

Outbreak of dengue in Tamil Nadu, India

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Dengue is known in India since 1940s, but the disease is very limited in its spread. Dengue is becoming rampant in many states of southern India. As of now, no specific treatments (therapies) or vaccines are available against the disease. The people of Tamil Nadu and Puducherry, where the dengue incidences are increasing, perceive this spurt as due to poor rainfall and power supply. We attempted to verify this perception. We also sought to find out whether these factors are in concert with the monthly surveillance reports, used to predict yearly dengue cases by formulating a prediction model. The results showed that a combination of rainfall and power supply had major effect on the spread of dengue. The prediction model, incorporating rainfall and power supply data for four seasons, could not predict the dengue outbreaks accurately. Due to poor rainfall and power supply, people resort to storing water when power is available, and this prolonged open storage of water provides habitat for the vector to breed. The present study emphasizes the need to strengthen the surveillance system for timely and effective execution of vector-control programme. It also highlights the need to improve awareness among the public about the vector's ecology. The strategy against such vector-borne diseases has to focus more on environmental health rather than only on disease management that is patient-centred, largely curative and chemical/medicine intensive.

Keywords: *Aedes aegypti*, dengue, power cut, rainfall deficit.

GLOBALLY climate change is getting reflected in unusual rainfall pattern leading to surplus rains in some locations, deficient rains elsewhere and untimely burst in rainfall. Studies indicate that the South Indian states are facing perceptible fluctuations in climatic conditions, and possibly the health of people is directly or indirectly affected because of these fluctuations^{1,2}. Rise in average temperature, an element of climate change, favours higher breeding and spread of the vectors such as *Aedes aegypti*, and consequently spread of dengue virus³. In general, incidences of dengue fever, a mosquito-borne tropical disease (Flavivirus, an RNA virus of the family Flaviviridae), are increasing fast resulting in higher morbidity and mortality in humans worldwide, particularly in tropical and subtropical countries⁴. More than 2.5 billion people of the global population are at risk and 50–100 million dengue

infections per year are likely⁵. Earlier in India, although dengue fever was recognized as a classical disease with high morbidity, but no mortality, the disease was mainly restricted to urban and semi-urban areas because of the favourable breeding sites for the vector *A. aegypti*^{6–8}. During the past few years, the frequency of dengue hemorrhagic fever (DHF) has increased remarkably in South India^{9–11}. The density and distribution of the vector depend on a few vital environmental factors such as season, temperature, rainfall and humidity that vary with latitude and altitude^{12–14}. The life span of the vector is strongly influenced by temperature and humidity and it survives best between 16°C and 30°C and relative humidity of 60–80%. The abundance of *A. aegypti* fluctuates with unusual rainfall pattern and water storage, as it breeds well in the open containers in and around houses¹⁵. Manmade factors such as environmentally negligent developmental activities also cause outbreaks at new locations^{16,17}.

Tamil Nadu gets rains in four spells: winter (January–February), pre-monsoon (March–May), monsoon (June–September) and post-monsoon (October–December). The northeast monsoon, starting in October and lasting up to December, is marked with heavy rainfall, whereas the southwest monsoon, from June to September, accounts for moderate rainfall. Rainfall is scanty in the pre-monsoon period. Of the total annual rainfall (945 mm) in the state, 48% is received during the northeast monsoon, 32% during the southwest monsoon and the rest during other seasons.

Rainfall critically influences several crucial issues of people¹⁸. Many towns and cities in Tamil Nadu and Puducherry are dependent on rivers for drinking water and deficit in rainfall reduces drinking water supply. Three consecutive rain-deficit years (2011, 2012 and 2013) and delayed monsoons have created drought-like situations; overall shortfall was 20–23% of the annual average rainfall¹⁹. The reduced rainfall also causes shortfall in power output from hydroelectric projects, and the changes in wind pattern, intensity and speed lead to decline in wind-generated electricity²⁰. Taking into account the economics of power purchase, there is no choice but drastic compulsory power cuts to counter the power shortage. Because of extended 16-hour daily power cuts in some parts of the state, people are forced to store water in open containers^{21,22}. An important, but indirect effect of this seems to be proliferation of *A. aegypti*, the vector spreading dengue. In 2010–2012, outbreaks of dengue/chikungunya-like illnesses with severe clinical manifestations were reported from several districts of Tamil Nadu, such as Tirunelveli, Virudunagar, Theni, Madurai, Thiruvallur, Vellore and Dharmapuri. Although the exact number of fever cases or number of fatalities is not available, approximately few hundred thousand people were affected^{23,24}.

