; 56:384-9.
25. Uneke CJ. Impact of placental Plasmodium falciparum malaria on pregnancy and perinatal outcome in sub-Saharan Africa: I: Introduction to Placental Malaria.. Yale J Med Biol 2007; 80(2):39-50.
26. AIDS epidemic update. World Health Organization, Geneva: UNAIDS/WHO. 2004, 203p.
27. Chandramohan D, Greenwood BM. Is there an interaction between human immunodeficiency virus and Plasmodium falciparum? Int J Epidemiol 1998; 27: 296–301.
28. French N, Gilks CF. Royal Society of Tropical Medicine and Hygiene Meeting at Manson House, London, March 18, 1999. Fresh from the field: some controversies in tropical medicine and hygiene. HIV and malaria, do they interact? Trans R Soc Trop Med Hyg 2000; 94: 233–7.
29. Rowland-Jones SL, Lohman B. Interactions between malaria and HIV infection-an emerging public health problem? Microbes Infect 2002; 4: 1265–70.
30. ter Kuile FO, Parise ME, Verhoeff FH, Udhayakumar V, Newman RD, van Eijk AM, Rogerson SJ, Steketee RW. The burden of co-infection with human immunoideficiency virus type 1 and malaria in pregnant women in sub-Saharan Africa. Am J Trop Med Hyg 2004; 71: 41-54.

31. Ticconi C, Mapfumo M, Dorrucci M, Naha N, Tarira E, Pietropolli A, Rezza G. Effect of maternal HIV and malaria infection on pregnancy and perinatal outcome in Zimbnabwe. J Acquir Imm Def Syndr 2003; 34: 289-294.
32. Greenwood BM, Greenwood AM, Snow RW, Byass P, Bennett S, Hatib-N'Jie AB.). The effects of malaria chemoprophylaxis given by traditional birth attendants on the course and outcome of pregnancy. Trans R Soc Trop Med Hyg 1989; 83:589-94.
33. Brabin B.J. The risks and severity of malaria in pregnant women: Applied field in malaria reports, no.1. TDR/FIELD-MAL/1. WHO. Geneva. 1991.
34. Ayisi JG, van Eijk AM, Newman RD, ter Kuile FO, Shi YP, Yang C, Kolczak MS, Otieno JA, Misore AO, Kager PA, Lal RB, Steketee RW, Nahlen BL. Maternal malaria infection and perinatal HIV transmission in a malarious area of western Kenya. Emerg Infect Dis 2004,10: 643–52.
35. Bloland PB, Wirima JJ, Steketee RW, Chilima B, Hightower A, Breman JG. Maternal HIV infection and infant mortality in Malawi: evidence for increased mortality due to placental malaria infection. AIDS 1995; 9: 721–26.
36. Ayisi JG, van Eijk AM, ter Kuile FO, Shi YP, Yang C, Kolczak MS, Otieno JA, Misore AO, Kager PA, Lal RB, Steketee RW, Nahlen BL. The effect of dual infection with HIV and malaria on pregnancy outcome in western Kenya. AIDS 2003; 17: 585–94.
37. Uneke CJ. Impact of placental Plasmodium falciparum malaria on pregnancy and perinatal outcome in sub-Saharan Africa. II: Effects of Placental Malaria on Perinatal Outcome; Malaria and HIV. Yale J Med Biol 2007; 80: 95-103.
38. Snow RW, Craig MH, Newton C, Steketee RW. The Public Health Burden of Plasmodium falciparum Malaria in Africa: Deriving the Numbers. Disease Control Priorities Project Working Paper No 11: Fogarty International Center, National Institutes of Health, Bethesda, Maryland, 2003.
39. Guerin PJ, Olliaro P, Nosten F, Druilhe P, Laxminarayan R, Binka F, Kilama WL, Ford N, White NJ. Malaria: current status of control, diagnosis, treatment, and a proposed agenda for research and development. Lancet Infect Dis 2002; 2(9): 564–73.
40. Sachs J, Malaney P. The economic and social burden of malaria. Nature 2002; 415: 680-5.
41. Anon. Global Forest Resources Assessment 2000 — Main Report. Rome: Food and Agriculture Organization of the United Nations. 2001.
42. Achard F, Eva HD, Stibig HJ, Mayaux P, Gallego J, Richards T, Malingreau JP. Determination of deforestation rates of the world’s humid tropical forests. Science 2002; 297: 999–1002.
43. Mayaux P, Holmgren P, Achard F, Eva H, Stibig H, Branthomme A. Tropical forest cover change in the 1990s and options for future monitoring. Phil Trans R Soc Trop Med Hyg Series B 2005; 360: 373–84.
44. Farnsworth NR. Ethnopharmacology and drug development. In: Chadwick DJ, Marsh J (eds) Ethnobotany and the search for new drugs. Ciba Foundation Symposium 185. Wiley, Chichester, 1994; p.42-51.
45. “Road map towards the implementation of the United Nations Millennium Declaration”, Report of the Secretary-General, A/56/326, (http://www.un.org/documents/ga/docs/56/a56326.pdf). United Nations General Assembly 2001.
