# 3

# Filariasis

Lymphatic filariasis (LF), a mosquito-borne disease is a major public health problem in many parts of India. Lymphatic filariasis in India is caused by *Wuchereria bancrofti* and *Brugia malayi* helminthic parasites and transmitted respectively by *Culex quinquefasciatus*, and *Mansonia annulifera* and *M. uniformis*. In Andaman and Nicobar islands, sub-periodic filariasis is transmitted by *Ae. niveus*. This disease is endemic in 17 States and 6 Union territories in India (Figure 32). Though the disease is not fatal, it is of great public health concern due to personal trauma it causes to the affected persons due to physical disfiguring of the affected parts and the associated social stigma. In India, 33 million persons are positive for microfilaraemia, 23 million cases with symptomatic filariasis and 473 million individuals are potentially at risk of infection. The disease globally is responsible for 5 million DALYs, of which 85–90% is contributed by Africa and India. India has been estimated to lose about $ 1 billion per year. The Indian National Health Policy envisages elimination of lymphatic filariasis by 2015 while the global goal is set at 2020.

The traditional methods of filariasis surveys are time consuming, static, laborious, and highly expensive and the results are influenced by human factor. It has been observed that by the time the filariasis delimitation surveys are completed, the situation would have already changed. Furthermore, these surveys cannot be conducted in reconnaissance scale and they cannot be repeated in short time interval. It was realized that the traditional method for delimitation of areas, using the night blood examination survey are useful only for identifying the areas of risk at the micro level. Therefore, successive projects were proposed and designed to develop a system to use Remote Sensing (RS) and GIS application tools for better understanding of epidemiology and to develop strategies for the control of lymphatic filariasis. Following studies were carried out by the Vector Control Research Centre, Puducherry: (i) Application of Remote Sensing and Geographical Information Systems (GIS) for Epidemiology and Control of Lymphatic Filariasis; (ii) Validation of Geo-Environmental Risk Model (GERM) for predicting filariasis risk areas; and (iii) Delimitation of Lymphatic Filariasis in India, based on GERM.

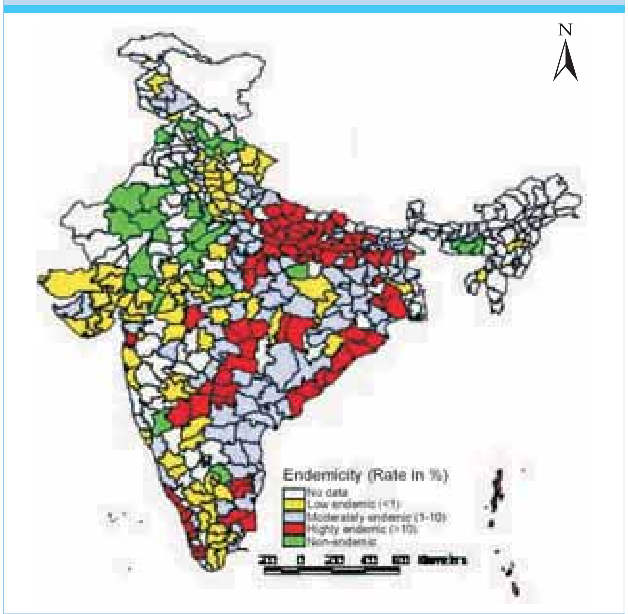


**Figure 32:** Lymphatic filariasis distribution in India

## 3.1 Remote Sensing and Geographical Information Systems (GIS) for Epidemiology and Control of Lymphatic Filariasis

The study was carried out by the Vector Control Research Centre, Puducherry in collaboration with the Regional Remote Sensing Service Centre, Bengaluru (RRSSC-B) of the Indian Space Research Organization (ISRO) during 2000–03 to achieve the following objectives: (i) Production of filariasis distribution maps for Tamil Nadu, Karnataka, Kerala and Puducherry; (ii) Identification of the environmental risk factors in relation to occurrence of disease; and (iii) Development of tools for decision making for the control of filariasis using RS and GIS.

### 3.1.1 Database Construction and Production of Filariasis Distribution Map

#### Study sites

Four sites, viz. Tamil Nadu, Puducherry, Kerala and Karnataka situated in the southern part of India between 8° 27′ 2″ N – 18° 20′ 55″ N and 74° 16′ 17″ E – 80° 11′ 45″ E were included in the study. This area receives rainfall by both monsoons, i.e. southwest (June–September) and north-east (October–February). The rainfall is moderate to high, with an annual average of 800 mm to 3000 mm. The mean annual temperature is 25°C – 27.5°C. Relief is ranging up to 1200 m from mean sea level. Major soil types include red sandy soil, red loamy soil, red and mixed black soil, black soil and alluvial soil. Total population of the study area is 131, 342, 450 (Source: Census of India 2001). The density of population ranges from 106 to 3917 persons per $km^2$.