In this context, the present study was designed to explore the relationships of rainfall and power supply

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with the dengue incidences to develop a model that can predict future possible seasonal dengue cases in Tamil Nadu and Puducherry that could be used for prevention and control of dengue outbreaks.

In this study, we have used three (2010–2012) years' monthly data on rainfall, power supply and reported cases of dengue in Tamil Nadu and Puducherry. The number of dengue cases was collected from the weekly disease alert reports of the Integrated Disease Surveillance Project (IDSP) launched by the Government of India through Central Surveillance Unit (CSU), State Surveillance Units (SSU) and District Surveillance Units (DSU). The annual dengue count from the National Vector Borne Disease Control Programme (NVBDCP) is prepared based on reports received. The state-wise monthly power supply data was sourced from the Central Electricity Authority (CEA) and the climatic data from the India Meteorological Department (IMD), Pune.

The data on monthly rainfall and power supply were correlated with the monthly dengue case. Data on seasonal rainfall and power supply were taken as independent variables and the reported dengue cases as dependent variable while attempting Pearson correlation. A regression model was also attempted to predict dengue incidences from the independent variables. One-way analysis of variance (ANOVA) was done to see if each of the variables differs significantly among seasons and Student's *t*-test was used to check the null hypothesis on validity of the prediction model. For prediction of seasonal dengue incidences, the two independent variables' (rainfall and power supply) deficit measurement units (mm and MW respectively) were converted into percentage units and weekly IDSP dengue numbers were grouped into seasonal numbers.

Over the last 5 years (2008–2012), 22,584 dengue cases were reported from Tamil Nadu region by NVBDCP and the number of reported cases varied from year to year. The highest dengue incidences were reported in 2012 ($n = 15,770$) and lowest in 2008 ($n = 565$, Figure 1). Interestingly, every year, until 2011, there was a 175% increase. But the increase in 2012 was 532%, three times more than the earlier years.

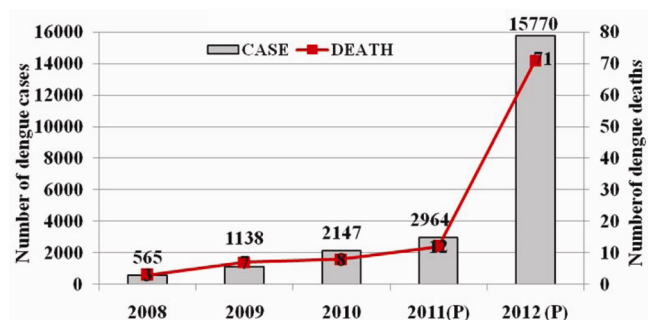


Figure 1. Dengue incidences and deaths during 2008–2012 in Tamil Nadu and Puducherry ($n = 22,584$) according to NVBDCP. P = Provisional.

Dengue cases showed a specific pattern of occurrence. In each year, except in 2010, while hardly there was any dengue case in winter, most cases were reported during northeast monsoon. The monthly data showed a distinct pattern in dengue incidences in 2012, a pattern hardly seen in 2011 or 2010. Substantial incidences were reported in June, a peak in October followed by gradual decline towards the beginning of the next year, reaching lowest in February (Figure 2). Across the seasons and years, the number of dengue cases varied; in 2012, the numbers increased from winter to northeast monsoon; in 2011, the numbers remained almost the same for the first three seasons and increasing in post-monsoon. In 2010, it wavered in all the four seasons (Table 1). The rainfall during these three years also varied considerably; in 2012, severe deficit in all the four seasons was seen, while in 2011 and 2010 the rainfall was in excess in two seasons and deficit in the rest (Figure 3). In general, the dengue outbreaks coincided mainly with the northeast monsoon, followed by the southwest monsoon with moderate rainfall.

With respect to the districts, according to IDSP records maximum cases were reported from Viluppuram district (226) in 2010, Puducherry (152) in 2011 and Puducherry (1600) followed by Tirunelveli (1365) in 2012. However, the deaths were negligible in contrast with the number of cases reported in 2010 and 2011; but deaths were high (40) in 2012, especially from the Tirunelveli district (32 deaths, Table 2).

