4

Visceral Leishmaniasis

Visceral leishmaniasis (VL), a deadly disease, also known as kala-azar is endemic in Brazil, Bangladesh, India, Nepal and Sudan. In India it is endemic in Bihar, Uttar Pradesh and West Bengal states. Bihar alone harbours 40–50% of the world's cases and 90% of the cases reported from India. *Phlebotomus argentipes*, commonly known as sand fly, is the vector species transmitting this disease. Sand fly is a peri-domestic species. Like malaria, kala-azar is also a local and focal disease and the reasons for the clustering of the cases is probably associated with local ecological and socio-demographic features. Some of the macro-environmental factors such as soil, humidity, soil pH, minerals in the soil and presence of certain vegetations in and around human habitats create suitable breeding grounds for the presence and survival of vector species to efficiently transmit the disease. Micro-environments like cracks and crevices in the mud-walls of human dwellings and cattlesheds were found to enhance the vector population and consequently the disease. Organic debris of cattle provides ideal breeding places for the vector. There are also areas which are not endemic to kala-azar but have *P. argentipes*. The distribution pattern of *P. argentipes* in endemic and non-endemic foci of kala-azar is very important from the disease transmission and control point of view. An analysis to determine the most important ecological factors affecting the presence of sand fly is the need of the day.

4.1 RS and GIS in Identifying and Mapping Sand Fly Distribution in Endemic and Non-endemic Kala-Azar Foci

This study was carried out by the Regional Medical Research Institute, Patna in collaboration with the Regional Remote Sensing Service Centre of the Indian Space Research Organization at the Indian Institute of Technology Campus, Kharagpur, West Bengal.

Keeping in view the importance of identifying the factors that promote sand fly presence and its prevalence, this study was planned using Remote Sensing and Geographical Information System technologies with the following objectives: (i) to find association of vegetation, soil and sub-soil water in different environmental conditions with sand fly distribution in endemic and non-endemic foci of visceral leishmaniasis; (ii) to map geographical distribution of vector to define macro-ecosystem of sand fly and kala-azar; and (iii) to monitor effect of specific vegetation cover, water bodies, human settlements and other land use features through conventional ground surveys as well as satellite images on vector abundance in endemic and non-endemic sites to evaluate its role as an "epidemic predictor".

Two study sites representing different types of eco-systems were selected. In Bihar state, Patepur PHC/block in Vaishali district, one of the high endemic areas of Kala-azar in north Bihar as endemic focus, and in Jharkhand state, Lohardaga PHC/block in Lohardaga district as non-endemic focus were selected.

Vaishali is situated in the eastern state of Bihar, about 55 km from Patna, the capital of the state (Figure 44). Vaishali extends from latitude 25° in the North to longitude 85° in the East. As in other places in the upper Gangetic plain, the climate of this area is tropical in nature. The region is almost flat plain. The principal soil type throughout the district is alluvial and alkaline (pH 7.0 – 8.3). Patepur PHC/Block is situated at the north-east corner of Vaishali district. The total estimated annual rainfall in this area is around 2500–5500 mm. The humidity ranges between 50% during winter and 95% during rainy and summer seasons.

(a) Bihar state (b) Vaishali district (c) Patepur block

Figure 44: Location of endemic study areas in Bihar state

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Table 10. Details of the selected villages in Patepur block, Vaishali district, Bihar

Village code	Village	Area (in ha)	Cultivable land (in ha)	Non-cultivable land (in ha)	Projected population	HH	F size
E1	Shahpur Buzurg	177.8	22.56	14.71	998	162	6.16
E2	Maina Chaprai	94.55	4.05	18.06	585	85	6.88
E3	Harlochanpur Suki	372.48	50.05	59.75	3391	507	6.69
E4	Mohhamadpur Suki	44.33	4.77	0.27	1004	166	6.05
E5	Mhathidhramchand	358.6	46.34	51.66	3322	503	6.60
E6	Mataiya	126.32	2.02	118.37	1155	147	7.86
E7	Chakiya	303.08	NA	39.07	1039	144	7.22
E8	Kawaibaraila	293.24	28.33	61.2	227	36	6.31
E9	Mowahchatur	206.8	21.31	55.16	2833	412	6.88
E10	Maudhabuzurg	180.85	18.38	0.52	2418	419	5.77
E11	Simarwaradurgapur	349.35	40.47	2.02	5994	880	6.81
E12	Chakrasulabad	38.6	0.78	1.98	437	73	5.99
E13	Bhagabanpur Kaiju	123.42	2.76	3.96	1087	168	6.47
E14	Lhanipati	74.48	1.51	2.02	910	139	6.55
E15	Bishunpurkawahi	142.46	14.57	54.29	785	153	5.13
E16	Khesarahi	414.19	29.34	36.01	5879	835	7.04
E17	Lohaladpur	54.3	2.08	7.7	965	183	5.27
E18	Maudahdih	152.69	10.38	43.43	1679	255	6.58

HH – Households; F size – Average number of family members per household.

