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GEOSPATIAL ANALYSIS OF FILARIASIS RISK IN VIZIANAGARAM DISTRICT OF ANDHRA PRADESH, INDIA

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Abstract

Mapping of geographical distribution and identification of disease-prone areas is an important element in disease management efforts. The present study demonstrates the significance of geospatial mapping in identifying the risk zones of vector-borne diseases by taking a case study of lymphatic filariasis in Vizianagaram district of Andhra Pradesh. Data on the filarial cases recorded during 2007-2014 from 62 primary health centres in the district and the land use/land cover map prepared from the satellite images from 2012 were spatially correlated. About 2.7 per cent of people have been affected by filariasis during 2007-2014 in the district with spatial variations at regional and mandal (tehsil) levels. Location quotient analysis has revealed that hilly region with dense forest cover is relatively less vulnerable, whereas the plain region characterized by large number of water bodies and extensive irrigated cropland besides urban environment is more vulnerable to filariasis.

Introduction

Diseases such as malaria, dengue, lymphatic filariasis, schistomiasis, leishmaniasis, chagas disease, onchocerciasis and yellow fever are some of the prominent vector-borne diseases accounting for one sixth of the illness and disability in the world with more than half of the population at risk (Campbell-Lendrum et al., 2015). Vectors are tiny organisms which include mosquitoes, ticks, flies, fleas, bugs and freshwater snails that inject disease causing pathogens during a blood meal from infected human or animal and later transmit them to a new host (Khan, 2015). In general, vector-borne diseases are region-specific (Githeko et al., 2000). However, environmental change induced by anthropogenic activities such as climate change, deforestation, intensive agriculture, dam construction, irrigation, population migration, international travel and urbanization are responsible for the extension of geographical range of vectors, thereby spread of disease globally (Githeko et al., 2000; Sutherst, 2004; Jaenson et al., 2012).

Mosquitoes are the most common disease causing vector. About 700 million people are infected and more than one million people succumb annually because of mosquito-borne diseases (Caraballo and King, 2014). India alone accounts for about 40 per cent and Sub-Saharan Africa about 37 per cent of the global burden, while the remainder spread across Americas, the Pacific Islands, Papua New Guinea and South-East Asia (Ramaiah et al., 2000; Zagaria and Savioli, 2002; Wynd et al., 2007). Identification of disease-prone areas is an important element in disease prevention and management efforts. Geospatial analysis of disease investigation improves operational planning (Freier et al., 2007) since geographical distribution and seasonal variation of vector-borne diseases are largely a function of climate, relief and a host of land use/cover variables (Palaniyandi et al., 2014).

Lymphatic filariasis, commonly known as filariasis or elephantiasis, transmitted by mosquitoes is a most debilitating but neglected tropical disease (Ram, 2015). It is the second leading cause of permanent and long-term disability in the world, after leprosy (Rautaraya et al., 2011). Lymphatic filariasis is associated with warm and humid climatic regions (Mackenzie et al., 2009). It is an ancient disabling and disfiguring disease found in Ancient Greek literature and humans suffered from it for over 1500-4000 years. In India, lymphatic filariasis was documented in 'Susruta samhita' as early as in 6th century B.C. (Cox, 2002). This disease is referred to as 'Malabar legs' by Clarke in 1709, as it widely prevailed in Malabar region along the west coast of India (Raghavan, 1957). As the lymphatic filariasis parasite is a thread-like worm, therefore the disease is named as Filariasis ('Filar' means 'thread-like'). Further, as the tiny microfilariae coil together in lymphatic vessels and glands of human lymph system, the disease is named as Lymphatic Filariasis (Park and Park, 1977; Knopp et al., 2012).

Filariasis is a prolonged disease with repeated episodes of inflammation and lymphedema which ultimately causes lymphatic damage, acute swelling and elephantiasis (an oedema with thickened skin and underlying tissue) of legs, arms and private parts of the human body (Meyrowitsch et al., 2010; Okon et al., 2010; Mathieu et al., 2011; Uttah, 2011; Molyneux, 2012). There is no gender or age specification for the incidence of lymphatic filariasis. Mortality due to lymphatic filariasis is not direct but through disability which impairs quality of life (Evans et al., 1993; Michael et al., 1996; Ramaiah et al., 1997; Ahorlu et al., 2001).