During the study period, the average seasonal rainfall in winter was 18.7 mm, in summer 117.9 mm, in southwest monsoon 304 mm and in northeast monsoon sharply

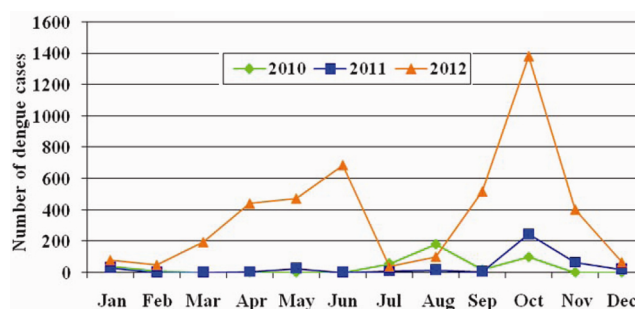


Figure 2. Monthly dengue cases in Tamil Nadu and Puducherry during 2010–2012 ($n = 5265$) according to the IDSP surveillance report.

Table 1. Seasonal variation in number of dengue cases according to IDSP surveillance monthly alerts during 2010–2012

Season	2010	2011	2012
Winter	48	31	131
Summer	0	31	1112
Southwest monsoon	255	31	1347
Northeast monsoon	98	328	1853

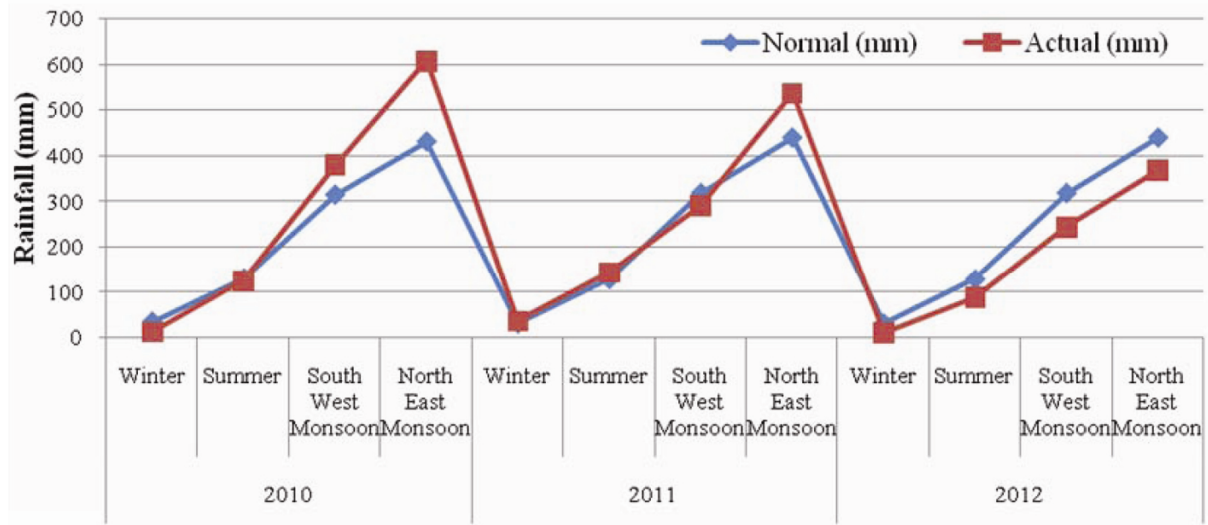


Figure 3. Seasonal rainfall pattern – normal versus actual rainfall (in mm) during 2010–2012 in Tamil Nadu and Puducherry.