Eighteen villages from five corners of the PHC were selected from the pool of villages in the PHC using the center point co-ordinate of a village. It was ensured that each village selected was at least 2–3 km away from the other selected villages to avoid overlap of surrounding features. Details of the selected villages in Patepur block are given in Table 10.

Lohardaga district in Jharkhand is situated between 84° 40′–84° 50′ East longitude and 23° 30′–23° 40′ North latitude in the Chotanagpur Plateau (Figure 45). The geographical area of the district is 1491 km^2. This area is hilly plain with seasonally flowing streams. The principal soil throughout this area is laterite and acidic (pH 5.7 to 6.1). The climate of this area is tropical in nature with an estimated annual rainfall of 900–1100 mm.

There are 5 development blocks (Lohardaga, Kuru, Bhandra, Senha and Kisko) and 354 revenue villages. As per 2001 censes, Lohardaga had a total population of 3.64 lakh (population density of 244/km^2). The inhabitants of this district mainly depend on agriculture, forest produce and seasonal migration to different parts of the country and 80% of the population depends upon agriculture. Net irrigated area is 13.4%. The main crop of this area is paddy. In the small irrigated area wheat is grown to meet the annual food requirement. The forest cover is around 32–35% of the total area of the district. Twelve (12) villages in Lohardaga PHC/block were selected randomly from the pool of villages in each block as has been done in the Vishali block. The details of the selected villages in this site are given in Table 11. Both the sites experience extreme climates of heat during May–June and cold during December–January. There are three main prevalent seasons in the area, summer, rainy and winter. Season wise temperature and humidity of both areas is presented in Table 12.

(a) Jharkhand state (b) Lohardaga district (c) Lohardaga block

Figure 45: Location of non-endemic study area in—(a) Jharkhand state; (b) Lohardaga district; and (c) Lohardaga block

Table 11. Details of the selected villages in Lohardaga block (non-endemic), Lohardaga district in Jharkhand

Village code	Village	Area (in ha)	Cultivable land (in ha)	Non-cultivable land (in ha)	Projected population	HH	F size
N1	Kujji	276.40	23.63	35.78	934	166	5.63
N2	Kurse	273.33	27.93	41.45	1586	295	5.38
N3	Hesal	738.11	23.22	43.32	1843	458	4.02
N4	Tigra	360.30	21.95	51.70	2097	400	5.24
N5	Joriya	697.75	22.78	48.49	4381	923	4.75
N6	Inta	438.43	24.44	43.42	1139	295	3.86
N7	Gurhi	482.44	41.10	21.67	1546	352	4.39
N8	Baghi	236.51	28.92	31.97	723	159	4.55
N9	Jori	257.99	18.81	53.18	1960	355	5.52
N10	Saheda	238.95	15.71	57.13	646	142	4.55
N11	Manko	397.23	14.91	60.76	1901	322	5.90
N12	Khakparta	483.19	33.90	22.69	1320	277	4.77

Table 12. Season-wise distribution of temperature and humidity in the two study sites

	Patepur (endemic)	Lohardaga (non-endemic)
Temperature	***Mean (Range) °C***	***Mean (Range) °C***
Summer	30.94 (30.39–31.50)	34 (33.39–34.61)
Rainy	27.56 (27.04–28.07)	28.50 (28–29)
Winter	16.72 (15.98–17.46)	17.42 (16.91–17.92)
Humidity	***RH(%)***	***RH%***
Summer	70.33 (68.79–71.88)	47.50 (46–49)
Rainy	91.89 (90.53–93.25)	74.58 (72–77)
Winter	60.11 (58.40–61.82)	64.50 (62–67)

4.1.1 Ground Surveys for Entomological and Environmental Data

Ground surveys were carried out to collect information for each house hold on various parameters like total family members, sex ratio, literacy, areas of water bodies near the settlement, peri-domestic vegetation – trees/plants, cattle shed, kala-azar cases, etc., in both endemic and non-endemic areas. Kala-azar cases reported to the nearest primary health center were also recorded from the registration file. For population data of each village, census data of 1991 were considered as baseline and necessary adjustment was done using annual growth rate.

A door-to-door survey was conducted during each season in each village site for collection of sand flies, recording of temperature and humidity. Adult sand flies were collected from human settlements and animal shelters during dawn and dusk in each season using man-held aspirator and torch. Collected sand flies were preserved in 70% alcohol and number of *P. argentipes* collected at each site in each season was recorded. A standard format was used to describe the location and relief of each site and its soil type, dominant trees and bushes. A crop calendar of both endemic and non-endemic foci was prepared. Important land cover features of both sites are presented in Table 13.

Soil samples were collected from each study site for soil chemistry analysis, which was carried out at the laboratory of Department of Geology, Patna University, Patna (Bihar).