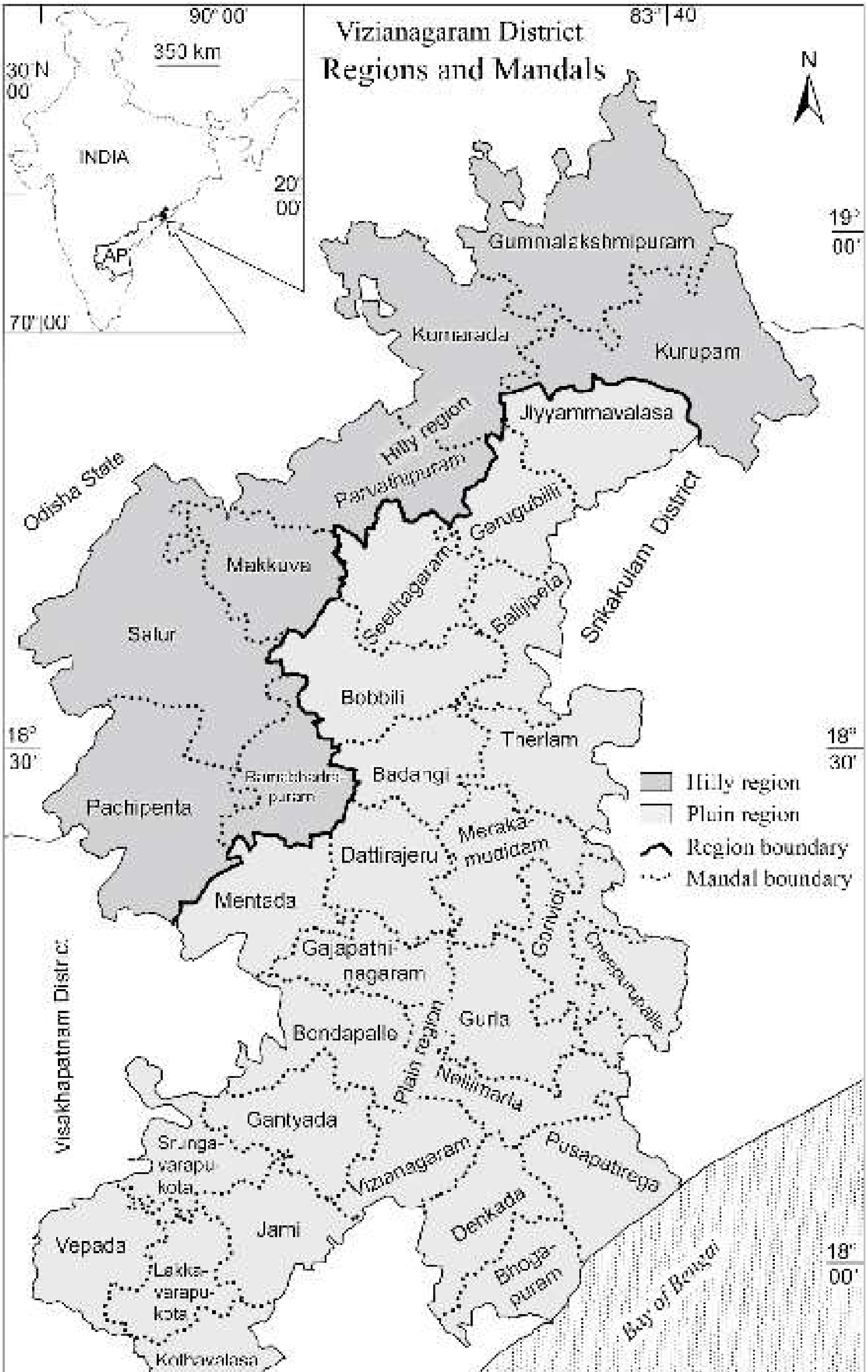
In India, lymphatic filariasis prevails in 17 States and six Union Territories with 553 million people at risk, of which, about 146 million live in urban areas, (Pani et al., 2005; Sabesan et al., 2010). Seven states, namely Andhra Pradesh, Bihar, Kerala, Odisha, Uttar Pradesh, Tamil Nadu and West Bengal account for over 86 per cent of carriers and 97 per cent of cases in the country (WHO, 2005). Out of 13 districts of Andhra Pradesh 10 districts including all the nine coastal districts and Chittor in the interior Rayalaseema region are endemic to filariasis. Therefore, in the present study, Vizianagaram district, which is highly endemic to filariasis in the northern part of the coastal Andhra Pradesh, is taken up as a case study to highlight the degree of filariasis risk and its spatial variations in the district.

Objective of the Study

The major objective of the present study is to identify the risk zones of vector-borne diseases through geospatial mapping by taking a case study of lymphatic filariasis in Vizianagaram district, Andhra Pradesh

Study Area

Vizianagaram district covering an area of 6,539 km^2 exhibits two distinct physiographic zones: hilly region and plain region (Fig.1). The hilly region, which forms a part of the Eastern Ghats, covers about 2360