Table 2. District-wise dengue cases and deaths each year in the study area according to IDSP surveillance monthly alerts during 2010–2012

District	2010		2011		2012	
	Case	Death	Case	Death	Case	Death
Ariyalur	–	–	7	–	–	–
Chennai	–	–	–	–	–	–
Coimbatore	–	–	13	–	–	–
Cuddalore	–	–	–	–	47	–
Dharmapuri	–	–	–	–	103	–
Dindigul	9	–	7	1	58	–
Erode	–	–	29	1	20	–
Kancheepuram	–	–	56	–	–	–
Kanniyakumari	–	–	–	–	–	–
Karur	–	–	4	–	17	–
Krishnagiri	–	–	–	–	11	–
Madurai	–	–	–	–	79	5
Nagapattinam	–	–	–	–	–	–
Namakkal	21	–	–	–	–	–
Perambalur	–	–	24	–	22	–
Pudukkottai	–	–	–	–	166	1
Ramanathapuram	–	–	37	–	224	2
Salem	18	–	8	–	106	–
Sivaganga	30	–	6	–	–	–
Thanjavur	–	–	20	–	132	–
The Nilgiris	–	–	–	–	–	–
Theni	–	–	11	–	35	–
Thiruvallur	–	–	–	–	–	–
Thiruvavur	22	–	–	–	55	–
Thoothukudi	–	–	–	–	80	–
Tiruchirappalli	–	–	16	–	156	–
Tirunelveli	–	–	16	–	1365	32
Tiruppur	–	–	–	–	–	–
Tiruvannamalai	27	–	–	–	67	–
Vellore	–	–	–	–	–	–
Viluppuram	226	–	16	–	67	–
Virudhunagar	38	1	–	–	33	–
Puducherry	10	–	152	1	1600	–
Total	401	1	422	3	4443	40

high 503 mm. The rainfall varied significantly (ANOVA $P < 0.05$) across the seasons. At the same time, seasonal rainfall deficit was not statistically significant (ANOVA $P < 0.05$). Regarding seasonal power supply, the average supply in winter was 9,889 MW, in summer 10,388 MW, during southwest monsoon 10,507 MW and during northeast monsoon 9,766 MW. However, the actual power supply and its deficit were not significantly different across seasons (ANOVA $P < 0.05$; Table 3). But the power deficit during winter was significantly lesser ($P < 0.05$) than in other three seasons.

The IDSP dengue cases were plotted against the seasonal rainfall and power supply to assess their associations. During the study period, while the rainfall deficit increased, the number of reported cases of dengue decreased. This was different from the pattern of declining rainfall deficit and concurrent inclining dengue cases during southwest monsoon to northeast monsoon (Figure 4). The same pattern of decreasing dengue case against power deficit was observed in these seasons except during the southwest monsoon. When the number of dengue incidences was plotted against annual rainfall and power supply, a distinct pattern (i.e. deficit increase concurrent with increasing dengue cases) was seen only during 2012 (Figure 5).

The incidences of dengue increased during northeast monsoon. The overall rainfall and power supply showed significant positive correlation with the weekly IDSP reported dengue cases ($r = 0.967$, $p = 0.033$ for rainfall, and $r = 0.972$, $p = 0.028$ for power supply). These positive correlations provided us a basis for a potential dengue prediction model. In this model, average monthly rainfall, power supply and the reported dengue cases were considered. We used tolerance measure to see collinearity between the two independent factors included in the

Table 3. Seasonal variation in rainfall, power supply and reported dengue cases during 2010–2012

Season	Average rainfall (mm)	Average rainfall (deficit/surplus) (mm)	Overall rainfall status (%)	Average power supply (MW)	Average power supply (deficit/surplus) (MW)	Overall power status (%)	Surveillance alert dengue cases
Winter	18.7	-14	-41	9,889	-2784	-12	210
Summer	118	-11	-9	10,388	-5149	-14	1,143
Southwest monsoon	304	-12	-3	10,507	-5045	-11	1,633
Northeast monsoon	504	69	16	9,766	-5328	-15	2,279

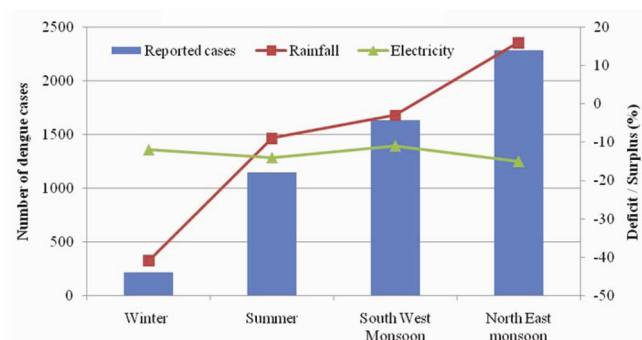


Figure 4. Seasonal variation in rainfall, power deficit and dengue cases reported by the IDSP surveillance alerts, during 2010–2012.