Satellite based information and extraction

Land use classification was derived from the apriori knowledge of the study area. Choice of these land use classes was guided by: (i) the objective of the research; (ii) expected degree of accuracy in image classification; and (iii) the easiness of identifying classes. Multispectral IRD-1D LISS3 data of DOP 11 November 1999 and 15 March 2000 for Patepur block and 3 January 2000 and 23 March 2000 for Lohardaga block were used. The satellite data were geometrically and radiometrically corrected and registered with respect to the known reference points obtained through GPS surveys during the site visit. The block boundary map of both the blocks were scanned and registered with the satellite data. Village boundary layer for each site was also digitized and vector layer was generated. The satellite data were subjected to enhancement technique like linear and histogram stretching and improved quality of the image. Supervised MXL classification techniques were applied with the available ground truth information of the study sites and delineated broad categories of land use/land cover. Village wise area estimates were made for each land cover category. The digital map of the

Table 13. Land cover features and environmental factors in Patepur and Lohardaga blocks

Variables	Patepur	Lohardaga
Land cover	Water bodies 30% Vegetation and agricultural land 40% Settlement 30%; Unclassified Nil	Water bodies 10% Vegetation and agricultural Land 55% Settlement 25% Unclassified 10%
Soil Type	Alluvial	Laterite
Soil pH	7.0 to 8.3 (alkaline)	5.7 to 6.1 (acidic)
Soil chemistry	Si, Al, Mg, Fe, Ca, etc.	Mg, Fe, Ca, etc.
Peri-domestic vegetation	Edible shrubs & plants with soft stem	Cacti, thorny plants typically of hilly terrain
Agriculture crops	Banana, sugarcane, bamboo, wheat, rice, tobacco etc.	Groundnut, barley, ragi, potato, rice, etc.
House flooring	Packed house, wet soil with organic debris	Hard rocky

study sites are presented in Figures 46 and 47 for endemic zone and Figures 48 and 49 for non-endemic zone.

Following landuse classes were considered in image classification: (1) Agricultural fallow; (2) Forest/plantation; (3) Urban settlement; (4) Water body; (5) Marshy area; (6) Moist fallow; (7) Dry fallow; (8) Barren lateritic; (9) Crop; (10) Sand; and (11) Settlement in endemic area.

The training sites were digitized over the LISS III satellite images and False Colour Composite/ Hybrid Colour Composite images were generated. Crops and vegetation appeared red to bright red in the false-color composite image (Figures 46, 47, 48 and 49). The post-monsoon season fallows appeared pink to light red in the false-colour composite image and were visually discernable in many instances by their mostly rectangular shape. Although ground truth sites were collected for only Level I fallows, both post-monsoon season and pre-monsoon season fallow training sites were developed in order to accommodate for the seasonal rotation of fallow use in the study areas. After selectively combining classes, classified images were sieved, clumped and filtered before producing final output. Sieving

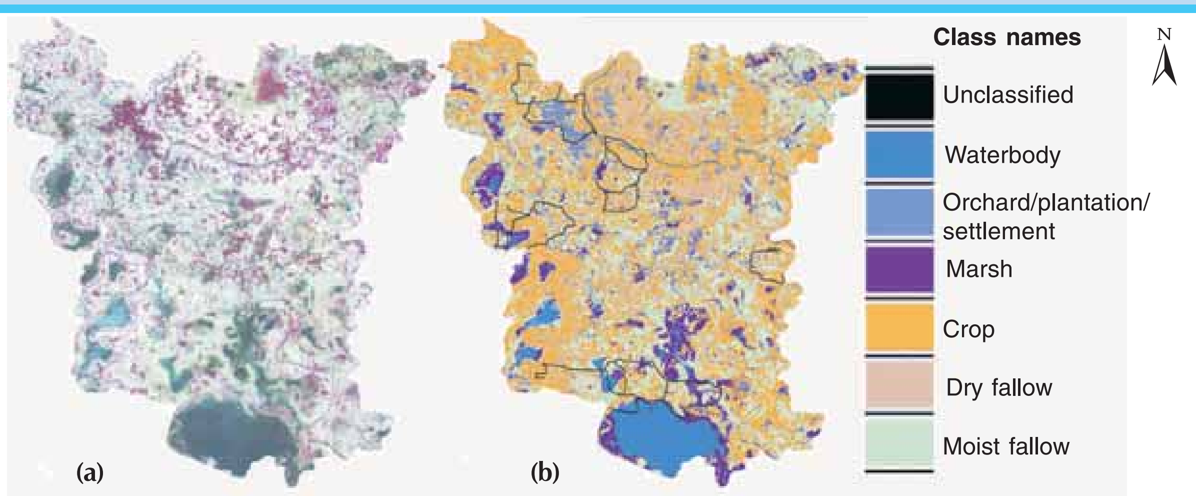

Figure 46: (a) FCC; and (b) Land use maps of Patepur Block, Vishali during lean season