Vizianagaram District
Regions and Mandals
N
INDIA
AP
350 km
90° 00'
30°N 00'
20° 00'
70° 00'
83° 40'
19° 00'
18° 30'
18° 00'
Gummalakshmipuram
Komarada
Kurupam
Jiyyammavalasa
Hilly region
Parvathipuram
Odisha State
Garugubilli
Makkuva
Seethanagaram
Balijipeta
Srikakulam District
Salur
Bobbili
Therlam
Ramabhadra-puram
Badangi
Pachipenta
Merakamudidam
Dattirajeru
Mentada
Garividi
Cheepurupalle
Gajapathinagaram
Visakhapatnam District
Gurla
Bondapalle
Plain region
Nellimarla
Gantyada
Srungavarapukota
Vizianagaram
Pusapatirega
Jami
Denkada
Vepada
Lakkavarapukota
Bhogapuram
Bay of Bengal
Kothavalasa
10 km
Hilly region
Plain region
Region boundary
Mandal boundary

Fig. 1

km^2 in the district. The average elevation of the hilly region is 900 m with the relief ranging between 600 and 1200 m. The remaining 4179 km^2 is the plain region, which is largely an undulating tract below 100 m elevation with only a few isolated hills rising up to 300 to 500 m above the sea level. The Nagavali, Suvarnamukhi, Vegavathi, Champavathi and Kandivalasa rivers and a host of ephemeral streams traverse the region.

Vizianagaram district comes under semi-arid climate notwithstanding some regional variations. The average annual rainfall of the district is around 1132 mm out of which 693 mm occurs during the south-west monsoon season (June-September), about 246 mm in the north-east monsoon season (October-November), 26 mm in winter (December-February) and 167 mm during summer (March-May). On the whole, the hilly region in the district receives about 1284 mm rainfall while the plain region receives 981 mm rainfall. The annual average temperature in the district is 28.1˚C with some minor seasonal variations, viz., about 29.8˚C during south-west monsoon season, 27˚C in north-east monsoon, 24.3˚C in winter and 30.4˚C in summer season. The normal monthly relative humidity ranges between 70 per cent and 82 per cent with highest of 78-82 per cent during south-west monsoon season, followed by 70-78 per cent in north-east monsoon season, 67-74 per cent in winter and 75-77 per cent in summer seasons.

Administratively, the district is divided into 34 revenue mandals (tehsils) with 23, 44,474 population, of which males constitute 49 per cent and females 51 per cent as per the Census of India, 2011. The population density in the plain region is 437 persons per km^2. On the other hand, the hilly region is relatively less densely populated with about 220 persons per km^2. The population of the forested hilly zone includes 1,77,229 tribal people. About 82 per cent of people in the district live in rural areas and 68.4 per cent are engaged in agricultural activities.

Database and Methodology

Monthly data on filariasis, recorded during 2007-2014, have been collected from 62 primary health centers distributed in 33 revenue mandals of Vizianagaram district, excluding Badangi mandal for which filarial data were not available. Two adjacent remote sensing images of IRS (Indian Remote Sensing Satellite) LISS-III sensor Path 104 and Rows 059 and 060 dated January 16, and March 4, 2012 have been used for mapping the various land use/land cover features of the district. Spatial variations in filariasis cases in the district have been mapped using GIS tools. Filariasis risk zones in the district are delineated by using the Location Quotient method (LQ), which is the ratio of the proportions that illustrates relative filarial incidence by mandal. The formula for deriving LQ is as follows:

$$LQ = \frac{N_{Mandal}/P_{Mandal}}{N_{District}/P_{District}}$$

where, N_{Mandal} and $N_{District}$ represent number of filariasis cases in the mandal and the district, respectively, and P_{Mandal} and $P_{District}$ represent the total population of the mandal and district, respectively. An LQ more than 1 indicates that the given mandal has more than its average share of cases proportionate to its size. The intensity levels of filariasis in different mandals of Vizianagarm district have been computed based on LQ distribution.

The filarial-risk zones in the district are demarcated based on computation of the mandal-wise filarial-risk factors. For this purpose, the yearly LQ values of each mandal are ranked into five levels: rank 1 (LQ value <0.5), rank 2 (0.5–1.0), rank 3 (1.1–2.0), rank 4 (2.1–3.0) and rank 5 (>3.0).

The rank frequencies (i.e., during how many years each rank value repeated) is counted for all the mandals. The rank frequencies are then multiplied by their respective rank values to obtain the weighted value for the disease intensity level. For instance, for mandal 12 (Balijipeta), the frequency of ranks 1, 2 and 5 are zeros and hence their weighted values are zeros (0x1=0, 0x2=0 and 0x5=0). Similarly, the frequency of rank 3 is one and hence its weighted value is 3 (1x3=3). Again, the frequency of rank 4 is 7 and its weighted value is thus 28 (4x7=28). The sum of the five weighted values is 31 (0+0+3+28+0=31) for the mandal (Balijipeta) for the entire period. This is divided by the total number of years (i.e., 8 from 2007 to 2014) to obtain the average annual weighted value for the mandal (which in this case is 31/8= 3.9).

