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GIS Based Health Vulnerabilities Reduction VIA Increasing Resilience against Vector-borne Disease Risks under Climate Change Conditions in India

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Abstract

Geographical information system (GIS) play extremely important role in monitoring, planning and management of environmental health and public health care delivery system. Reducing health vulnerabilities and increasing resilience against vector-borne disease risks under climate change conditions in India is challenging task for next decade. Climate change is adding new pressures throughout the country on populations already suffering from poverty, food insecurity, ecological and social vulnerabilities.

Keywords: GIS, vulnerability, vector-borne disease, risks, climate change.

1. Introduction

Visceral leishmaniasis, which is also called kala-azar, is transmitted by a sand fly and affects the poorest of the poor in India, Bangladesh and Nepal – 186 million people are at risk. Lack of treatment causes 30% of those infected to die. Priorities that were agreed include work to better understand the behavior of the sand flies, to develop alternative, environmental tools to control the insects, to critically analyse an improved monitoring system for the performance of the programmes in case detection, case management and vector control, to get a better understanding of how the disease is spread through cases that present no symptoms and through PKDL (post kala-azar dermal leishmaniasis).

Ecosystem management is helpful to prevent dengue and Chagas disease. Dengue fever is one of the most rapidly growing epidemics in the world. The proximity of vector breeding sites to households and household water containers is a major factor in the transmission of both dengue fever and Chagas disease. A range of other ecological, biological and social factors also tend to promote disease transmission or inhibit efforts at vector control are natural factors include climate (rainfall, humidity, temperature etc), development of urban settlements and agriculture also have a profound impact, biological factors relate to the behaviour of the dengue vector, Aedes aegypti, and the transmission dynamics of the disease, and social factors include vector control and health services, water and sanitation services, and community and household based practices (such as those related to garbage disposal and sanitation).

Climate scientists say a rise of up to two degrees Celsius more than pre-industrial global temperatures could be manageable, with people only in specific, vulnerable regions suffering catastrophic environmental effects. Any larger temperature increase puts the whole planet's population at risk. The Intergovernmental Panel on Climate Change predicts that if emissions continue to rise unchecked — they are already 38 per cent higher than in 1990 — the world could warm by as much as four degrees Celsius by 2100 [1]. The rise in greenhouse gasemissions over the past few decades has already warmed the planet by 0.8 degrees Celsius. The lag between growing emissions and the corresponding increase in temperature means that we can expect at least another 0.6-degree Celsius global temperature rise over the next few decades. Global warming predictions are based on different emission scenarios [2].

2. Harmful Health Effects

The Global Humanitarian Forum (GHF) published a report estimating that 315,000 people die due to climate change every year, and they predict this will rise to half a million by the year 2030 [3]. While such estimates of direct deaths remain low relative to the size of the global population, about 310 million people are expected to have suffered ill health because of climate change by 2030. Nine out of ten of these people will be in developing countries and the number of healthy years of life lost to environmental change, including climate change, is set to be 500 times higher in Africa than Europe. Effects of climate change are estimated on health through number of Disability Adjusted Life Years (DALYs) — the sum of years of potential life lost due to premature death, and the years of productive life lost due to disability, associated with climate change [4].

Developing countries already bear the brunt of the global disease burden. Their populations are more likely to be undernourished, lack access to clean water and contract infectious diseases such as malaria. They are also dealing with a growing epidemic of chronic diseases such as diabetes and cancer. Climate could worsen the problems in many ways. Changing rainfall patterns and sea level rises mean some areas will become drought-prone while others are flooded. Both situations have dire consequences for access to clean water. This, in turn, means a likely spread of waterborne diseases such as cholera and diarrhoea, which alone kills nearly two million children a year. Increasing hunger and malnutrition are expected as increasingly common extreme weather events destroy crops, patterns of crop pest infestation change, and salt infiltrates flooded coastal areas [5]. Both temperature and humidity influence how air pollutants and fine particulates form, and evidence suggests that fine particulates contribute to respiratory disease (such as pneumonia, asthma and chronic obstructive pulmonary disease), especially in children [1].

