Development

More crops, more disease?
Melba Gomes

The intensity of disease transmission by insect vectors may be influenced by developments in agriculture and forestry. The author illustrates what can happen with special reference to projects in Thailand and Ethiopia which increased the incidence of malaria, and to the introduction of a new variety of coffee in Colombia, as a result of which the incidence of leishmaniasis among plantation workers decreased. Development programmes need to take predictable disease outcomes fully into account.

Many tropical diseases are transmitted to humans by vectors such as mosquitos, sandflies and snails. The epidemic potential of these diseases is invariably associated with the degree of contact between host, vector and pathogen. Epidemics may arise when social and environmental conditions allow pathogens to gain access to new host populations or to become more virulent in immunocompromised hosts. Of course, the same conditions may change in such a way as to reduce the habitats of vectors, whose contact with humans consequently diminishes.

Malaria

In the case of malaria the vectors are anopheline mosquitos. Changed conditions may permit a great increase in their populations and in the numbers of people to whom they can transmit the disease. It may be very misleading to explain epidemics and increased transmission of malaria solely in terms of pathogen virulence because this ignores the role of economic and social factors.

Three species of anopheline mosquito are responsible for most of the transmission of Plasmodium falciparum malaria. The potential for malaria transmission is influenced by changes in the habitats of Anopheles dirus in South-East Asia, A. gambiae in Africa and A. darlingi in Latin America. These species are important because their behaviour and reproductive patterns allow small numbers to survive as efficient transmitters of the disease. Moreover, their adaptability to variations in conditions, including altitude, temperature, humidity, rainfall, shade, tree cover and soil composition, heightens their ability to survive.

Dr Gomes is with the Special Programme for Research and Training in Tropical Diseases, World Health Organization, 1211 Geneva 27, Switzerland.
There is a major threat of new epidemics of malaria as a result of changes in land use associated with development activities. Agricultural and water projects have important economic benefits but can also generate adverse health outcomes, which could be diminished or even avoided with the help of advance information, improved screening and good project design.

**Tree plantations in Thailand**

In Thailand there is a very high level of resistance to antimalarial drugs, a succession of which has been introduced since 1973. Although there is no known resistance to artesunate, which was introduced in 1994, there is a risk that increases in the incidence of malaria will lead to resistance to the artemisinin derivatives. The level of malaria transmission in South-East Asia is a matter of global significance, since any increase there means more drug-resistant malaria without a future cure.

Why should there be increases in malaria in South-East Asia? Is malaria reappearing in areas where it was supposedly eliminated and is it spreading to new areas? The answers to these questions depend in part on detailed knowledge of the vector.

*Anopheles dirus* is a highly efficient vector, and malaria has been most stable and dangerous in South-East Asia when people have entered or closely approached the tropical forests that are its natural habitat. It has a relatively long life, and prefers to deposit its eggs in shaded places. Its population density decreases with the amount of tree canopy, and it does not live where there is no shade from trees.

The incidence of malaria in Thailand is greatest in the provinces adjacent to Myanmar and Cambodia, where the forest cover exceeds 35%. Trees are being replanted for watershed protection and commercial revenue. Significant reductions in the incidence of malaria have been achieved by closing the border with Cambodia and thereby reducing movements of people between the two countries. Nevertheless, there is a significant risk of infection, and the question arises as to whether the planting of trees in formerly forested areas has been responsible for the reintroduction of the disease. The following approaches were adopted in order to throw some light on this matter.

- Changes in land use during the past 10 years were analysed.
- Assessments were made of changes in land use which might have produced habitats suitable for *A. dirus*.
- An investigation was made of the transmission potential and the incidence of malaria in new commercial plantations.

The work involved the use of satellite and land-use maps, the classification of land use, and the attribution of malaria incidence according to land-use category.

*It may be very misleading to explain epidemics and increased transmission of malaria solely in terms of pathogen virulence because this ignores the role of economic and social factors.*

Image-processing software was employed to establish vegetation categories, and these were subsequently confirmed by observation on the ground. The total area for each land-use type was calculated.

Data on the incidence of malaria in 1985, 1989 and 1994 were obtained and
P. falciparum cases were depicted on maps, together with their presumed origins, i.e., within or outside the study area or across the border. The highest incidence was in Kanchanaburi Province, bordering on Myanmar, and there was also a significant incidence adjacent to the border with Cambodia. Possible errors attributable to presumptive classification of case origin, inherent in the data for 1986–1994, were eliminated for 1995 through interviews with patients at selected malaria clinics. For every person attending with confirmed malaria during one calendar year starting in 1996 an effort was made to establish where the infection had been contracted by asking about movements during the preceding two weeks, and where the patient lived. This information allowed an assessment of the percentages of malaria cases likely to have been contracted from different ecotypes.

Between 1986 and 1995 the proportion of the land area covered by forest in Chantaburi Province on the Cambodian border fell from 37% to 23.5%, and that in Kanchanaburi Province on the Myanmar border fell from 59.6% to 23.5%. Some of the land made available by these reductions was used for commercial tree crops; thus the area under rubber plantations and orchards increased from 18.5% to 25.2% in Chantaburi Province during the same period.