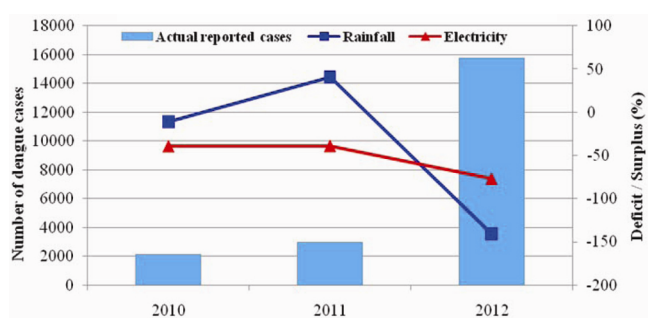


Figure 5. Annual rainfall, power deficit and number of dengue cases during 2010–2012.

model. The tolerance value of collinearity diagnostics (0.709) and Variance Inflation Factor (VIF = 1.141) fell clearly within the acceptable values >0.2 to <5 . We also checked the independence of the data points using Durbin Watson estimates. The value (2.151), noticeably away from zero, suggests significant independence of the data points.

The prediction model was developed using multiple regression of dengue cases with rainfall and power supply for all the seasons in three consecutive years. However, the model showed relatively higher accuracy in the prediction of actual dengue numbers reported by NVBDCP and but lower accuracy with that by IDSP. From this, it is clear that poor accuracy of the model could be due to influences of other variables (externalities) on the rainfall, power supply and dengue relationships (Table 4).

Table 4. Number of predicted and actual number of dengue cases during 2010–2012 according to prediction model

Cases	2010	2011	2012
Predicted	400	421	4442
Actual (NVBDCP)	2,147	2,964	15,770
Accuracy (%)	18.6	14.2	28.1

Table 5. Overall difference between predicted and actual number of cases during 2010–2012

Variables	N	Mean	SD	t-value	Significance
Predicted cases	3	1754.3	2327.6	-1.129	0.322*
Actual cases (NVBDCP)	3	6960.3	7640.3		

*Statistically not significant (*t*-test; $p < 0.05$).

We also attempted to evaluate the prediction capability of our model retrospectively to predict the number of dengue incidences that occurred in 2010, 2011 and 2012 in Tamil Nadu and Puducherry. When the predicted dengue cases were plotted against the actually reported cases for the respective years, the model exhibited significant correlation between the predicted and the actual number of cases ($r = 0.999$, $p = 0.031$). The overall difference between predicted and actual number of dengue cases was also insignificant ($t = -1.129$, $p = 0.322$, Table 5).

Dengue is becoming ubiquitous throughout the tropics, with local spatial variations in risk being influenced strongly by rainfall, temperature and degree of urbanization²⁵. The authors estimate that there were 96 million dengue infections globally in 2010. Asia, holding 70% (67 million infections, ranging between 47 and 94 millions) of this burden, is characterized by large densely populated human habitation highly conducive for disease transmission. India alone accounted for 34% of the global total; 33 million infections, ranging between 24 and 44 million. This number would certainly be higher if we take into account the very likely unreported dengue infections in the country²⁶. The country had dengue-like illnesses for long, although the virus was isolated in Japan only in 1943 and in Calcutta in 1944. The first clinically recorded epidemic of dengue-like illness occurred in Madras in 1780, but the full-blown confirmed dengue epidemic in

its severe form was reported from north India only in 1996 (ref. 27). In 2001, a major outbreak was recorded in Chennai, 90% of the 861 cases recorded from the whole of Tamil Nadu²⁸. The incidence brought out the community knowledge on dengue, vector transmission, breeding sites, biting behaviour and dismal preventive measures. Since then, the number of dengue incidences in Tamil Nadu has been increasing considerably²⁹ and the spread of the disease in rural³⁰ and semi-urban areas of Tamil Nadu has become a matter of concern for public health.