Further, the annual average weighted LQ values are rationally divided into four filarial risk categories: low-risk (weighted value < 1.0); moderate-risk (weighted values 1 to 2), high-risk (2.1 to 3) and very high-risk (>3). However, three categories (moderate, high and very high) of filaria risk could be identified in the district. Based on filaria risk levels for all the mandals of Vizianagaram district a map has been prepared for geospatial analysis.

Results and Discussion

(i) Land use/land cover

Agriculture is the dominant land use/land cover feature occupying 3976 km^2 comprising 60 per cent of the study area (Table 1). Cropland is predominant in the plain region occupying 3181 km^2 (80 per cent) against only 795 km^2 (20 per cent) in the hilly region. The major crops grown in the district are paddy, groundnut, ragi, bajra, cotton, mesta, sugarcane and pulses. Forest cover is the most dominant feature in the hilly region occupying 1267 km^2 (53 per cent) against only 208 km^2 (5 per cent) in the plain region. Forest types constitute a variety of tropical dry deciduous vegetation in the plain region and dry evergreen vegetation in the hilly region. While scrub/gullied land covers 159 km^2 and 66 km^2 in the hilly and plain regions respectively, the built-up land (both urban and rural settlements) comprises 81 km^2 in the hilly region and 371 km^2 in the plain. The district, however, is known for large number of ephemeral tanks and farm ponds of different sizes (Fig. 2), which were built by constructing earthen embankments across the streams at regular intervals all along their courses to create series of garland tanks besides a host of farm ponds dug up as water harvesting structures to store water in this water-scarce region. There are about 6700 water bodies in the district covering 411 km^2 with 58 km^2 (14 per cent) in the hilly region and 353 km^2 (86 per cent) in the

Table 1
Vizianagaram District: Land Use/Land Cover, 2012

Land Use/Land Cover Category	Area (km^2)		
	Hilly Region	Plain Region	Total
Forest Land	1267	208	1475
Scrub/Gullied Land	159	66	225
Water Bodies	58	353	411
Plantation/Cropland	795	3181	3976
Built-up Land	81	371	452
Total	**2360**	**4179**	**6539**