The WHO estimates that 800,000 people already die each year because of outdoor air pollution. For virulent vectors, one area of particular concern is how climate change will affect the spread of insect-borne diseases. These include dengue fever, malaria, Lyme disease, West Nile virus, Rift Valley fever, chikungunya and yellow fever. They are spread through the bite of 'vectors' such as mosquitoes, ticks and flies. Researchers currently focus much of their attention on dengue fever and malaria, partly because the diseases are so prevalent but also because outbreaks seem linked to climate. Increased rainfall in normally dry areas, for example, can create stagnant pools of water where mosquitoes breed. But the links between climate and insect-borne disease are far from simple. The same rainfall increase in wet regions could reduce malaria by washing immature mosquitoes away.

Changes in temperature can also have opposing effects, depending on where they occur. Generally speaking, the malaria mosquito digests blood quicker and feeds more often in warmer weather, thus speeding up transmission. The parasite meanwhile completes its life cycle more quickly, increasing replication. In theory then, global warming might allow these vectors to spread into areas they weren't previously able to colonize. By 2080, up to 320 million more people could be affected by malaria because of these new transmission zones [6]. Worryingly, the disease would then also be spreading to people whose immune systems may never have been exposed to malaria, and who may be more vulnerable as a result. But increased temperatures in already hot regions could reduce the spread of malaria mosquitoes by pushing temperatures higher than the mosquitoes can survive. Most mosquitoes cannot survive above about 40 degrees Celsius, so regions where climate change pushes temperatures above this level could see a drop in malaria. This is starting to be seen in Senegal, for example, where malaria prevalence has dropped by more than 60 per cent in the past 30 years [7]. And an increase in the population of vectors does not automatically translate into an increase in disease. The dynamics of malaria transmission, for example, depend on both the human population's immunity and the parasite's levels of drug resistance.

Other ecological and societal factors are equally important: water storage and disposal systems, agricultural practices, deforestation, population density, living conditions, control programmes and health infrastructure all play a role in determining the reach and spread of malaria. The complexities of dengue transmission also lead studies to report conflicting associations between climate variations and infection rates. The clearest links come from small countries such as Honduras and Nicaragua, where the number and spread of the dengue mosquito population has been well correlated with climate [8]. Links in larger countries like Brazil and China have not been significant — although this may be because climate data was country-wide rather than location-specific. Nevertheless, some scientists estimate that by 2080, six billion people will be at risk of dengue, compared with 3.5 if the climate does not change. If the global population grows to about 10 or 11 billion by then, as some estimates suggest, over half the planet could be at risk. The spread of other vector-borne diseases could also increase. The cholera bacteria *Vibrio cholerae* can live on some species of plankton.

3. Strategic Policies Using GIS

Using GIS system, developing accurate models and surveillance to predict or detect disease outbreaks and act as early warning systems is central to this. Such systems will require both climate and disease data, and lots of it, if they are to be rigorous enough to be reliable (see Better surveillance key to malaria early warning systems). In the past, the paucity of surveillance systems has meant developing countries have lacked up-to-date information on diseases. One outcome of the threat of SARS and bird flu H5N1, and the current pandemic of swine flu A(H1N1), is that many countries have been shocked into action. Several, including China and India, are pledging to update their disease-monitoring systems. These systems require advanced computer hardware and software to collate and analyze incoming data. Such technology might include, for example, geographic information systems that can link data to specific locations and allow both spatial and temporal analyses of disease data. The infrastructure of existing systems may need to be upgraded to accommodate these additions. But monitoring disease is just one aspect of creating an early-warning system. Accuracy will also rely on researchers understanding how non-climatic factors, such as drug resistance, influence epidemics. And early warning systems will only work if there are resources to respond to the alarm bells.