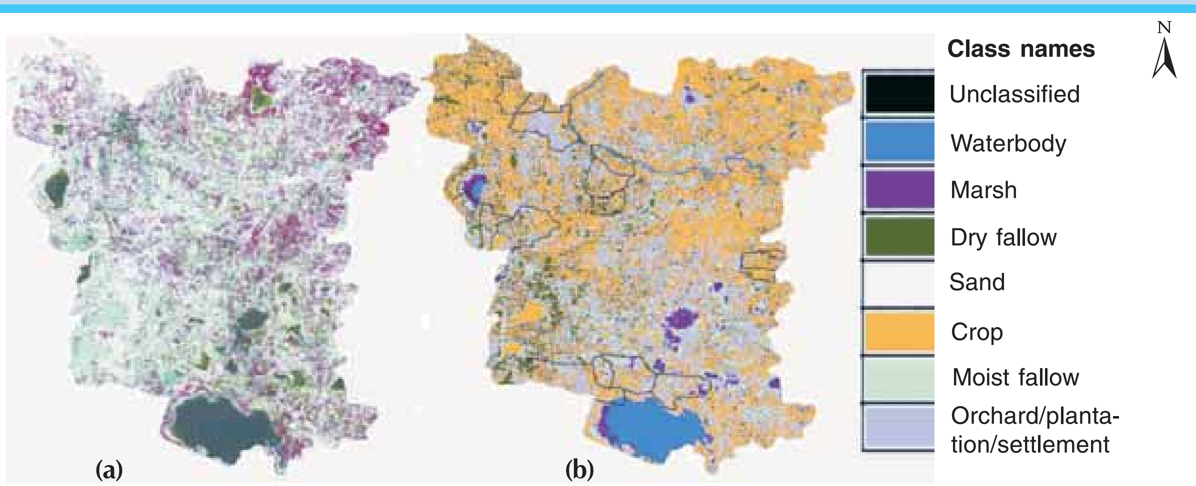

Figure 47: FCC (a); and Land use (b); maps of Patepur Block, Vaishali during peak season

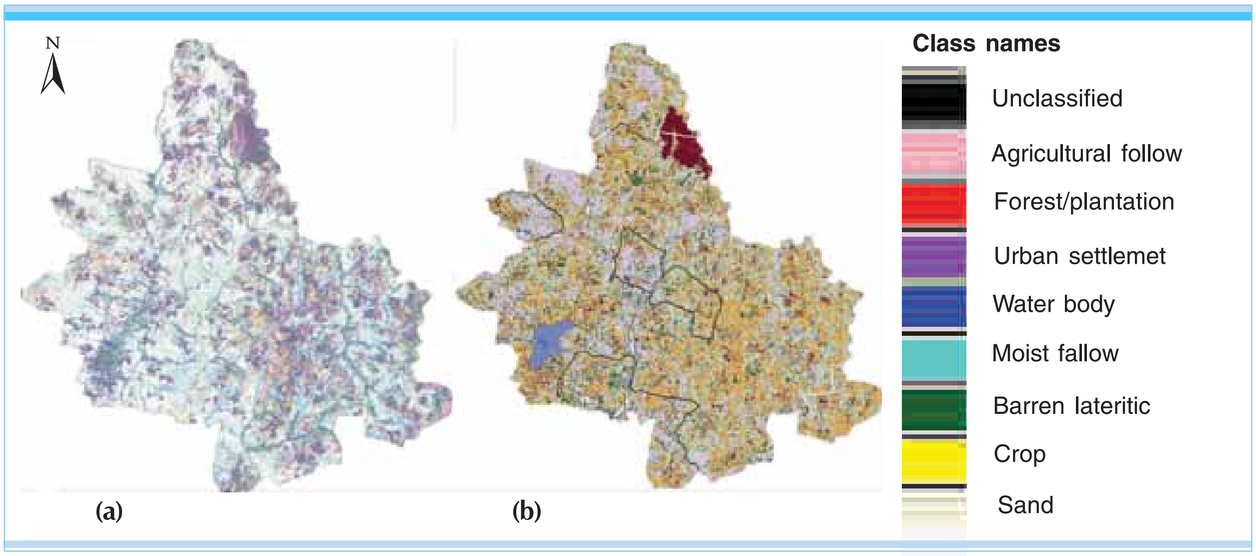

Figure 48: FCC (a); and Land use (b) maps of Lohardaga Block during lean season (03.01.2000)

