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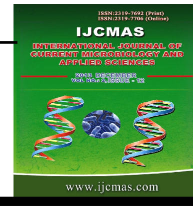

Original Research Article

Aedes vector population dynamics and occurrence of dengue fever in relation to climate variables in Puducherry, South India

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A B S T R A C T

Keywords

Aedes vector; Dengue fever; Diurnal Temperature Range; Larval Indices; Rainfall; Puducherry.

Puducherry (previously Pondicherry) had reported regular dengue outbreaks since 2003 with increase in number of cases every year. The study was aimed to assess changes in the intensity of vector breeding and its reflection upon case occurrence in relation to climatic variables. Dengue vector surveys were carried out in six Primary Health Centres (PHCs) representing both rural and urban areas round the year, and entomological indices were determined using standard methods**.** *Aedes aegypti* and *Ae. albopictus* were the vectors encountered in the survey, and *Ae. aegypti* present in high numbers in urban as well as rural areas. For both species, the size of immature populations found to increase with increasing rainfall, though heavy rains resulted in population loss. A significant relationship was found between larval indices and rainfall. Diurnal temperature range was found a critical factor negatively associated with vector abundance (larval indices) and occurrence of dengue cases.

Introduction

Dengue fever is the most rapidly spreading mosquito-borne viral disease and an increasing public health problem globally (WHO, 2008). According to current estimates, at least 100 countries are endemic of dengue and about 96 million apparent dengue infections were recorded globally in 2010, with about 70% (67 million) infections from Asia and India alone contributed 34% (33 million) of the global total (Bhatt *et al*., 2013). The first outbreak of dengue fever in India with haemorrhagic manifestations was reported in Calcutta city in 1963 (Sarkar *et al*., 1964). Since then, outbreaks of dengue have been recorded in almost all parts of India. In 2011, 18806 dengue fever cases were reported from 22 States & 5 Union Territories (UTs); while in 2012, a total of 11465 cases had been reported from 19 States & 5 UTs (NVBDCP, 2013). Puducherry experienced dengue outbreak for the first time in 2003 with 60 confirmed cases of infection from 10 urban and 9 rural Primary Health Centres (PHCs) (Hoti *et al*., 2006). A four - fold increase of dengue cases had been observed in 2011 (n = 230 cases). In 2012, there was a sudden and manifold increase in the incidence of Dengue (total: 1391 cases) (NVBDCP, 2013). The incidence of dengue is largely dependent on vector populations and the frequency of contact between the vectors and susceptible human hosts, reflected by a positive correlation of *Aedes* abundance and prevalence with dengue (Tewari *et al*., 2004; Mahadev *et al.,* 2004; Chadee, 2009). This supports the necessity of entomological surveillance to assess and predict the abundance of vectors and possibilities of occurrence of dengue (WHO-SEARO, 2006; Focks and Alexander, 2006).

Conventionally, assessment and prediction of the vector population levels are made using the productive larval habitats and data on human demography as components of different indices recommended by the WHO (Focks and Alexander, 2006). The information provided by these indices is useful supplement for the management strategies against the dengue vectors, in different parts of the world [Chadee, 2009; Focks and Alexander, 2006). Estimates of *Aedes* abundance in different dengue endemic regions can help in vector management and enhance necessary precautionary measures. Climate factors such as rainfall, temperature and humidity are known to influence dengue transmission. The high level of humidity and warmer ambient temperature during the rainy season makes the survival of the mosquito to be longer (Gubler, 1997; Jetten and Focks, 1997; Kumar and Kumar, 2013). Various studies have shown that the abundance of *Aedes* mosquitoes are affected by air temperature and rainfall, as the immature stages of the mosquitoes are aquatic. Rain can help build breeding sites; but, very heavy or prolonged rain may disrupt the sites and wash the eggs and larvae away or kill the mosquito directly (Mellor and Leak, 2000). Due to the lack of vaccination, the dengue control programme relies on vector control to reduce viral transmission. The risk of dengue has been reported to be associated directly or indirectly with seasonal changes in climate (Hales *et al.*, 2002) and mosquito larval indices (Arunachalam *et al*., 2010), thus the present study as a control intervention step, attempted to determine the vector abundance and dengue fever risk in relation to climate variables in Puducherry.