Source: Computed by Authors

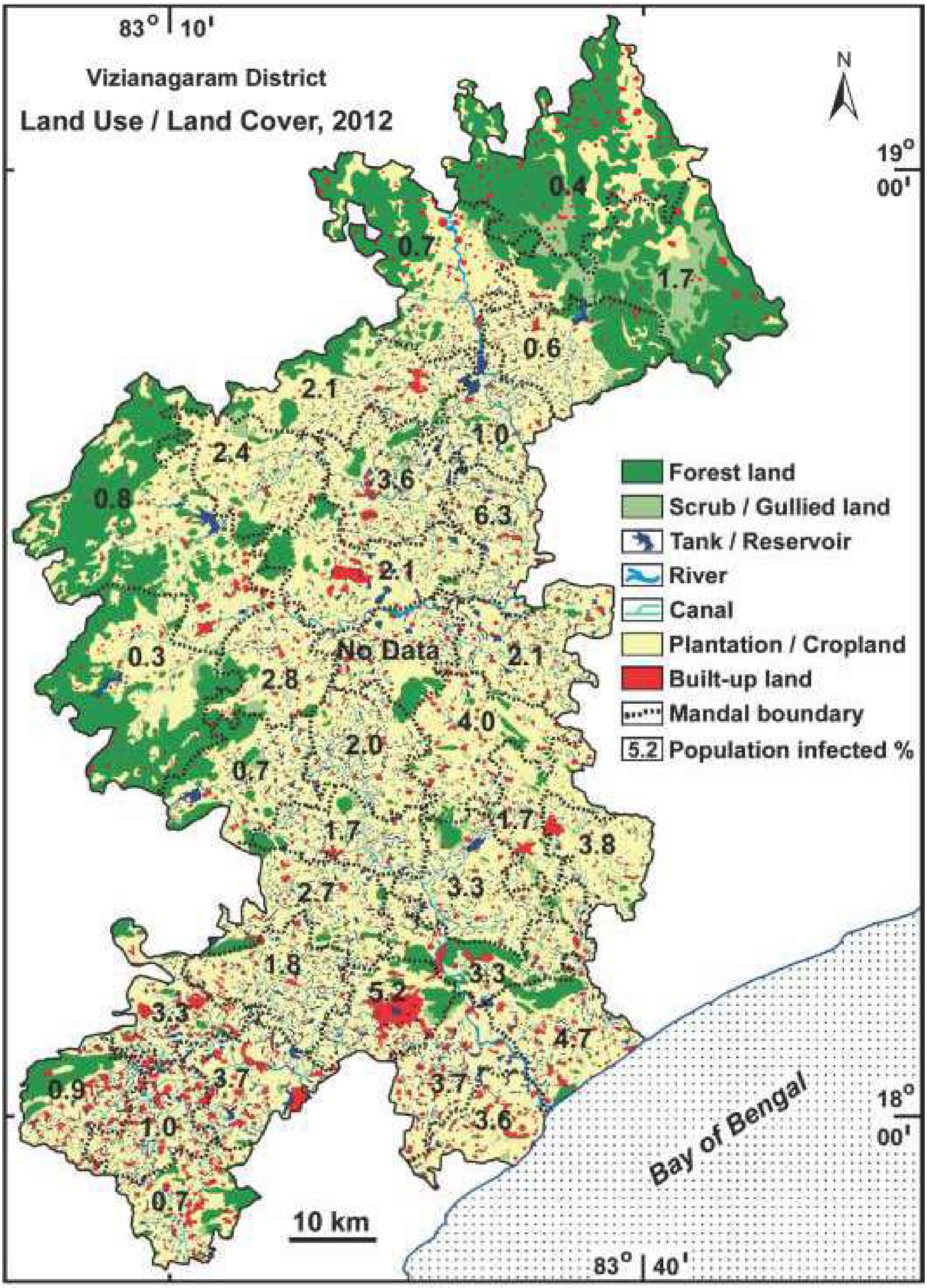

83° 10'
Vizianagaram District
Land Use / Land Cover, 2012
N
19° 00'
0.4
0.7
1.7
0.6
2.1
1.0
2.4
3.6
0.8
6.3
2.1
No Data
0.3
2.8
2.1
4.0
2.0
0.7
1.7
1.7
3.8
2.7
3.3
1.8
3.3
5.2
3.3
4.7
0.9
3.7
3.7
1.0
3.6
0.7
18° 00'
Bay of Bengal
10 km
83° 40'
Forest land
Scrub / Gullied land
Tank / Reservoir
River
Canal
Plantation / Cropland
Built-up land
Mandal boundary
5.2 Population infected %

Fig. 2

plain region, respectively accounting for about 1.59 per cent area of the hilly region and 6.6 per cent area of the plain region. The total water holding capacity of the tanks is about 284 million m^3, which is used for irrigating about 670 km^2 out of total 3976 km^2 of cropped area in the district. About 80 per cent of paddy crop in the district is cultivated under tank irrigation.

(ii)Trends in Filaria incidence

About 61775 filarial cases have been reported from all the mandals of the district during 2007-2014 excluding Badangi mandal. The filarial incidence by and large has increased since 2007 with maximum 8613 cases in 2009 and minimum of 6467 in 2011 (Table 2). Notably, no year during the study period was free from filarial incidence. On an average, 2.7 per cent of the total population of the district has been inflicted with this disabling disease in just about eight years (2007-2014) with a relatively higher percentage of 3.05 per cent population in the plain region when compared with 1.4 per cent in the hilly region (Table 3). Out of the total 61775 cases, filariasis has manifested in elephantiasis of legs in 56653 persons, hands 2878 persons and private parts 2244 persons.

Distribution of filarial cases in Vizianagaram district indicated large spatial variations. The plain region accounts for 88 per cent cases against 12 per cent cases in the hilly region during the study period. Out of the 25 mandals of plain region (excluding Badangi mandal) Vizianagaram mandal recorded 14836 (24.0 per cent), the highest number of filarial cases among all mandals. However, Balijipeta mandal tops the list in terms of percentage of people (6.3 per cent), inflicted with filariasis, whereas Jiyyammavalasa mandal stands lowest with only 0.6 per cent infected population during the study period (Table 3; Fig. 2). Among the mandals of hilly region, Parvatipuram recorded highest number (2388) of cases comprising 32.26 per cent of total cases reported from the hilly region. However, Ramabhadrapuram mandal reported highest percentage (2.8) of population infected, while Pachipenta mandal recorded lowest percentage (0.3) of population infected by filariasis from the hilly region (Table 3; Fig. 2). On the whole, the predominantly forested hilly region has low filarial incidence when compared to the agriculture dominant plain region. Earlier studies indicated that areas with irrigated agriculture coincide with proliferation of filariasis causing vectors (Erlanger et al., 2005) which may be true in the case of Vizianagaram district as well. Similarly, urban areas are also known for higher filarial incidence (Simonsen

Table 2
Vizianagaram District: Year-wise, Number of Cases of Filariasis, 2007-14

Year	No. of Cases	Percentage
2007	6613	10.7
2008	8355	13.5
2009	8613	13.9
2010	8015	13.0
2011	6467	10.5
2012	8110	13.1
2013	8400	13.6
2014	7202	11.7
Total	**61775**	**100**

Source: Compiled from the Records of 62 Primary Health Centres in the District

Table 3
Vizianagaram District: Mandal-wise, Population, Number of Cases and Percentage of Population Infected by Filariasis, 2007-2014