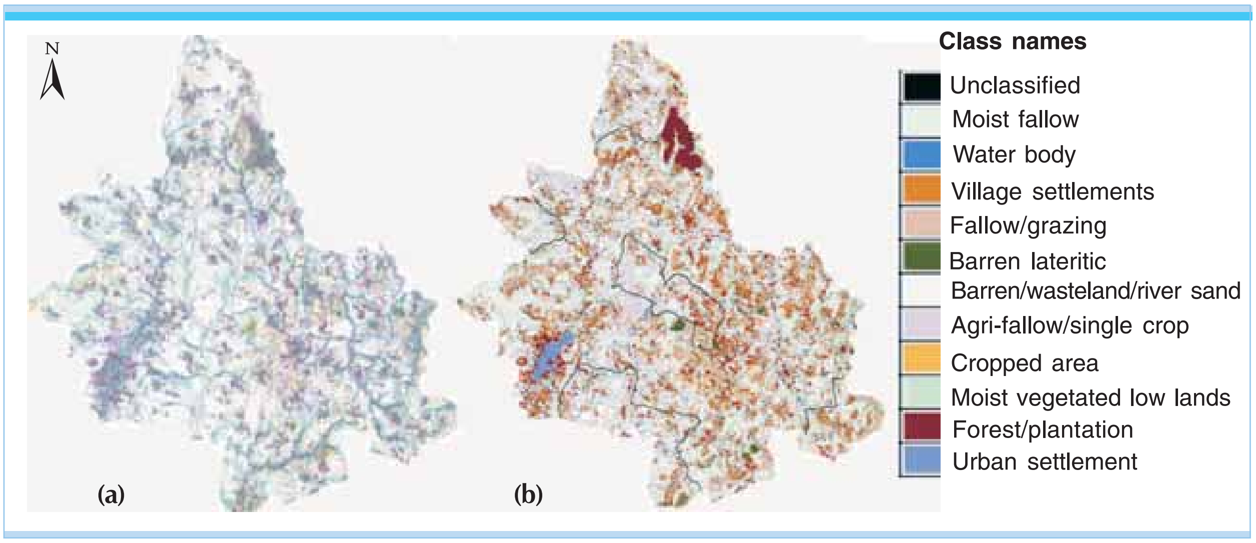

Figure 49: FCC (a); and Land use (b) maps of Lohardaga Block during peak season (23.03.2000)

removes isolated classified pixels using blob grouping, while clumping helps maintain spatial coherency by removing unclassified black pixels (speckle or holes) in classified images.

An initial error matrix was generated for the initial supervised 1999 land use and land cover map prior to the mode filtering by creating a maximum likelihood report. This report calculates area and percentages of each land class incorporated in a maximum likelihood classification. The ground truth data were utilized in the maximum likelihood report as the independent data set from which the classification accuracy was compared. The accuracy is essentially a measure of how many ground truth pixels were classified correctly. An average accuracy of 84.9% and an overall accuracy of 81.1% was achieved with a Kappa coefficient of 0.70638. The average accuracy is the average of the accuracies for each class, and the overall accuracy is a similar average with the accuracy of each class weighted by the proportion of test samples for that class in the total training or testing sets. Thus, the overall accuracy is a more accurate estimate of accuracy.

NDVI Integer scaling

The NDVI image generated from the LISS-III bands (Red and NIR) of IRS-1D was used to distinguish the vegetative and non-vegetative areas. The Normalized Difference Vegetation Index (NDVI), which is related to the proportion of photosynthetically absorbed radiation to distinguish vegetative and non-vegetative areas, is calculated from the visible and near infrared IRS 1D channels as:

$$CH4_{(NIR)} - CH3_{(Red)} \,/\, CH4_{(NIR)} + CH3_{(Red)}$$

Where, CH3 is the reflectance in the visible wavelengths (0.58–0.68 mm) and CH4 is the reflectance in the reflective infrared wavelengths (0.725–1.1 mm). The principle behind this is that Channel 3 is in a part of the spectrum where chlorophyll causes considerable absorption of incoming radiation, and the Channel 4 is in a spectral region where spongy mesophyll leaf structure leads to considerable reflectance**.**

4.1.2 GIS Analysis of Entomological and Environmental Data

The results of the ground-based survey and the relevant point data extracted from the digital environmental data were entered into MS 2000 Excel spreadsheet and analyzed with SPSS software (version 10.0). The preliminary analysis of both ground and other data sources included the construction of a digital map to show location of field-collection sites at which *P. argentipes* were collected. These maps were overlaid on the digital environmental data and the relevant data for the collection sites using GIS software.

For comparison of land cover and environmental variables between two seasons, appropriate student's t-test was applied after checking equality of variance. Statistical analysis was carried out to test the association between *P. argentipes* and the various ecological factors investigated in forms of binary data using chi-square test. One-way analysis of variance (ANOVA) was used to compare the continuous variable in two endemic foci. A univariate correlation analysis was initially undertaken to determine the relationship between vector density and different land covers and environmental variables. Stepwise multivariate linear regression analysis was carried out using population of the study sites as weight to determine predictor variables affecting vector density. It was observed that *P. argentipes* was present in all the sites selected for the study. The effect of average monthly temperature and humidity on vector density in endemic sites throughout the year is presented in Figure 50.