District level digital map of India (Survey of India administrative boundary maps — Scale 1:50,000) was used. All GIS databases were developed using Arc-view 3.2 GIS software (ESRI, Redlands, CA) and ERDAS IMAGINE 8.3 (ERDAS, Atlanta, GA) Image processing software.

#### Filariasis data base

The district level estimate of filariasis prevalence has been derived from the unpublished results of the filariasis surveys carried out by the National Filaria Control Programme (NFCP) (which has now been integrated into National Vector Borne Disease Control Programme) and also the data from the individual publications. Though it was advantageous to use the already existing data, the limitation was that most of the time the surveys conducted were in a small isolated locality/village/town, and hence the data do not represent the real situation of the district.

#### Geo-environmental and climatological data source

Geo-environmental factors, viz. altitude, temperature, rainfall, relative humidity, soil type, and land use/ land cover level-I categories were considered for the study. The data pertaining to soil, and agro-ecological features were obtained from the National Bureau of Soil and Land Use Planning, Nagpur, Maharashtra. The weather data were received from the Indian Meteorological Department, Pune.

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### Remote sensing data analysis

Space-borne data (IRS- WiFs data) at various time points acquired by the NRSA, Hyderabad was processed jointly with technical experts of the collaborating institute, RRSSC-B. The processed image files were calibrated for producing the Normalized Differences Vegetation Index (NDVI) by the given standard formula:

$$\frac{\text{Infrared} - \text{Red}}{\text{Infrared} + \text{Red}} \quad \text{(or) [(Band 4 – Band 3) / (Band 4 + Band 3)]}$$

The NDVI was further calibrated into composite NDVI value for defining the land use/land cover level-I categories for different filariasis endemic zones.

## Filariasis Distribution Map for Southern India

### Spatial mapping

The available filariasis data were captured into GIS platform and then attached to the respective districts of Tamil Nadu, Kerala, Karnataka and Puducherry for the preparation of filariasis distribution map.

As per the observations, the pattern of distribution of filariasis shows that 37 districts were found endemic out of 40 districts surveyed from the total of 59 districts and the map was stratified at the district level, based on endemicity (Figure 33).

This map shows that the spatial pattern of filariasis endemicity [i.e. the prevalence (%) of microfilaraemia added to the prevalence (%) of filarial disease] at the district level. Based on the level of endemicity, these districts were stratified as high (>10%), moderate (1%– 10%) and low (<1%) endemicity. A series of standard GIS techniques was applied to accept the existing database for the construction of spatial interpolation to derive value for the area not surveyed. This revealed the spatial trend of filariasis prevalence for the entire region including the unsurveyed areas. High endemicity is seen in the coastal region of all the four states and north-eastern districts of Karnataka. High endemicity seen in the east coast districts, namely Cuddalore, Villupuram (South Arcot: pre-bifurcation) and its spread up to 100 km towards west. Second belt is seen at north-eastern part of Karnataka, namely Bidar district which is extended towards south-west up to 150 km. And the third belt is seen along the coastal districts of Kerala and Karnataka. Also, a low level endemicity in most of the unsurveyed areas and zero endemicity in the western coast hinder land has been observed (Figure 33).