Mandal	Population	No. of Cases	Population Infected (%)
Hilly Region			
Kurupam	48402	840	1.7
Gummalakshmipuram	49507	178	0.4
Komarada	51993	346	0.7
Parvathipuram	113638	2388	2.1
Makkuva	50506	1228	2.4
Salur	105389	893	0.8
Pachipenta	48233	136	0.3
Ramabhadrapuram	50464	1394	2.8
Hilly Region Total	**518132**	**7403**	**1.4**
Plain Region			
Jiyyammavalasa	52360	330	0.6
Garugubilli	46773	490	1.0
Seethanagaram	58182	2088	3.6
Balijipeta	59764	3794	6.3
Bobbili	122964	2541	2.1
Therlam	59688	1271	2.1
Mentada	46855	306	0.7
Badangi	49384	No data	-
Merakamudidam	57237	2298	4.0
Dattirajeru	54499	1094	2.0
Gajapathinagaram	57529	984	1.7
Garividi	68289	1133	1.7
Cheepurupalle	63408	2406	3.8
Gurla	64695	2167	3.3
Bondapalle	51146	1392	2.7
Nellimarla	77031	2556	3.3
Pusapatirega	71955	3385	4.7
Gantyada	65579	1178	1.8
Vizianagaram	283550	14836	5.2
Denkada	54382	2018	3.7
Bhogapuram	54891	1952	3.6
Srungavarapukota	75917	2543	3.3
Jami	58066	2130	3.7
Vepada	50580	472	0.9
Lakkavarapukota	53039	526	1.0
Kothavalasa	68579	482	0.7
Plain Region Total	**1826342**	**54372**	**3.05***
District Total	**2344474**	**61775**	**2.7***

*Source: Computed by Authors (*excluding the population of Badangi mandal for which filarial data are not available).*

Table 4
Vizianagaram District: Mandal-wise, Location Quotient of Filariasis, 2007-14

Mandal	2007	2008	2009	2010	2011	2012	2013	2014	Average
Hilly Region									
Kurupam	0.67	0.69	0.68	0.53	0.55	0.78	0.78	0.56	0.66
Gummalakshmipuram	0.12	0.13	0.13	0.14	0.10	0.15	0.15	0.15	0.13
Komarada	0.25	0.25	0.24	0.25	0.20	0.28	0.28	0.26	0.25
Parvathipuram	0.85	0.75	0.76	0.77	0.70	0.85	0.87	0.82	0.80
Makkuva	0.97	0.90	0.88	0.87	0.80	1.01	1.01	0.92	0.92
Salur	0.33	0.29	0.35	0.33	0.27	0.30	0.37	0.32	0.32
Pachipenta	0.08	0.11	0.11	0.12	0.07	0.12	0.12	0.12	0.11
Ramabhadrapuram	0.93	1.08	1.11	0.94	0.76	1.22	1.29	1.00	1.04
Plain Region									
Jiyyammavalasa	0.16	0.25	0.25	0.26	0.13	0.29	0.29	0.27	0.24
Garugubilli	0.43	0.37	0.36	0.40	0.35	0.42	0.42	0.42	0.40
Seethanagaram	1.23	1.37	1.34	1.35	1.02	1.55	1.55	1.43	1.36
Balijipeta	2.37	2.34	2.28	2.48	1.95	2.64	2.56	2.59	2.40
Bobbili	0.65	0.78	0.79	0.82	0.54	0.88	0.92	0.85	0.78
Therlam	1.01	0.78	0.76	0.83	0.78	0.82	0.83	0.66	0.81
Mentada	0.21	0.25	0.24	0.26	0.17	0.28	0.28	0.28	0.12
Badangi	-	-	-	-	-	-	-	-	-
Merakamudidam	1.22	1.54	1.50	1.63	1.00	1.74	1.74	1.74	1.51
Dattirajeru	0.90	0.78	0.40	0.94	0.74	0.88	0.46	1.00	0.76
Gajapathinagaram	0.63	0.60	0.64	0.70	0.52	0.68	0.74	0.66	0.65
Garividi	0.57	0.62	0.70	0.60	0.47	0.69	0.83	0.52	0.63
Cheepurupalle	1.47	1.32	1.38	1.54	1.21	1.53	1.60	1.44	1.44
Gurla	1.37	1.45	1.41	0.75	1.13	1.63	1.63	0.74	1.26
Bondapalle	1.07	0.98	0.96	1.04	0.88	1.11	1.11	1.11	1.03
Nellimarla	1.61	1.33	1.30	0.73	1.32	1.50	1.50	0.77	1.26
Pusapatirega	1.38	1.74	1.81	1.96	1.14	1.96	2.09	2.08	1.77
Gantyada	0.87	0.72	0.70	0.76	0.59	0.61	0.63	0.56	0.68
Vizianagaram	2.17	1.90	1.96	2.02	1.79	2.03	2.15	1.82	1.98
Denkada	1.43	1.36	1.34	1.41	1.17	1.53	1.55	1.44	1.40
Bhogapuram	1.13	1.22	1.38	1.51	0.93	1.38	1.60	1.59	1.34
Srungavarapukota	1.56	1.45	1.41	1.45	0.89	1.42	1.42	0.51	1.26
Jami	0.98	1.43	1.48	1.61	0.77	1.39	1.77	1.60	1.38
Vepada	0.30	0.39	0.38	0.41	0.25	0.38	0.38	0.32	0.35
Lakkavarapukota	0.32	0.36	0.38	0.41	0.26	0.40	0.44	0.44	0.38
Kothavalasa	0.21	0.27	0.26	0.28	0.18	0.31	0.31	0.30	0.27