46. Riesco IL. Forest loss and human health: focus on EU policies and practices. FERN Briefing Notes 2005. Available at: www.fern.org. Assessed June 15, 2008.
47. Colfer CJP, Sheil D, Kaimowitz D, Kishi M. Forests and human health in the tropics: some important connections. Unasylva 2006; 224 (57): 3-10.
48. Patz JA, Daszak P, Tabor GM, Aguirre AA, Pearl M, Epstein J, Wolfe ND, Kilpatrick AM, Foufopoulos J, Molyneux D, Bradley DJ, Working Group on Land Use Change and Disease Emergence. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. Environ Health Perspect 2004; 112: 1092–98.
49. Taylor D. Seeing the forests for more than the trees. Environ Health Perspect 1997; 105:1186–91.
50. Guerra CA, Snow RW, Hay SI. A global assessment of closed forests, deforestation and malaria risk. Ann Trop Med Parasitol 2006; 100(3): 189–204
51. Butler RA. Nigeria has worst deforestation rate, FAO revises figures. mongabay.com. 2005. Available at: http://news.mongabay.com/2005/1117-forests.html. Assessed June 15, 2008.
52. World Energy Assessment Overview: 2004 Update. United Nations Development Programme.Available at: http://www.energyandenvironment.undp.org/indexAction.cfm?module=Library&action=GetFile&DocumentAttachmentID=1010. Assessed June 15, 2008.
53. Côte d’Ivoire: Environmental Issues. Microsoft Encarta Online Encyclopedia 2006, s.v
54. World Bank Group: International Development Association. United States Treasury 2006. Available at: http://www.ustreas.gov/offices/international-affairs/intl/fy2006/ida.pdf. Assessed June 15, 2008.
55. Hughes A, Verra F. Very long-term population size in the virulent human malaria parasite, Plasmodium falciparum. Proc R Soc B 2001; 268(1478): 1855-60.
56. Volkman SK, Barry AE, Lyons EJ, Nielsen KM, Thomas SM, Choi M, Thakore SS, Day KP, Wirth DF, Hartl DL. Recent Origin of Plasmodium falciparum from a single progenitor. Science 2001; 293(5529): 422-4.
57. Mu J, Duan J, Makova KD, Joy D, Huynh CQ, Branch OH, Li W, Su X. Chromosome-wide SNPs reveal an ancient origin for Plasmodium falciparum." Nature 2002; 418(6895): 323-6.
58. Cliff A, Haggett P, Smallman-Raynor M. Deciphering global epidemics: analytical approaches to the disease records of world cities, 1888-1912. Cambridge, Cambridge University Press. 1998.
59. Afrane YA, Lawson BW, Githeko AK, Yan G. Effects of microclimatic changes caused by land use and land cover on duration of gonotrophic cycles of Anopheles gambiae (Diptera: Culicidae) in western Kenya highlands. J Med Entomol 2005; 42(6): 974–80.
60. de Castro MC, Monte-Mor RL, Sawyer DO, Singer BH. Malaria risk on the Amazon frontier. Proc Nat Acad Sci US A, 2006; 103(7): 2452–7.
61. Jongwutiwes S, Putaporntip C, Iwasaki T, Sata T, Kanbara H. Naturally acquired Plasmodium knowlesi malaria in human, Thailand. Emerg Infect Dis 2004; 10(12): 2211–3.
62. Singh B, Kim Sung L, Matusop A, Radhakrishnan A, Shamsul SS, Cox-Singh J, Thomas A, Conway D.J. A large focus of naturally acquired Plasmodium knowlesi infections in human beings. Lancet 2004; 363(9414): 1017–24.
63. Reiter P. Climate change and mosquito-borne disease. Environ Health Perspect 2001; 109(S1):141-161.
64. Chivian E. Biodiversity: Its Importance to Human Health, Interim Executive Summary. Boston, MA: Harvard Medical School. 2002.
65. Yasuoka J, Levins R. Impact of deforestation and agricultural development anopheline ecology and malaria epidemiology. Am J Trop Med Hyg 2007; 76(3):450–60
66. Afrane YA, Zhou G, Lawson BW, Githeko AK, Yan G.

Effects of microclimatic changes caused by deforestation on the survivorship and reproductive fitness of Anopheles gambiae in western Kenya highlands. Am J Trop Med Hyg 2006; 74: 772–8.
67. Munga S, Minakawa N, Zhou G, Mushinzimana E, Barrack OOJ, Githeko AK, Yan G. Association between land cover and habitat productivity of malaria vectors in western Kenyan highlands. Am J Trop Med Hyg 2006; 74: 69–75.
68. Manga L, Toto JC, Carnevale P. Malaria Vectors and transmission in an area deforested for a new International Airport in Southern Cameroon. Ann Soc Belge Med Trop 1995; 75: 43-49.