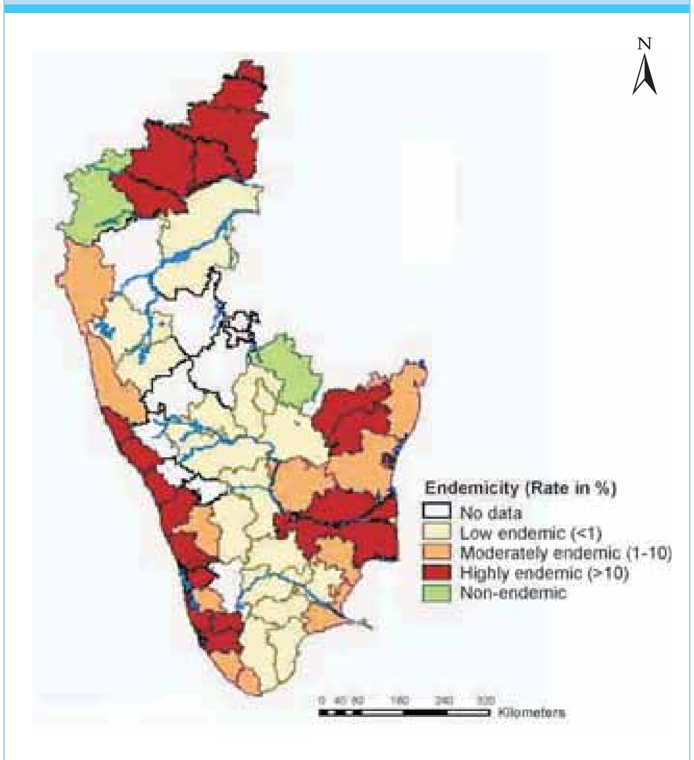


**Figure 33:** Filariasis distribution in southern India

### Spatial interpolation

A GIS based spatial interpolation was made for predicting and filling the value for the area that has no information or the area that was not surveyed. The Inverse Distance Weighted (IDW) spatial interpolation technique was applied for predicting the filariasis for the blank area based on the pair of 12 neighboring sample points, and the Spline spatial interpolation method was also performed for further smoothening of spatial trend of filariasis. This revealed the spatial trend of filariasis prevalence for the entire region including the unsurveyed areas (Figure 34).

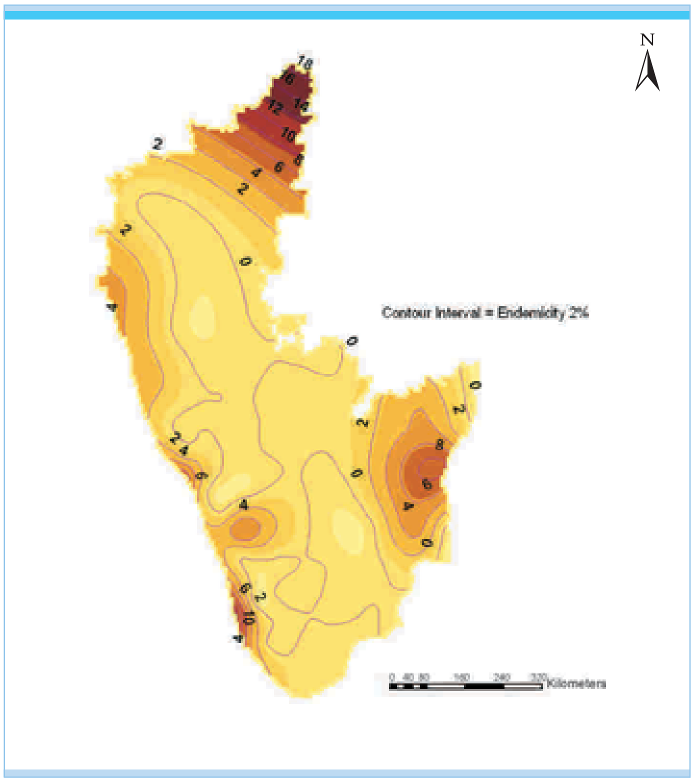


**Figure 34:** Spatial interpolation of filariasis distribution in southern India

### 3.1.2 Data Analysis and Identification of Environmental Risk Factors

Filariasis transmission like other vector-borne infectious diseases is dependent on the geo-environmental variables (physiographic and climatic) at a macro level. Physiographic factors mainly contributed to vector abundance; whereas the climatic factors influenced the extrinsic incubation (of parasites) directly, as well as via vector survival. Once the environmental conditions are conducive, the human (demographic) factors become the determinants contributing to the occurrence of filariasis at the micro level (Figure 35).