Source: Computed by Authors

Table 5
Vizianagaram District: Mandal-wise, Filariasis Risk Factor Analysis

Mandal	Rank-wise Frequency of Filariasis Incidence					Weighted LQ Value	Annual Average	Risk Category
	1	2	3	4	5			
Hilly Region								
Kurupam	0	8	0	0	0	16	2.0	Moderate
Gummalakshmipuram	8	0	0	0	0	08	1.0	Moderate
Komarada	8	0	0	0	0	08	1.0	Moderate
Parvathipuram	0	8	0	0	0	16	2.0	Moderate
Makkuva	0	6	2	0	0	18	2.3	High
Salur	8	0	0	0	0	08	1.0	Moderate
Pachipenta	8	0	0	0	0	08	1.0	Moderate
Ramabhadrapuram	0	4	4	0	0	20	2.5	High
Plain Region								
Jiyyammavalasa	8	0	0	0	0	08	1.0	Moderate
Garugubilli	8	0	0	0	0	08	1.0	Moderate
Seethanagaram	0	0	8	0	0	24	3.0	High
Balijipeta	0	0	1	7	0	31	3.9	Very High
Bobbili	0	8	0	0	0	16	2.0	Moderate
Therlam	0	7	1	0	0	17	2.1	High
Mentada	8	0	0	0	0	08	1.0	Moderate
Badangi	-	-	-	-	-	-	-	-
Merakamudidam	0	1	7	0	0	23	2.9	High
Dattirajeru	2	6	0	0	0	14	1.8	Moderate
Gajapathinagaram	0	8	0	0	0	16	2.0	Moderate
Garividi	1	7	0	0	0	15	1.9	Moderate
Cheepurupalle	0	0	8	0	0	24	3.0	High
Gurla	0	2	6	0	0	22	2.8	High
Bondapalle	0	2	6	0	0	22	2.8	High
Nellimarla	0	0	6	2	0	23	2.8	High
Pusapatirega	0	0	2	4	2	34	3.3	Very High
Gantyada	0	8	0	0	0	16	2.0	Moderate
Vizianagaram	0	0	4	4	0	28	3.5	Very High
Denkada	0	0	8	0	0	24	3.1	Very High
Bhogapuram	0	1	7	0	0	23	2.9	High
Srungavarapukota	0	2	6	0	0	22	2.8	High
Jami	0	2	6	0	0	22	2.8	High
Vepada	8	0	0	0	0	08	1.0	Moderate
Lakkavarapukota	8	0	0	0	0	08	1.0	Moderate
Kothavalasa	8	0	0	0	0	08	1.0	Moderate

