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Vector-borne diseases, development and climate change: An editorial comment

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The distribution of vector-borne diseases is limited by the climatic tolerance of their vectors and by biological restrictions that limit the survival and incubation of the infective agent in the vector population. Therefore, climatic changes can play a major role in determining the distribution and abundance of insects, either directly or indirectly through its effects on host plants and animals. It is anticipated that climate change will have a significant effect on the geographical range of many vector species. In addition, certain human activities that help to prevent the spread of pathogens and reduce vector populations restrict the distribution of many diseases in countries that can afford those activities.

Several types of models have been developed to forecast the impact of climate change on vector-borne disease transmission, most models focusing on malaria. Some mosquito species have been successfully mapped in Africa using meteorological data. For example, Rogers has mapped the projected changes of three important disease vectors (ticks, tsetse flies and mosquitoes) in Southern Africa under three climate change scenarios [1]. The results indicate significant changes in areas suitable for each vector species, with a net increase for malaria mosquitoes (*Anopheles gambiae*).

Martin and Lefebvre [2] developed a Malaria-Potential-Occurrence-Zone (MOZ) model. This model was combined with 5 GCMs (General Circulation Models) to estimate the changes in malaria risk based on moisture and minimum and maximum temperatures required for parasite development. An important conclusion of this modelling exercise was that all simulation runs showed an increase in seasonal (unstable) malaria transmission, under climate change, at the expense of perennial (stable) transmission.

Rogers and Randolph [3], using a multivariate empirical-statistical model, estimated that, for the IS92a (business as usual) climate change scenario, there would be no significant net change by 2050 in the estimated portion of world population living in malaria-transmission zones: malaria increased in some areas and decreased in others.

An integrated, process-based model to estimate climate change impacts on malaria (that is part of MIASMA (Modelling framework for the health Impacts ASsessment of Man-induced Atmospheric changes) [4]) has been developed by Martens and colleagues [5,6]. This model differs from the others in that it takes a broad approach in linking GCM-based climate change scenarios with a module that uses the formula for the basic reproduction rate (R_0) to calculate the 'transmission or epidemic potential' of a malaria mosquito population. The results of this model show a projected increase of the population at risk of potential malaria transmission due to climatic changes.

All of the examples discussed above have their specific disadvantages and advantages. For example, the model developed by Rogers and Randolph [3] incorporates information about the current social, economic, technological modulation of malaria transmission. It assumes that those contextual factors will apply in future in unchanged fashion. This adds an important, though speculative, element of multivariate realism to the modelling – but the model thereby addresses a qualitatively different question from the biological model. The biological model of Martens and colleagues assumes that there are known and generalisable biologically-mediated relationships. Also, this biological modelling, in its early stages, did not include the horizontal integration of social, economic and technical change.

In general, the incorporation of socio-economic factors in modelling the future impact of climate change on human health has so far been limited. One recent attempt has been made by Tol and Dowlatabadi (see this issue). They integrate the results of MIASMA within the FUND (Climate Framework for Uncertainty, Negotiation and Distribution) framework (developed by Tol) to estimate the trade-off between climate change and economic growth on malaria risk. In this study, a (linear) regression analysis between per capita income and malaria incidence (data on a regional basis, excluding China and Africa) indicated a cut-off limit of $3100 above which a population is not vulnerable to malaria transmission.

Although this exercise indicates the importance of including the economic dimension in analysing climate change impacts upon future malaria risk, their approach may be too simplistic. Characterising the relationship between socio-economic development and malaria incidence is difficult for various reasons: First and foremost, malaria incidence is hugely influenced by geography and prevailing climate. Hence, since the world's poorest countries tend to be in high-risk tropical and subtropical regions, it is inevitable that na-

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tional rates of malaria incidence correlate with per capita income. Apportioning malaria causality between environment, income, and social practices is, therefore, problematic. Other related reasons include: (i) The income per capita at a country or regional level is an inadequate description of how that wealth is distributed within a society and to what public uses it is applied (e.g., Costa Rica and Cuba, with lower per capita income, outperform Brazil in social and health indices); (ii) Political instability can undermine the influence of development (i.e., Russia, Azerbaijan); (iii) Economic development can increase transmission temporarily (e.g., deforestation, population movement, water development projects); (iv) Many control programs depend on external/donor funding (e.g., Viet Nam) from richer developed countries.

Furthermore, the quality of malaria data is very poor in most developing countries. National indicators of malaria include national mortality or morbidity data. Mortality data generally reflect falciparum transmission as *P. vivax* is rarely fatal. Further, in areas with very high levels of transmission where nearly everyone is infected, with or without immunity, the morbidity figures are meaningless. Estimates can vary considerably from year to year because of changes in reporting rather than a true change in disease transmission. For these reasons therefore, a straightforward relationship between national income per capita and malaria status is not very likely.

Gallup and Sachs [7] explored the correlation between the malaria index and income levels. They took into account some of the factors that also affect malaria risk (e.g., low agricultural productivity, presence of other tropical diseases, colonial history and geographical isolation). The malaria index is defined as the fraction of the population living in areas of high malaria risk in 1994 times the fraction of malaria cases in 1990 that are of the malignant *P. falciparum* species. The malaria index showed a strong negative association with income levels indicating that income grows more slowly in countries where the disease is present. This trend appears to apply equally to countries in Africa and in other continents. In countries that include large malaria-free regions (e.g., Brazil, Venezuela, Malaysia, Indonesia, Turkey, Kenya and Ethiopia), the prevalence of infection correlates with poverty. Malaria, of course, is not the sole determinant of poverty, just as poverty alone does not explain the distribution of malaria.

So it appears that the relationship between poverty and malaria is two-way: poverty is an effect of malaria as well as a cause. Little research has been carried out on the determinants of vulnerability of populations to malaria, so it is difficult to develop assumptions about future adaptation to changes in disease risk associated with climate change and economic development. Populations can respond to changes in local malaria transmission associated with climate change. With planning and development of adaptation capacity, potential increases in disease incidence associated with climate change may be largely prevented. However, the effectiveness of adaptation responses will vary depending on the circumstances of the population at risk.

In tropical countries, successful prevention and control in the future would probably involve *technical, political* and *socio-economic adaptation*. Technical adaptation includes, for example, the use of insecticides. Political adaptation involves adequate administration of control programs, funding of research and training, investments in health infrastructure, etc. It should be noted here that, after the initial success of global eradication programs of the 1950s and 1960s, resources available from international agencies have declined along with those of national governments. The disease is now resurgent in many countries where it previously had been controlled. However, the relation between the level of malaria incidence and political willingness to adapt policy is unknown. In the meantime, it is not clear to what extent economic growth on its own will reduce the incidence of malaria.

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