Strengthening health systems in poor countries, a long-called-for necessity, is even more urgent in the face of these future challenges. Moreover, the medical staff within these must be fully aware of how climate is likely to affect the people they treat. A WHO feasibility analysis for creating prediction systems calls for health policymakers' involvement at the earliest stages, because even the best early warning systems will be worth little if operational responsibilities aren't clearly delineated and agreed from the beginning [9]. High infant mortality rate (IMR), maternal mortality ratio (MMR), malnutrition among children and women, high incidence of childhood diseases, declining sex ratio of girls, low female literacy in comparison to national average, inadequacy in drinking water supply and sanitation, poor health and poor socio-economic status of women along with social discrimination, are all already a cause of concern for population health in many states. Operational integration in policy and programme between various vertical programmes within the health sector, and between health and other related sectors such as drinking water, sanitation, and nutrition has also been limited, resulting in a lack of holistic approaches to health. It is unequivocal that climate change is happening and is likely to expand the geographical distribution of several vector-borne diseases, including malaria and dengue etc. to higher altitudes and latitudes.

India is endemic for six major vector-borne diseases (VBD) namely malaria, dengue, chikungunya, filariasis, Japanese encephalitis and visceral leishmaniasis [10]. Malaria is a major public health problem in India and one which contributes significantly to the overall malaria burden in Southeast Asia. The National Vector Borne Disease Control Program of India reported ~1.6 million cases and ~1100 malaria deaths in 2009. Some experts argue that this is a serious underestimation and that the actual number of malaria cases per year is likely between 9 and 50 times greater, with an approximate 13-fold underestimation of malaria-related mortality. The difficulty in making these estimations is further exacerbated by (i) highly variable malaria eco-epidemiological profiles, (ii) the transmission and overlap of multiple Plasmodium species and Anopheles vectors, (iii) increasing antimalarial drug resistance and insecticide resistance, and (iv) the impact of climate change on each of these variables [11]. Climate change shall definitely affect vector borne diseases profile [12-14] in the country and need integrated approach for management.

4. Conclusion

Spatial technology in the form of GIS, remote sensing and GPS has potential applications in all vector borne diseases and programs. The National Vector Borne Disease Control Programme (NVBDCP) is the agency responsible for the prevention and control of all vector-borne diseases in India, including malaria. The NVBDCP goals are to develop a well-informed and self-sustained health care system in India with equitable access to quality health care and to ensure that the program activities are in accord with the Millennium Development Goal of halting and reversing the incidence of malaria and other vector-borne diseases by the year 2015. Climate change shall affect vector borne diseases profile geographically.

Table 1: The effect of climate change on insect-borne disease recorded in research studies [1].

Climate factor	**Potential effects on vector**	**Potential effects on pathogen**
Increased temperature	Decreased survival of some mosquito species; change in susceptibility to some pathogens; increased population growth; increased feeding rate to combat dehydration (so higher vector-human contact); expanded seasonal and spatial distribution	Faster incubation in vector; extended transmission season

Decreased rainfall	Increase in container-breeding mosquitoes because of more water storage; higher numbers of vectors that breed in dried-up river beds; reduction — or elimination — of vectors such as aquatic snails, through drought	Expanded distribution; no effect
Increased rainfall	More breeding sites and increased size of vector population; increased vector survival due to increased humidity; more potential habitats downstream of floods for vectors such as aquatic snails; heavy rain can synchronise vector host-seeking and virus transmission; breeding sites washed away by heavy rain; habitat destruction by flooding	Little evidence of direct effects
Sea-level rise	Increased abundance of mosquitoes that breed in brackish water	No effect

GIS can be extremely useful for action plan for major strategies being pursued by the NVBDCP to help achieve its objectives including (i) disease management through early case detection and complete treatment, (ii) integrated vector management (IVM) to reduce the risk of vector-borne transmission; and (iii) supportive interventions which include communicating behavior change, capacity building and monitoring and evaluation of programs. To facilitate disease management, fever treatment depots (FTDs) exist at the village level. There is need for further research.

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