69. Smith N JH. Colonization lessons from a tropical forest. Science 1981; 214: 755–61.
70. Deane LM. Malaria vectors in Brazil. Mem Instit Oswald Cruz 1986; 81 (Suppl. 2): 5–14.
71. Forattini OP, Kakitani I, Massad E, Marucci D. Studies on mosquitoes (Diptera: Culicidae) and anthropic environment. 2. Immature stages research at a rice irrigation system location in south–eastern Brazil. Revista de Sau´de Pu´ blica 1993; 27, 227–36.
72. Forattini O P, Kakitani I, Massad E, Marucci D. Studies on mosquitoes (Diptera: Culicidae) and anthropic environment. 3. Survey of adult stages at the rice irrigation system and the emergence of Anopheles albitarsis in south–eastern, Brazil. Revista de Sau´de Pu´ blica 1993; 27, 313–25.
73. Briet OJ, Dossou Yovo J, Akodo E, van de Giesen N, Teuscher T M. The relationship between Anopheles gambiae density and rice cultivation in the savannah zone and forest zone of Coˆte d'Ivoire. Trop Med Int Health 2003; 8: 439–448.
74. Mouchet J, Brengues J. Les interfaces agriculture–sante´ dans les domaines de l'e´pidemiologie des maladies a` vecteurs et de la lutte antivectorielle. Bulletin de la Socie´te´ de Pathologie E´ xotique 1990; 83: 376–393.
75. Anon. Ecosystems and Human Well-being: Synthesis. Washington, DC: World Resources Institute. 2005.
76. Pattanayak S, Butry D. Forest Ecosystem Services as Production Inputs. In: E Sills and K. Abt editors. Forests in a Market Economy, Forestry Sciences Series, Volume 72, Dordrecht: Kluwer Academic Publishers. 2003; p 361-79.
77. Petney TN. Environmental, cultural, and social changes and their influence on parasite infections. Int J Parasitol 2001; 31: 919-32.
78. Wilson ML.. Ecology and Infectious Disease. In: J Aron, and JA Patz editors. Ecosystem Change and Public Health. Baltimore, MD. The Johns Hopkins University Press 2001; 285-291.
79. Castilla R, Sawyer D. Malaria rates and fate: a socio-economic study of malaria and Brazil. Soc Sci Med 1993; 37(9): 1137-45.
80. Bouma MJ, van der Kaay HJ. Epidemic malaria in India and the El Niño Southern
81. Lancet 1994; 344: 1638-9.
82. Martens WJM, Rotman J, Niessen LW. Potential impact of global climate change on malaria risk. Environl Health Perspect 1995; 103: 458-64.
83. Barat LM, Palmer N, Basu S, Worrall E, Hanson K, Mills A. Do malaria control interventions reach the poor? a view through the equity lens. Am J Trop Med Hyg 2004; 71(Suppl 2):174–8.
84. Castro-Leal F, Dayton J, Demery L, Mehra K. Public social spending in Africa: do the poor benefit? World Bank Res Observer 1999; 14: 49–72.
85. Kayode J. Conservation of indigenous medicinal botanicals in Ekiti State, Nigeria. J Zhejiang Univ SCIENCE B 2006; 7(9):713-8.
86. Africa Malaria Report 2003. Roll Back Malaria. Available at: http://www.rbm.who.int/amd2003/amr2003/ch3.htm Assessed June 15, 2008.
87. Wakin D. Simple Nets Used to Fight One of Africa's Worst Killers. The Associated Press, May 24, 1999.
88. Malaria: Frequently Used Figures for Malaria. UNICEF, Press Centre. Available at:
89. unicef.org/media/media_36234.html Assessed June 15, 2008.
90. Malaria vector control and personal protection: report of a WHO study group. WHO technical report series; WHO 2006; no. 936. 62p
91. Utzinger J, Tozan Y, Singer B. Efficacy and cost-effectiveness of environmental management for malaria control. Working paper, Princeton, NJ. 2001.
92. McCombie SC. Treatment seeking for malaria: a review of recent research. Soc Sci Med 1996; 43:933-45.
93. Report of Nutrition Network/Household and Community IMCI Meeting, UNICEF, Morogoro, Tanzania. Nairobi, United Nations Children's Fund/Eastern and Southern Africa Regional Office, 1998.
94. Foster SD. Pricing, distribution, and use of antimalarial drugs. Bull World Health Organ 1991; 69:349-63.
95. Lengeler C. Insecticide-treated bed nets and curtains for malaria control (Cochrane review). In:The Cochrane Library, 1998;3. Oxford, Update software.
96. Pagnoni F, Convelbo N, Tiendrebeogo J, Cousens S, Esposito F. A community-based programme to provide prompt and adequate treatment of presumptive malaria in children. Trans R Soc Trop Med Hyg 1997, 91:512-7.
97. Ault SK. Environmental management: a re-emerging vector control strategy. Am J Trop Med Hyg 1994; 50(Suppl): 35-49.
98. Osemeobo GJ. Forest Recreational Land use and zoological gardens in a Developing Economy. The case of Southern Nigeria. Environ Conserv 1989; 16(i): 69-74.

Author Information

CJ Uneke
Department of Medical Microbiology/Parasitology Faculty of Clinical Medicine Ebonyi State University PMB 053 Abakaliki Nigeria