These frequent outbreaks stress the pressing need for putting in place permanent dengue surveillance systems in India. The Ministry of Health and Family Welfare established NVBDCP and formulated strategies, which were intensified during the XI five-year plan (2007–2012) for prevention and control of different vector borne diseases. After the implementation of the surveillance system in the country, the season and the area that require more attention in terms of monitoring, prevention and forecasting the impending outbreaks was identified³¹. However, the data-acquisition strategy needs further improvements; the present study also indicates the failure of the surveillance system in 2012, while it was relatively satisfactory in 2010 and 2011. Earlier studies on the relative prevalence and distribution have shown high *A. aegypti* larval indices during the monsoon and the post-monsoon period^{32–34}. The present study shows the outbreak coinciding mainly with the post-monsoon period of heavy rainfall (northeast monsoon). In India, hydroelectric power is a major source of power and severe rainfall deficit results in disruption of power generation. In 2012, the power shortage in the state, led to 14–18 hours power cut every day and this severely affected the public water supply, forcing people to adopt inappropriate water storage methods when power was available. Generally, dengue vector breeds in clear water, collected in open storage tanks or in plastic or other water holders left unattended. Such accumulated water provides perfect opportunity for the vector to flourish. Dengue cases were reported more during the months of northeast monsoon when power shortage was also relatively high. Nevertheless, the difference between total rainfall and power supply during the four seasons in a year not being statistically significant ($p < 0.05$) reveals the risk of vector-borne disease outbreaks being determined by other unknown complex factors.

The present study also reveals a few other interesting observations. First, the outbreaks coincided with the northeast monsoon with 1–2 times more number of dengue cases than during the southwest monsoon. Deficit in rainfall and power supply paved the way for severe outbreak in 2012. Such an outbreak did not happen in 2011 and 2010, because the deficit in one of the determinant variables was counterbalanced by the surplus in the other determinant variable. Secondly, in each year, the number of dengue cases varied almost corresponding to the fluctua-

tuations in rainfall and power deficit. It was observed that the seasonal dengue infection in a particular season in a year was related with rainfall and power supply. However, across the years, these did not correlate adequately. This signifies the role of other factors, the externalities, in conjunction with rainfall and power supply, influencing dengue infection in a given geographical area. The present study shows that rainfall, as a single factor, likely plays a small but significant role. While power-cut alone was ruled out of any significant role, it along with the rainfall was important in the spread of dengue. However, earlier studies have reported no specific role for climatic factors in dengue infection^{35,36}. Thirdly, the present prediction model showed significant correlation with NVBDCP dengue cases, but not with IDSP dengue cases. This suggests that reliability of a prediction model in the case of contagious diseases, such as dengue, depends on accuracy and timely updation of the data by the surveillance system. It is discernible that IDSP does not have actual figures of dengue cases. Incidentally, highly populated districts such as Chennai, Coimbatore, Tiruppur and Vellore (where dengue is prevalent) and some coastal districts did not report any dengue cases in these three years. This would be possibly due to underreporting of the infections for the high dependency of patients on private health care, lack of adequate testing facilities, mix-up of the symptoms of dengue and other seasonal viral fevers and perhaps intentional attempts to underreport the cases. The flaws in the surveillance and reporting system could be a possible, but crucial, reason for the failure of this prediction model. Thus, possibly this model emphasizes the need for accurate IDSP alert reporting through better collection, collation, compilation and validation of data. It is also to be kept in mind that oversimplified prediction model without proper identification of the significant quantitative relations among the factors and externalities may lead to wrong forecast of epidemic outbreaks and might hinder prevention and control programme for the disease³⁷. Yet, the factors identified in the present study have inevitable roles in the overall dengue outbreak. This study also highlights the need for a detailed study taking into account various other factors, such as human population and mobility, urbanization rate, waste management, water supply and distribution and densities of vector mosquitoes. It is felt that strategy to deal with such vector-borne diseases has to be an integrated one, developed from environmental and health management perspectives rather than only from the standpoint of health management and therapeutics.

Dengue continues to spread to newer areas, newer populations and in increasing magnitude. This study examined rainfall, power supply and alerts from surveillance system as the factors for predicting dengue occurrences. The study also highlighted the importance of reliable and precise data for preparing a prediction model for the epidemic diseases. Further detailed studies could reveal the

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relations of climatic, environmental and human-induced factors with dengue outbreaks, which would help in evolving strategies to deal with likely outbreaks well in advance. Surveillance programmes and appropriate models capable of detecting rise in vector outbreaks, strains, or disease emergence well in time are crucial.

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