Materials and Methods

Study area

Puducherry district lies between 11° 46´ & 12° 13´ North and 79°36´ & 79° 53´ East, with a population of 9, 46,600 covering an area of 293 sq. Kms (Fig. 1). Puducherry experiences hot and humid climate except during January & February months which are comparatively colder but the temperature never falls below 20°C. The temperature normally varies between 26°C and 38°C. The northeast monsoon sets in during the middle of October, and Puducherry gets the bulk of its annual rainfall during the period from October to December. Average annual rainfall is 1254 mm and relative humidity varies from 70 to 80% (Anonymous, 2012).

Sampling units

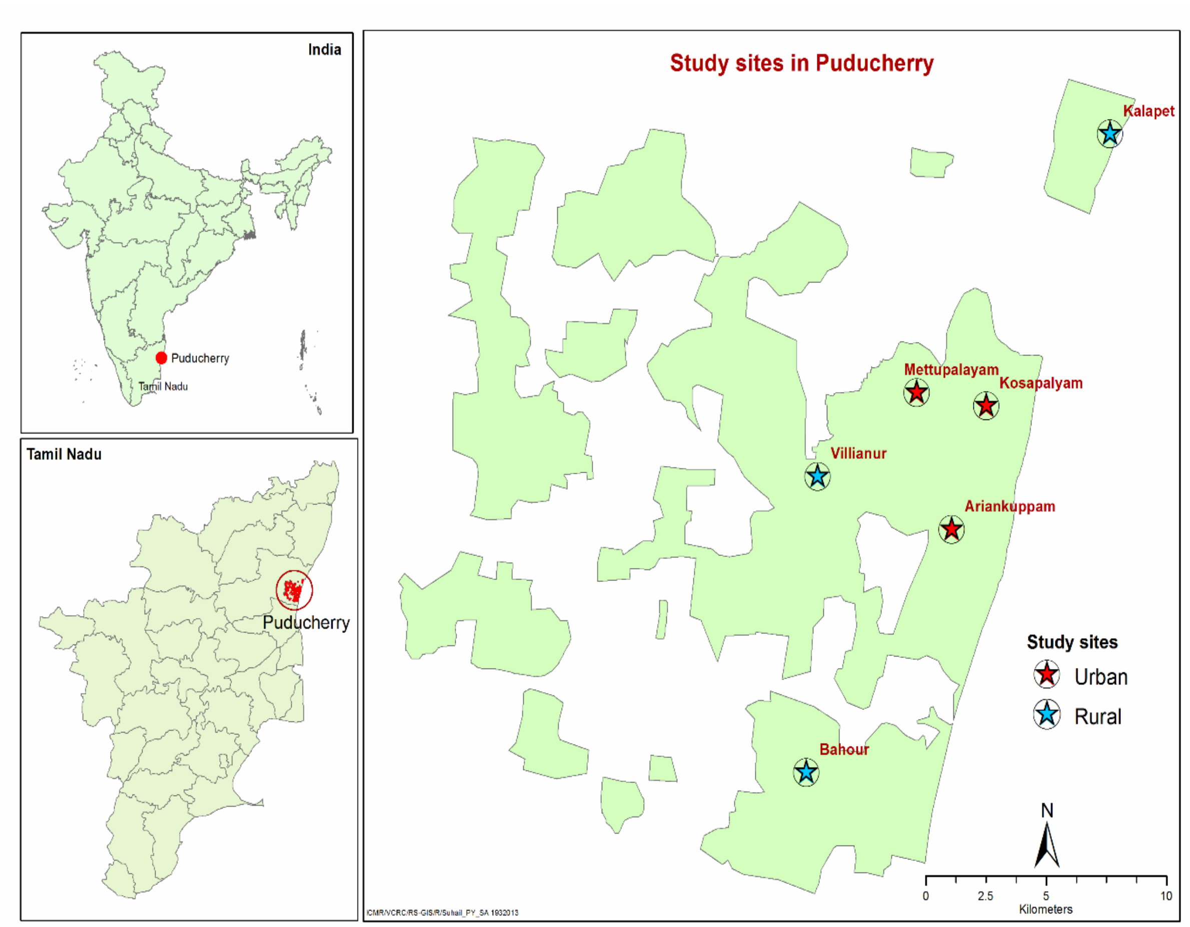
A total of six PHCs (three rural and three urban) were selected based on past dengue case records, for the survey. Assuming House index of 15% with an error margin of 7% and 95% confidence interval, the minimum number of households (units) to be sampled was estimated to be 100 each for rural and urban area.