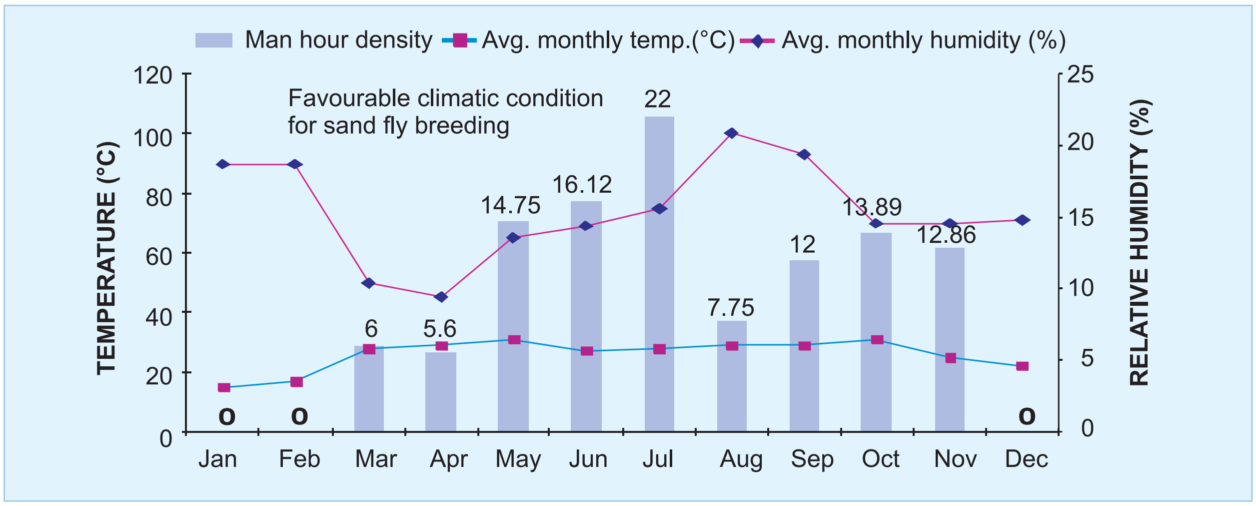

Figure 50: Average monthly mean temperature, humidity and MHD of sand fly in endemic areas

Table 14. Season-wise comparison of man hour density (MHD) in Patepur and Lohardaga blocks

Season	Patepur Mean (95% CI)	Lohardaga Mean (95% CI)	p-value
Summer	21.22 (19.64–22.80)	4 (3.26–4.74)	<0.001
Rainy	20.55 (19.26–21.84)	5 (4.10–5.89)	<0.001
Winter	5.11 (4.66–5.57)	0.58 (0.31–0.85)	<0.001
Annual	15.63 (13.15–17.75)	3.19 (2.45–3.93)	<0.001

Mean man-hour-density (MHD) in endemic villages was significantly higher as compared to those in non-endemic villages in Lohardaga block ($p<0.001$) in all the three seasons (Table 14). In endemic sites, the MHDs were significantly similar in all the villages ($p>0.05$) and were in the range of 15–22 during summer and rainy seasons whereas in winter season they were in the range of 4–5. Similarly, in Lohardaga block, the MHDs in all seasons were similar in all sentinel sites ($p > 0.05$) and were in the range of 1–6 during summer and rainy seasons but very low during the winter season. In endemic area, the density of vector was 2 to 3 times higher than the critical density (in an earlier study 8 per man hour was estimated as an optimal density for transmitting the infection from one infected host to a new host) was found required for the transmission in summer and rainy months (from March–October) subject to the presence of host and conducive environmental situation. On the contrary, in non-endemic foci, even in summer and rainy months the MHD ranged from 1–6, which is far below the critical density. This suggests that even in the presence of infective host, poor vector abundance would not support the transmission. Low densities probably minimize the chances of man-vector contact even if the environmental conditions are favourable.

The soil moisture contents in endemic sites were significantly higher as compared to those in non-endemic sites. In endemic sites, the high levels of aluminum, calcium, magnesium, sodium and potassium were observed which are indicative of endemic sites and the level of these chemicals were found in low levels in non-endemic sites. The result of soil chemistry analysis is presented in Figure 51.

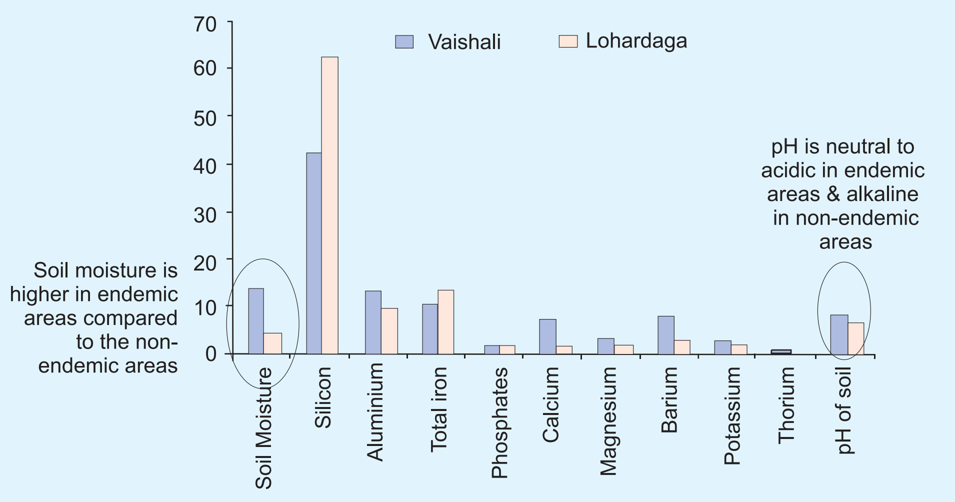

Figure 51: Analyses of soil samples from endemic and non-endemic sites

Table 15. Association of *P. argentipes* with common vegetation types as observed in field survey