Evidence was found that A. dirus was biting people in substantial numbers in new tree plantations, which, to judge from the numbers of larvae collected, offered suitable breeding habitats for the vector. Natural forest was evidently not essential for this mosquito. Indeed, it was far more efficient in transmitting malaria in new plantations than in its original habitat. Thus malaria, which was endemic in natural forest and disappeared when clearing took place, reappeared in plantations offering suitable habitats and hosts for mosquitoes. Malaria became an occupational hazard again, and there was a prospect of migrant workers in the plantations carrying the parasite to their homes throughout the country.

There appear to be differences between plantations in the potential for malaria transmission, possibly because of varying ecological conditions. It is not known why the ecosystems created by certain monocultural plantations increase transmission. The soil, water, fertilizer, pesticide and spacing requirements vary with the species of tree and the scale of production. Greater complexities arise when different tree species are grown together for economic or ecological reasons and when people from areas where malaria is not endemic arrive to work either permanently or temporarily. As labour requirements for planting, maintenance and harvesting vary, so does the degree of contact between humans and vectors. These factors determine transmission potential, which may become high if immunocompromised hosts are brought into areas with high vector potential.

The data obtained on the adaptability of A. dirus to the new habitats demonstrate the possibility of increased malaria transmission and confirm suspicions about recent epidemics in rubber plantations. Perhaps more importantly, the observations that have been made make it possible to predict epidemics in areas where large tracts of virgin forest are being logged and replaced by plantations.

Rubber planting is increasing in Cambodia, Myanmar, Thailand and Viet Nam. In Myanmar large tracts of natural forest are
being cut and replaced with rubber plantations, in which new settlements are being established. In Viet Nam, people from the north were relocated in the south to provide a permanent labour force in very large plantations. Thirteen years after the stands were created the country recorded its highest death rates from malaria, a significant proportion of them in rubber plantations, where the trees had reached the age at which they provide highly favourable breeding conditions for *A. dirus*. Non-immune persons were exposed to very high levels of transmission and all age groups were at risk of illness and death. Clearly, preventive measures might have been taken had it been possible to predict this situation.

In Myanmar and Thailand, people are contracted by the day to work in plantations. If they fall ill they receive no pay and have to bear all the costs associated with treatment. In Viet Nam the rubber plantations have permanent work forces that live nearby with their families, and both adults and children are at risk. Because the enterprises are adversely affected when time is lost through ill-health, however, preventive measures are maintained and all necessary care is provided for the workers and their families.

The microdams, together with appropriate irrigation and agronomic services, are expected to produce favourable microclimatic and environmental changes and to increase agricultural productivity. It is estimated that irrigation would permit the production of 4.5 tonnes more wheat and 16 tonnes more potatoes per hectare every year, equivalent to feeding 930,000 people who would otherwise depend on food aid.

This scheme is going ahead in an area where malaria is endemic. The disease is seasonal, being associated with the annual rains. The microdams are potentially important breeding sites for the mosquitoes that act as vectors, while the shade provided by afforestation could prolong their survival. Consequently, there could be an increase in the incidence of malaria and indeed a change from seasonal to uninterrupted transmission. In other words, the risk of an individual acquiring a single malaria infection per year could be replaced by a risk of infection every night, with the possibility of six or more episodes of the disease annually. The more intense transmission would increase the probability of death, partly because of the associated risk of anaemia. In the agricultural sector an outcome might be that death and illness among non-immune adults would reduce productivity. Malaria incidence could be particularly high among migrant workers. In addition, poor operation of the drainage system could

---

**Microdams and afforestation in Ethiopia**

In 1994 a rural development programme was initiated in Ethiopia’s Tigre Province with the aim of attaining self-sufficiency in food production and creating suitable conditions for afforestation. The plan included building over 500 microdams and terracing 200,000 hectares of land. Sixty-five microdams have so far been constructed.

---

The observations that have been made make it possible to predict malaria epidemics in areas where large tracts of virgin forest are being logged and replaced by plantations.
result in increased soil salinity and the abandonment of the irrigated land.

The incidence of malaria was monitored in a population of 7400 children aged under 10 years by means of four paired quarterly blood surveys in which the interval between paired observations was 30 days. A history of fever and current temperature was taken at the same time, and fever cases occurring between the paired observations were examined for malaria so that the incidence of symptomatic infection could be determined. The incidence of malaria in villages near dams and afforestation projects was 3.18%, whereas it was only 0.54% in villages away from these sites.

In much of Africa the epidemiology of malaria is determined by climate and altitude. In the Sahel region and the dry areas of East Africa, malaria transmission peaks during the short period of the annual rains, and the storage of water for irrigation during the dry season can result in high densities of anopheline mosquitoes and intense malaria transmission. Irrigation schemes supplying water during the dry season have the potential for increasing the incidence of malaria by providing suitable breeding sites for the mosquitoes as well as by exposing to risk a different and possibly larger population employed in agricultural production.