Table.1 Entomological indices in different study sites

PHC		House index(HI)	Container index(CI)	Breteau index(BI)	*Aedes aegypti*	*Aedes albopictus*	Pupae per person (PPI)	Pupae per container (PCI)
Urban	Mettupalayam	16	17.8	20.4	358	75	0.44	1.01
	Kosapalayam	12.8	17.6	20.6	269	21	0.52	1.39
	Ariankuppam	13.4	17.4	23.2	608	135	0.49	1.48
Total		14.1	17.7	21.4	1235	231	0.47	1.29
Rural	Kalapet	11.2	12.5	17.1	247	57	0.43	1.12
	Villianur	12.2	14.2	18.3	458	74	0.45	1.11
	Bahour	12.8	12.8	17.7	297	73	0.48	1.16
Total		12.1	14.8	18.9	1002	204	0.45	1.13

Pupae per person index (PPI): the ratio of pupae and persons living in each PHC
Pupae per container index (PCI): the ratio of pupae and containers surveyed in each PHC

Fig.1 Map showing study sites



Entomological data

Mosquito immature surveys were conducted in 6 selected PHCs of Puducherry district throughout the year 2012. Every month, containers inside and outside randomly (simple) selected houses were examined for the presence of *Aedes* mosquitoes. The containers holding water with immature were designated as positive containers (PC), while the containers holding only water were designated as wet containers and all the larvae/pupae from the positive containers were collected. Specimens of immature mosquitoes kept in plastic containers were labelled with date of collection, area code, house identification code, and container code before being transported to the laboratory. The larvae/ pupae collected from each locality were reared up to the emergence of adults and identified using standard keys.

Entomological indices namely Breteau index (BI; The number of positive containers per 100 houses), House index (HI; The percentage of houses with positive containers) and Container index (CI; The percentage of containers with immature *Aedes*) were calculated following standard procedures (WHO-SEARO., 2011). As it has been reported that pupal indices are a better proxy indicator for adult vector abundance (Wai *et al*., 2012], the pupal productivity surveys were carried out to identify the key breeding habitats. The pupal indices, pupae per person index (PPI: the ratio of pupae and persons living in each PHC) and pupae per container index (PCI: the ratio of pupae and containers surveyed in each PHC), were also determined. To identify the most productive container types, the percentage contribution of each breeding container to the total count of pupae was calculated. This was done by taking the total number of pupae found in a given category of container and dividing it by the total number of pupae in all containers in the area studied (Arredondo and Valdez, 2006].

Climate data

The temperature and rainfall data was provided by Weather Station installed at our Institute (VCRC) on daily basis. Diurnal Temperature Range (DTR) was calculated from differences between mean values of daily maximum and minimum temperatures.

Dengue fever case data

Dengue case incidence data was obtained on weekly basis from the Directorate of National Vector Borne Disease Control Programme (NVBDCP), Puducherry.

Data analysis

All data were entered into an MS Excel spreadsheet and exported to IBM SPSS version 19.0 software for further analysis. Pearson correlation coefficients were calculated by relating larval indices with climate variables. χ^2 -test was used to compare the rural and urban area in terms of HI & BI, and Student t-test for independent samples to compare CI.

Result and Discussion

Breeding habitat of dengue vectors

During entomological survey we identified uncovered water containers (including household water storage containers and other types of artificial containers) as breeding habitats of *Aedes* vectors. The Plastic containers were found as most productive breeding habitat as the 23.2% of the total pupae collected was contributed by plastic containers followed by coconut shell (14%), grinding stone (10.6%) and tyre (8.1%) (Fig.2).

A total of 2819 houses from 6 PHCs were checked for *Aedes* larvae during the year-long surveillance. Immature *Aedes* were found in 379 houses and in 572 containers situated in and around the houses, which produced an overall 2237 *Ae. aegypti* and 435 *Ae.albopictus*. The immature indices of *Aedes* vectors in urban areas were relatively higher as compared to rural areas. Urban and rural areas showed closer HI compared to BI & CI, and both *Ae. aegypti* & *Ae. albopictus* were found in high numbers in urban PHCs as compared to the rural (Tab. 1).

While the container index (CI) between rural and urban area showed a significant difference (χ^2=7.40; P=0.007), the HI (χ^2=0.62; P=0.43) and BI (t=1.05; df =70; P=0.30) did not differ significantly.