Source: Computed by Authors

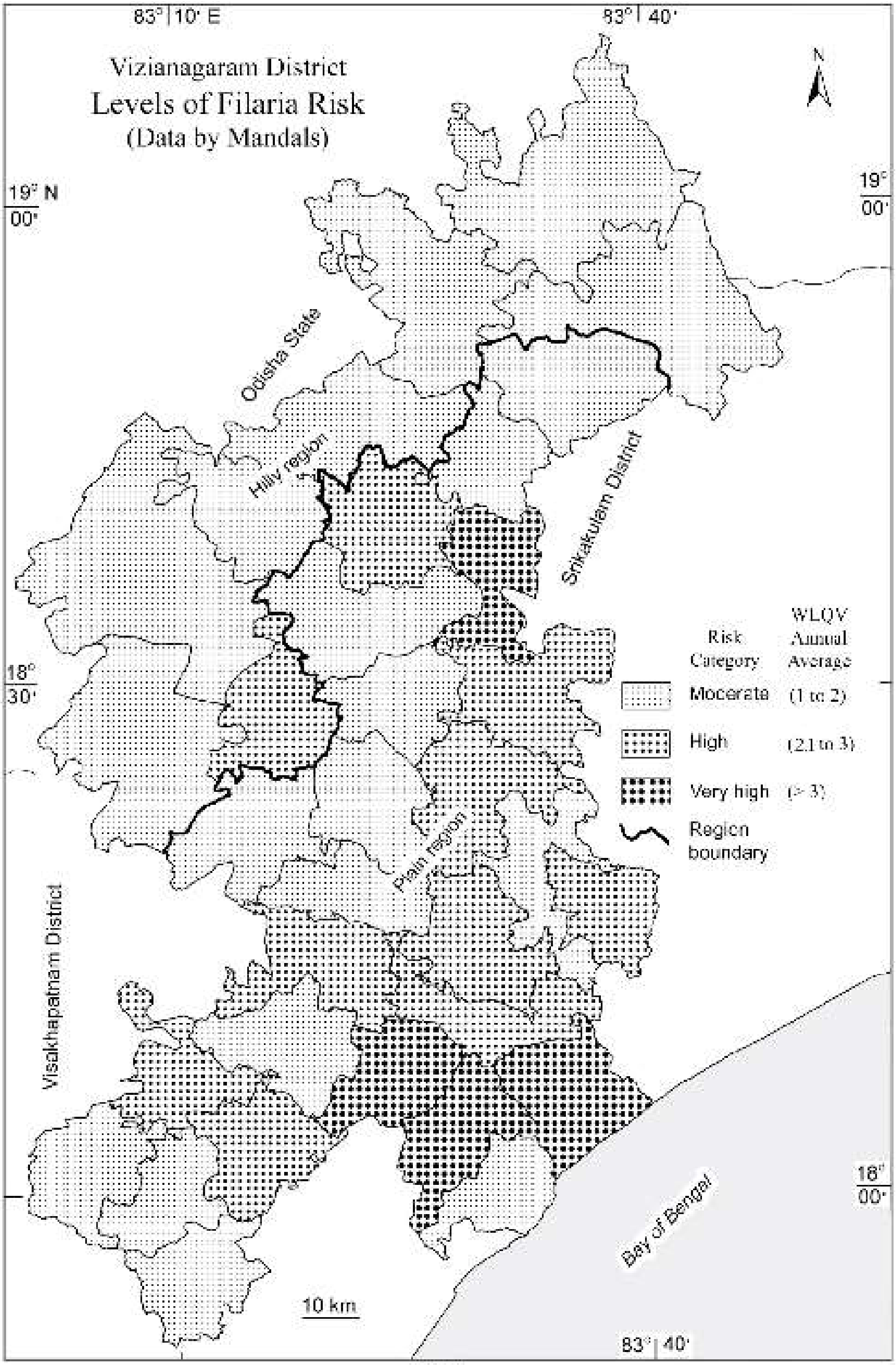

83° | 10' E
83° | 40'
Vizianagaram District
Levels of Filaria Risk
(Data by Mandals)
N
19° N
00'
19°
00'
Odisha State
Hilly region
Srikakulam District
Risk Category
WLQV Annual Average
Moderate (1 to 2)
High (2.1 to 3)
Very high (> 3)
Region boundary
18°
30'
Plain region
Visakhapatnam District
18°
00'
Bay of Bengal
10 km
83° | 40'

Fig. 3

and Mwakitalu, 2013), which seems to hold good in the study area as Vizianagaram mandal (including Vizianagaram town) and Parvathipuram mandal (including Parvathipuram town) have shown comparatively higher percentage of infected population 5.2 and 2.1 per cent respectively in the district (Table 3; Fig. 2).

(iii) Filaria Risk Analysis

The yearly intensity of filaria based on computed LQ indicated that filarial incidence is at higher levels in the plain region as 13 out of the 25 mandals showed annual average LQ values more than 1, whereas only one out of the eight mandals in the hilly region has the average LQ value more than 1 (Table 4).

Based on the risk analysis, it was found that out of the total 33 mandals (sans Badangi mandal) of the district, four mandals (12.1 per cent) are under 'very high risk' category, 12 mandals (36.4 per cent) are under 'high risk', while, 17 (51.5 per cent) are under 'moderate risk' category. All the four mandals (Vizianagaram, Pusapatirega, Denkada and Balijipeta) under 'very high risk' category followed by 10 other mandals in 'high risk' category are located in the plain region. On the other hand, six out of total eight (75 per cent) mandals in the hilly region are in 'moderate risk' category indicating the moderate level of filariasis in the forested hilly zone of the district (Table 5; Fig 3). Even the remaining two mandals (Ramabhadrapuram and Makkuva), in the hilly region, which are under the 'high risk' category are located along the plain region boundary. Thus, the study brings out that the plain region is more risky for filariasis disease than hilly region.

Conclusions

The study revealed that Vizianagaram district is highly prone to filarisis as not even a single mandal of the district is free from this disease. Notably, no mandal in the district come under 'low risk' category therefore, district is termed as filarial-endemic zone. The plain areas with irrigated cropland, higher concentration of water bodies, high density of population and urban environment (Vizianagaram town) are predominantly prone to filariasis. On the other hand, hilly areas with forested land, low concentration of water bodies, and less pressure of population with no major urban centres are less prone to filariasis.

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