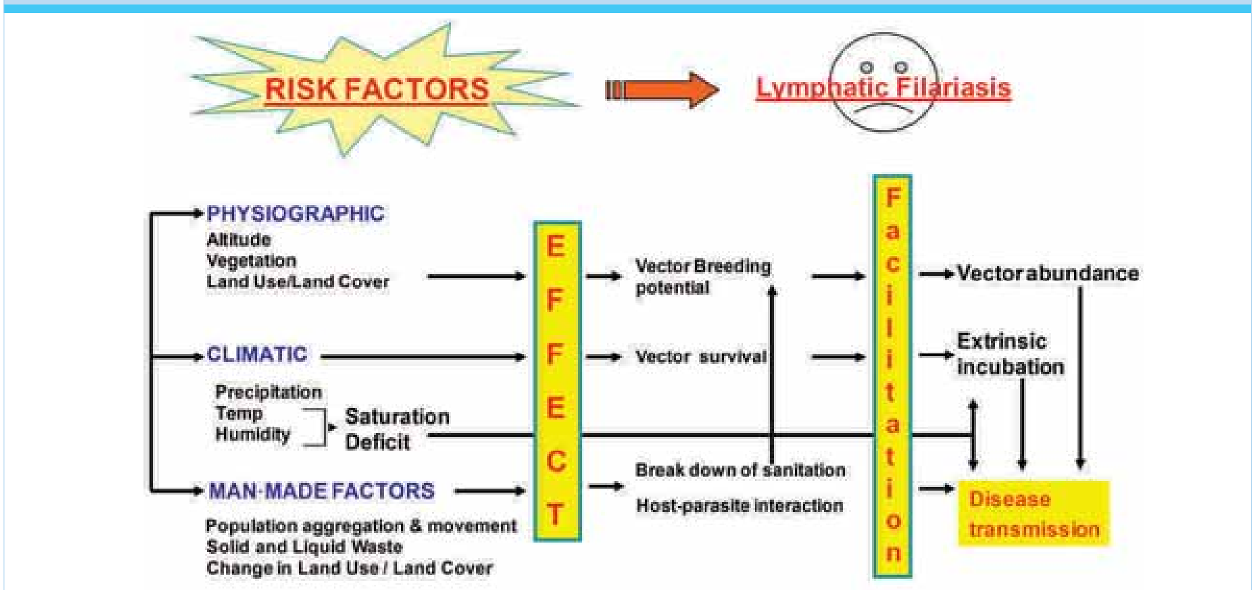


**Figure 35:** Conceptual frames for lymphatic filariasis transmission

### Geo-statistical analysis

***Parametric value:*** Initially, simple correlation between environmental variables (altitude, rainfall, relative humidity and saturation deficit) and filarial endemicity was examined using Pearson's correlation.

***Non-parametric value:*** The relationship of other variables ('dummy indicators') like vegetation and land use/land cover (soil types, built up structures, etc.) and filarial endemicity was analyzed using Spearman's correlation.

***Multivariate analysis:*** A multiple linear regression– stepwise remove method was used for identifying the key variables amongst the risk variables as listed above using the SPSS 10.0 for windows software.

***Environmental risk analysis:*** Bivariate ('Pearson' correlation) analysis explained a positive association of filariasis endemicity (point data available in Tamil Nadu) with temperature ($r=0.409$, $p<0.05$) (Figure 36) and rainfall ($r=0.441$, $p<0.05$) (Figure 37). Also, a significant association was observed between filariasis endemicity and saturation deficit ($r=0.534$, $p<0.01$). The filariasis endemicity

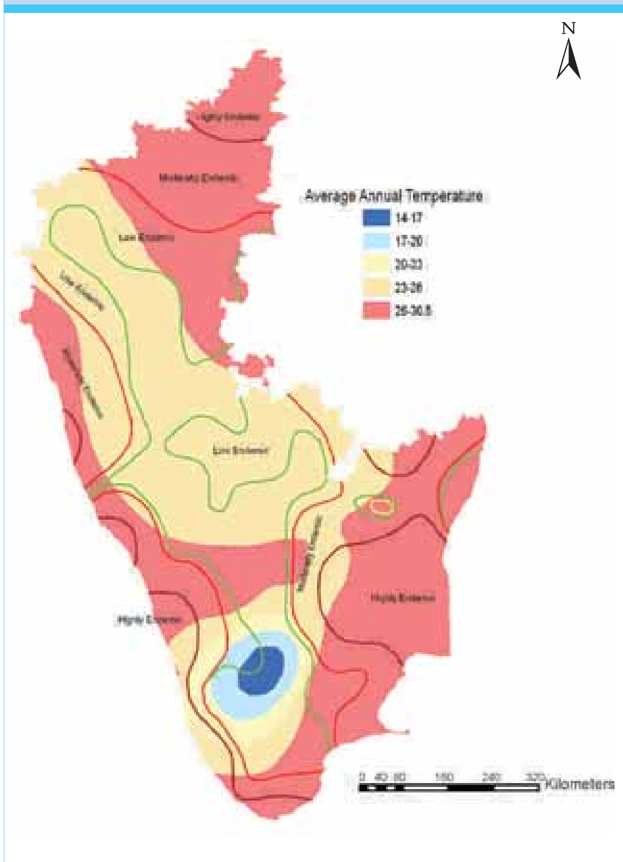


**Figure 36:** Map showing association between temperature and filariasis endemicity in southern India (filariasis endemicity overlaid on temperature distribution)