Influence of rainfall & DTR on vector breeding

Immature stages of *Aedes* were found throughout the year. The lowest larval indices were recorded in May (HI-3.5, CI-7.8 & BI-4.8), after which the number started to rise and peaked in the month of November (HI-35.8, CI-19.4 & BI- 53.3). The monthly HI (r=0.74, P = 0.005) and BI (r=0.71, P = 0.008) were found positively correlated to the monthly rainfall, while no significant relation was found between CI & rainfall (r=0.27; P=0.38).The DTR was found negatively correlated with HI(r=-0.62; P=0.029) and BI(r=-0.56; P<0.05), while no significant correlation was found between DTR and CI(r=0.11; P=0.72)(Fig.3).

Climate variability and incidence of dengue

A total of 455 dengue cases were reported from the study sites throughout the year 2012. Maximum number of cases were recorded during the period of October to December (76.53) with a peak during November (166 cases) and a gradual decline thereafter. During the month of October, highest rainfall (301.6 mm) and lowest DTR (5.9°C) were recorded and 128 dengue cases were reported. The DTR was negatively correlated with number of cases reported(r= -0.58; P<0.05). On the other hand, there was no significant correlation between rainfall and number of cases reported (r=0.56; P=0.05) (Fig.4).

The results of the present study revealed the infestation characteristics of dengue vectors and indicated that the dengue vectors, *Ae. aegypti* and *Ae. albopictus* has spread all over the study area with moderate to high immature indices. Our study reflects that the immature indices can be used as an indicator of the abundance of the *Aedes* mosquitoes, serving as a supplement to assess the risk of dengue in Puducherry.

Pupal productivity differs in the larval habitats depending on the size and material of the container type. This was observed in rural areas of American Samoa (Burkot *et al*., 2007). Outdoor, non-potable water storage containers pose significant breeding risk contrast to potable water storage containers. In another study in Kolkata, India, Plastic drums and small plastic containers are found as the key habitats of *Ae. aegypti* breeding and discarded plastic pots are identified as the most productive containers (Banerjee *et al*., 2013).

Fig.2 Pupal productivity of the containers surveyed

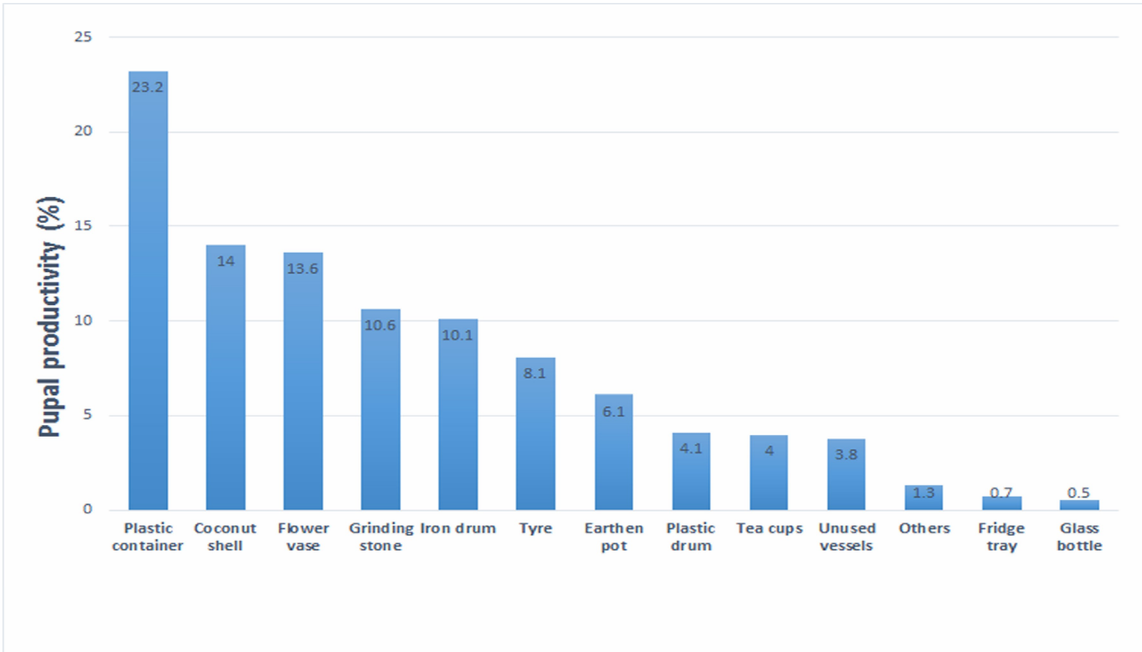


Fig.3 Correlation between monthly larval indices, rainfall and DTR (2012)