Areas	Vector presence and absence				χ^2	p-value
	Endemic sites		Non-endemic sites			
	Present	Absent	Present	Absent		
Banana plantation	20	3	2	38	39.63	<0.01
Bamboo plantation	16	4	1	24	24.17	<0.01
Sugarcane plantation	18	2	3	21	23.25	<0.01
Maize crop plantation	17	2	2	24	26.84	<0.01
Peri-domestic edible vegetation	18	2	4	36	28.92	<0.01
Grass	45	5	4	45	53.03	<0.01

The association of common vegetation in peri-domestic areas with the presence of vector in both endemic and non-endemic sites was evaluated using Chi-square test. The presence of vector was positively associated with the presence of trees and plants like banana, bamboo, sugarcane, etc. found in endemic sites (Table 15).

During pre-monsoon season, except for dry fallow, all the variables in both endemic and non-endemic foci were significantly different where as during post-monsoon season a few variables in both foci were similar while others were statistically different. The season wise distribution of environmental variables in both endemic and non-endemic sites is presented in Table 16.

Results of one-way ANOVA of the combined output of the two seasons in all the sites of both endemic and non-endemic areas are given in Table 17. Except temperature and water body, all the variables were statistically significant. This indicated that the land cover and environmental variables were not similar in both the sites. The results of the univariate analysis of the relationship between vector density and various land covers and environmental variables is presented in Table 18. Most important climatic factor determining the distribution of *P. argentipes* was temperature, which showed a significant positive correlation with that of man-hour-density. Temperature plays an important role in survival and the speed of development of the different stages in the life cycle of vector. Physical as well as chemical nature of soil supplemented with water retaining capacity was found to be an important factor contributing to more positive sand fly-genic condition in endemic sites. Alkaline alluvial type of soil in endemic foci enhances its capability of retaining water as well as successful growth and abundance of edible shrubs, plants or agricultural crops. On the contrary, acidic, non-porous, granular laterite type of soil found in non-endemic sites neither has water-retaining capacity, nor does it assist in growth/propagation of shrub/soft-stemmed plants. In addition, the alluvial soil with alkaline pH of 7–8 and settlement areas having house flooring of loose wet soil with organic debris were also indicators of high *P. argentipes* density. In case of non-endemic sites, the land cover features were mostly devoid of water bodies and marshy areas, vegetation was of hard stem with thorny plants, laterite soil was with acidic pH of 5-6, and the house flooring was of hard rocky type. The significant association between the presence of vector and trees/plants like banana, bamboo, sugarcane, etc. in endemic sites has a very important bearing on the life-cycle of *P. argentipes*. The presence of soft stem peri-domestic vegetation within 5 km radius of human settlement in endemic foci are helpful in penetrating and imbibing plant-sap by male sand fly population but also serve as a source of sucrose for naturally infected vector population for development and multiplication of

Table 16. Season-wise distribution of environmental and land cover variables in both endemic and non-endemic sites

Environmental variables	Pre-monsoon		p-value	Post-monsoon		p-value
	Endemic	Non-endemic		Endemic	Non-endemic	
MHD	21.22 (3.42)	4.00 (1.41)	0.0001	5.11 (0.96)	0.58 (0.515)	0.001
Temperature (°C)	30.94 (1.11)	34 (0.95)	0.0001	16.72 (1.48)	17.41 (0.79)	>0.05
Humidity (%)	70.33 (3.10)	47.5 (2.19)	0.001	60.11 (3.445)	64.5 (3.77)	0.003
Water body (area)	0.899 (2.14)	3.26 (1.11)	0.002	2.72 (5.06)	0.83 (0.73)	>0.05
Orchard/Settlement	25.56 (11.19)	3.31 (2.09)	0.0001	7.31 (9.75)	4.92 (3.98)	>0.05
Crop	48.12 (14.70)	7.04 (2.14)	0.0001	37.90 (10.82)	24.78 (7.43)	<0.05
Dry Fallow	8.30 (6.02)	11.32 (6.49)	>0.05	9.78 (7.97)	35.79 (12.97)	<0.05
Moist Fallow	15.19 (7.02)	37.02 (8.41)	0.0001	32.82 (9.10)	31.70 (6.51)	>0.05
Mean NDVI	0.47 (0.016)	0.184 (0.068)	0.001	0.67 (0.029)	0.031 (0.01)	0.001
Max. NDVI	0.409 (0.097)	0.553 (0.072)	0.001	0.411 (0.076)	0.43 (0.06)	>0.05
Min. NDVI	-0.19 (0.075)	-0.24 (0.066)	0.04	-0.23 (0.096)	-0.40 (0.13)	0.001
Standard Deviation of NDVI	0.07 (0.012)	0.16 (0.049)	0.04	0.098 (0.017)	0.057 (0.0119)	0.001