Transmission potential, however, is linked to ambient temperature and humidity. In the Gambia it was found that although vector densities increased with the availability of irrigation water during the dry season, the incidence of malaria did not rise correspondingly, possibly because of reduced longevity of *A. gambiae* or because high temperatures stopped parasite development. The daily survival rate of mosquitoes has a major influence on inoculation rates, and may be low in the dry season because of exposure to temperatures exceeding 35°C for several hours each day and to low humidity.

In Ethiopia, mosquito survival evidently increases where the relative humidity in small areas rises because of afforestation accompanying microdam development. Trees provide shade, increase water retention in the soil, and inhibit evapotranspiration and rises in temperature. The lower temperatures are more conducive to mosquito survival and therefore to transmission potential.

**Leishmaniasis**

In Colombia, coffee has been traditionally grown under trees that serve as resting sites for sandflies, among which are vectors of *Leishmania*. It has not been possible to control these insects with chemicals, and consequently the growers and their families, and the migrant workers who harvest the crop by hand, are exposed to infection with cutaneous leishmaniasis.

However, the introduction of the Colombia variety of coffee in place of the traditional Arabica Bourbon variety has been associated with a lowered incidence of leishmaniasis. The new variety of bush is resistant to rust fungus, is much shorter than the traditional one, and can be grown
at higher densities. Many growers have increased productivity by growing the new variety in dense stands and in full sunlight, and it is thought that this has led to reduced vector densities and consequently to a diminished incidence of the disease.

Almost eight times as many sandflies have been found in traditional coffee plantations as in the new ones. In 1997, 33.5% of workers in traditional plantations were Montenegro-positive, whereas only 11.4% in new plantations gave this result. However, since many of these people have worked in both kinds of plantation the clinical significance of these differences in transmission potential will emerge when the incidences of new clinical infections can be determined.

**Weighing up the costs and benefits**

Agricultural or water development projects promising important economic benefits may also generate adverse health outcomes, and these can be minimized through adequate screening and good design. An epidemic is the most feared and costly expression of disease for the following reasons:

- The unexpected nature of the problem means that people die because the cause must be known before resources can be allocated. The response is constrained because the normal levels of staff and supplies are insufficient.

- An epidemic places people in all age groups at increased risk of morbidity and mortality. The heightened intensity of infection is accompanied by heightened risk, even persons with a degree of acquired immunity being placed at risk of death.

- The cost to the health system is extremely high, because unforeseen rapid resource use is more costly than planned use.

A health system is particularly vulnerable when epidemics or changes in disease transmission have causes beyond its jurisdiction. The health system meets the costs but has no ability to control the causes. In the case of vector-borne diseases such as malaria and leishmaniasis the proliferation and survival of the vectors are strongly influenced by changes in temperature and humidity. Where ecological or environmental changes give vectors and parasites a demographic advantage, and where this is accentuated through the availability of human blood meals at regular intervals, epidemics can result. As a rule the benefits of investment are obtained by the agricultural sector while the health costs incurred are borne by the health sector, which has little or no ability to mitigate the cause. This disequilibrium will continue until agricultural planning and financing take health risks fully into account.

In the Thai plantations the costs of malaria are borne by the workers. Because the plantation enterprises do not bear the costs and lose little as a result of workers becoming ill, they have no incentive to diminish the incidence of the disease. In the Ethiopian example, investment yields both a benefit and a cost: food yields are raised but there is an increased incidence of malaria, possibly sufficient to cause people to abandon the land. In Colombia, the introduction of the new coffee variety can bring both increased yields and a reduced incidence of leishmaniasis.

When investment in a development programme is being considered, a thorough
appraisal should be made of the likely benefits and costs so that the internal rate of return can be calculated. If health impacts are predicted they should be quantified and costed so that their effect on economic viability can be assessed. This is a complex process, especially where a project affects mortality as well as morbidity, and where, therefore, a value has to be placed on human life.

The kind of information discussed in this article is particularly valuable for project design and appraisal for two main reasons. Firstly, the data can be extrapolated to the regions concerned because of the regional distribution of the vectors. Secondly, the data make it possible to attach economic values to the health risks.

In appraising a project it is necessary to obtain data on impacts that can be attributed to it alone. This may be difficult, particularly if baseline data have not been collected. It is necessary to ask whether the economic benefits of a project are likely to be nullified by adverse effects. If they are not, the scale of any required mitigation programme has to be assessed. The prediction of health benefits and costs is essential.

Acknowledgements
The projects in Thailand and Colombia were funded by the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR). The work in Tigre was developed by TDR and largely funded by the Swedish International Development Authority.

A better start
It is estimated that 9 million children have been born within the area of the Onchocerciasis Control Programme in West Africa since operations began; none of them has ever run the risk of contracting onchocercal blindness, and will never do so within the OCP area. By the year 2000, or even before, the number of children thus protected will have grown to 15 million.