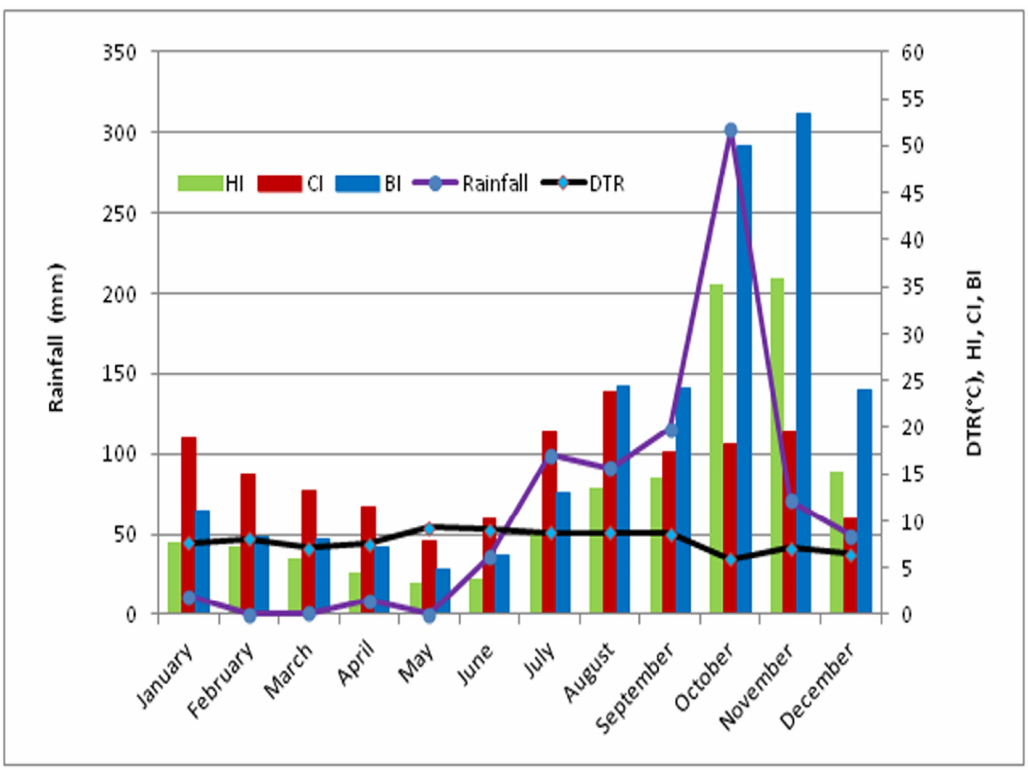
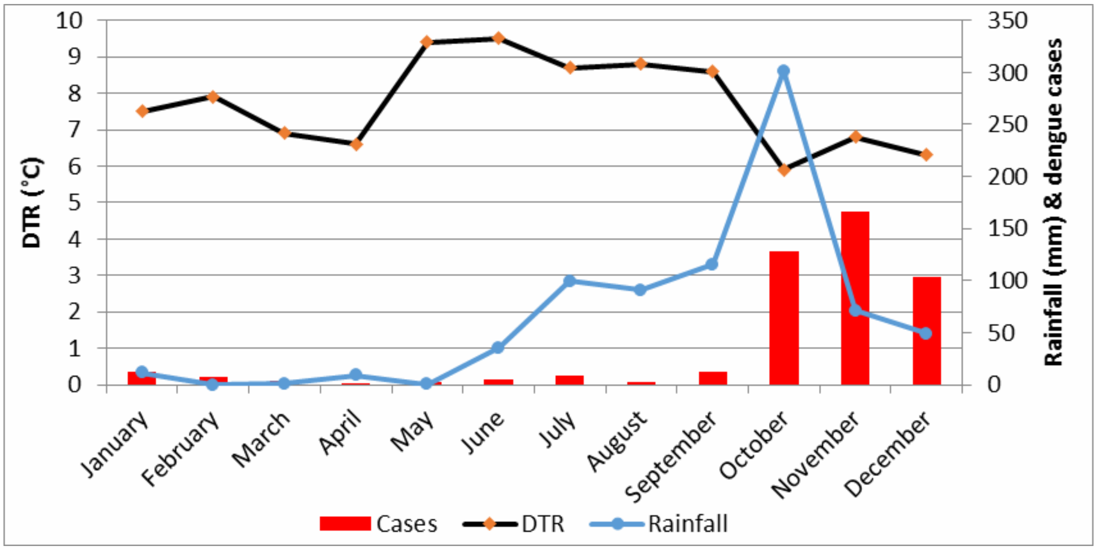