parasite within its gut. Also, the annual distribution of MHD in the endemic sites corresponded with that of the plantation of banana, bamboo, sugarcane, etc. as indicated in crop calendar. Near total absence of these crops of these plants in non-endemic study sites may be another distinct "determinant" for lesser vector abundance. Thus, except for water body (in hectare), mean NDVI and maximum NDVI, all other variables were significantly correlated with vector density. Therefore, it can be said that favourable condition for the breeding of sand fly in an area arising due to specific environmental composition of soil type, peri-domestic vegetation, agricultural crops, minimum NDVI, etc. can be assessed for macro-stratification for vector abundance/non-abundance vis-à-vis kala-azar occurrence/non-occurrence.

Using significantly correlated variables with MHD, stepwise multivariate linear regression analysis using population of the study sites as weight was carried out to determine predictor variables affecting vector density. Six models were generated and the various coefficients estimated for the best model is presented below:

The above variables are the best predictors of vector density as analyzed by linear regression (adjusted R2 = 0.848). According to this model, the predicted vector density in terms of MHD is given by the following equation:

$$Z = -42.23 + (\text{Temp.} \times 0.597) + (\text{Humd.} \times 0.684) - (\text{dry fallow} \times 0.170) + (\text{Min. NDVI} \times 11.44)$$

where, Z is the estimated man-hour-density.

This model derived from the environmental variables and land cover features, i.e. temperature, humidity, dry fallow and minimum NDVI would be useful to produce a map of distribution of *P. argentipes* in endemic sites and can be used to predict the vector density in those areas not covered by the initial data. The map produced from the study could be of great use for planning and identifying areas of high vector abundance for vector control programme such as localized and intensive indoor residual insecticide spraying.

Table 17. Mean (S.D.) of the land cover and NDVI for endemic and non-endemic sites

Environmental variables	Endemic sites	Non-endemic sites	p-value
MHD	13.17 (8.54)	2.29 (2.03)	0.0001
Temperature (°C)	23.83 (7.33)	25.71 (8.51)	>0.05
Humidity (%)	65.22 (6.11)	56 (9.19)	0.001
Water body (area)	1.81 (3.95)	2.04 (1.54)	>0.05
Orchard/Settlement	16.44 (13.88)	4.11 (3.21)	0.0001
Crop	43.01 (13.74)	15.91 (10.52)	0.0001
Dry Fallow	9.04 (7)	23.56 (16.01)	0.001
Moist Fallow	24 (12)	34.45 (7.87)	0.0001
Mean NDVI	0.57 (0.025)	0.107 (0.091)	0.001
Max. NDVI	0.41 (0.085)	0.49 (0.088)	0.001
Min. NDVI	-0.21 (0.075)	-0.32 (0.13)	0.001
Standard Deviation of NDVI	0.084 (0.020)	0.108 (0.063)	0.001

Table 18. Correlation of vector density with different land cover and environmental variables in all sites in both areas

Environmental variables	Endemic sites	Non-endemic sites	Pearson's coefficient of correlation	p-value
Temperature (°C)	23.83 (7.33)	25.71 (8.51)	0.532	<0.01
Humidity (%)	65.22 (6.11)	56 (9.19)	0.567	<0.01
Water body (area)	1.81 (3.95)	2.04 (1.54)	–0.18	0.170
Orchard/Settlement	16.44 (13.88)	4.11 (3.21)	0.734	<0.01
Crop	43.01 (13.74)	15.91 (10.52)	0.537	<0.01
Dry Fallow	9.04 (7.00)	23.56 (16.01)	–0.433	<0.001
Moist Fallow	24.00 (12)	34.45 (7.87)	–0.657	<0.001
Mean NDVI	0.57 (0.025)	0.107 (0.091)	0.253	0.051
Max. NDVI	0.41 (0.085)	0.49 (0.088)	0.210	0.108
Min. NDVI	–0.21 (0.075)	–0.32 (0.13)	0.439	<0.01
Standard Deviation of NDVI	0.084 (0.020)	0.108 (0.063)	–0.265	0.041

Variables	B	SE	Significance
Temperature	0.597	0.064	0.000
Humidity	0.684	0.053	0.000
Dry Fallow	–0.170	0.039	0.000
Minimum NDVI	11.44	4.303	0.021
Constant	–31.73	5.614	0.000

Although, this model was based on data pertaining to two PHC/blocks of the state, it can also be used for prediction of vector density in other high endemic areas of Bihar and other parts of the country.

Probably, these variables influence the population of the vector by affecting other microclimatic factors in the area. *P. argentipes*, the vector in the area, is known to thrive in habitats characterized by the presence of many peri-domestic trees and soil. No definitive correlation could be established between sand fly density and land use variables in non-endemic sites.