Fig.4 Monthly number of Dengue fever cases (2012) in relation to rainfall and DTR



X-axis: Monthly average Diurnal Temperature Range (DTR) & Monthly rainfall recorded in year 2012

Y-axis: Monthly number of dengue cases recorded during the year 2012

Similar observations were made from the present study with the plastic containers being more productive than other container types. The individual and population level fitness of the principal vectors of dengue can be evaluated from the densities in the respective container habitats. Considering Puducherry and the type and amount of solid wastes generated, it is more probable that the plastic, glass and rubber waste materials generated from household or otherwise augment the availability of possible larval habitats and their utility as ovipositor sites by *Aedes* mosquitoes.

Dengue vector, *Ae. aegypti* has adapted to breeding in outdoor containers, and thus even a moderate rainfall can boost its population that can spread dengue rapidly under conditions with an ideal temperature of 22–35° C (Rozilawati *et al*., 2007). The higher larval indices recorded in the month of November (HI-35.8, CI-19.4, BI-53.3) as compared to October (HI-35.2, CI-18.2, BI-50.01), was due heavy rainfall in October that resulted in loss of some larval population. The higher larval population of dengue vectors in the rainy months (September to November) was due to the greater number of larval habitats, which were reduced in the dry months but maintained a low level via some pocket breeding sites, as seen in previous studies (Moore *et al.*, 1978). The present study witnessed a higher BI and HI values with rainfall, while a lower value for CI is of concern. This could be due to increase in number of wet containers during rainy season. The DTR seems to have a direct effect on the infectivity of *Ae. aegypti* with dengue virus. It is reported elsewhere that a high DTR range (20°C) reduces the probability of infection as the mosquitoes are less susceptible to virus infection and die faster under a higher DTR while a low range (10°C) increases the rate of infection (Lambrechts *et al*., 2011). The current study also observed the critical transmission of dengue during the month of October with lowest DTR (5.9) as the low DTR favored vector survival and virus replication thereby increasing number of dengue cases. The population of immature *Aedes* mosquitoes is reduced in the dry months, because light rain of 10 mm/day is not sufficient to produce positive containers due to the rapid drying effect of strong sunlight in Puducherry (tropical area). This has been evidenced by the current study with lower values of larval indices during dry periods of April (BI 7.6,) and May (BI 9.7). Generally, the combination of higher temperature and rapid drying is detrimental to egg, larval, and adult production (Alto and Juliano, 2001). Moreover, container-breeding mosquitoes do not lay eggs under low moisture conditions, because freshly laid eggs require contact with sufficient moisture for about 48 hour for proper embryonic development (Saifur *et al*., 2010). Proliferation of *Ae. aegypti* has been favored by improper waste management, or poor sanitation, which results in the accumulation of potential water-holding discards suitable as larval habitats. In addition, various reasons have been cited for the increases in dengue vector populations and dengue cases in various outbreaks, including the migration of susceptible individuals from non-endemic to endemic areas, rapid and uncontrolled urbanization, disturbance of human ecology with concurrent population growth, and the creation of slums and living conditions that perpetuate vector breeding, thus facilitating transmission of vector-borne disease (Sutherst, 2004). All of these conditions are prevailing in Puducherry, though we have not dealt with them in the present study.

Increasing number of cases during 2011 & 2012, in both urban and rural villages when compared to the outbreak in 2003, gives an indication of the continued existence of potential risk of dengue and endemic stability. In Puducherry, population increase from 9.74 lakhs in 2001 to 12.44 lakhs in 2011(urban population: 8,52,753 & rural population: 3,95,200), migration from neighboring states and rapid urbanization created strain on resources such as land and water, leading to ugly environmental consequences (Directorate of Economics and Statistics, Puducherry., 2013). Frequent outbreaks and spread of dengue infection in Puducherry in 2011 and 2012, reveal the demand for the in depth analysis of climate variables in future both at macro and micro level towards advance warning of epidemic forecasting for dengue containment.

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