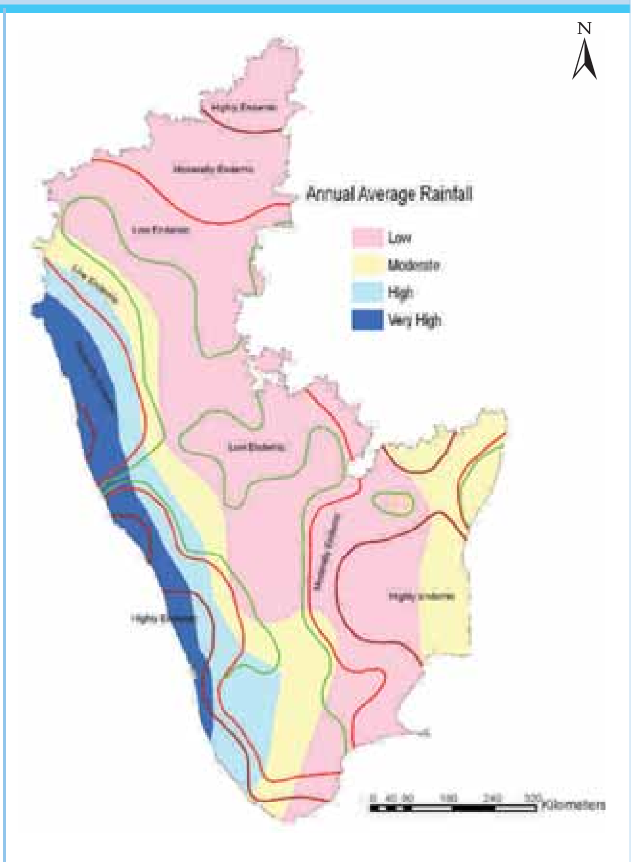


**Figure 37:** Map showing association between rainfall and filariasis endemicity in southern India (filariasis endemicity overlaid on rainfall distribution)

**Tables 8a. Multiple regression analysis of possible risk variables selected in the study correlations**

| | | NDVI | SWV | Height | Temp | RF | RH | SD | ASINMF95 |
|---|---|---|---|---|---|---|---|---|---|
| NDVI | Pearson correlation | 1.000 | –0.13 | 0.291 | –0.133 | 0.485** | –0.131 | 0.08 | –0.051 |
| | Sig. (2-tailed) | 0 | 0.487 | 0.112 | 0.477 | 0.006 | 0.481 | 0.667 | 0.806 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| SWV | Pearson correlation | –0.130 | 1.000 | –0.465** | 0.993** | 0.189 | 0.840** | –0.060 | 0.259 |
| | Sig. (2-tailed) | 0.487 | 0 | 0.008 | 0 | 0.309 | 0 | 0.748 | 0.201 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| Height | Pearson correlation | –0.291 | –0.465** | 1.000 | –0.513 | 0.209 | –0.0281 | –0.148 | –0.408 |
| | Sig. (2-tailed) | 0.112 | 0.008 | 0 | 0.003 | 0.259 | 0.126 | 0.425 | 0.039 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| Temp | Pearson correlation | –0.133 | 0.993** | –0.513** | 1.000 | 0.208 | 0.802** | –0.003 | 0.296 |
| | Sig. (2-tailed) | 0.477 | 0 | .003 | 0 | 0.261 | 0 | 0.988 | 0.142 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| RF | Pearson correlation | –0.485** | 0.189 | 0.209 | 0.208 | 1.000 | 0.103 | 0.133 | 0.400* |
| | Sig. (2-tailed) | 0.006 | 0 | 0.259 | 0.261 | 0 | 0.580 | 0.474 | 0.043 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| RH | Pearson correlation | –0.131 | 0.840** | –0.281 | 0.802** | 0.103 | 1.000 | –0.587** | –0.130 |
| | Sig. (2-tailed) | 0.481 | 0 | 0.126 | 0 | 0.580 | 0 | 0.001 | 0.526 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| SD | Pearson correlation | 0.080 | –0.060 | –0.148 | –0.003 | 0.133 | –0.587** | 1.000 | 0.631** |
| | Sig. (2-tailed) | 0.667 | 0.748 | 0.425 | 0.988 | 0.474 | 0.001 | 0 | 0.001 |
| | N | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 |
| ASINMF95 | Pearson correlation | –0.051 | 0.259 | –0.408* | 0.296 | 0.400* | –0.130 | 0.0631** | 1.000 |
| | Sig. (2-tailed) | 0.806 | 0.201 | 0.039 | 0.142 | 0.043 | 0.526 | 0.001 | 0 |
| | N | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |

*Correlation is significant at 0.05 level (2-tailed); **Correlation is significant at 0.01 level (2-tailed)

**Table 8b. Model summary**

| Model | R | $R^2$ | Adjusted $R^2$ of the estimate | Standard error |
|---|---|---|---|---|
| 1 | 0.631[a] | 0.398 | 0.373 | 5.9861 |
| 2 | 0.737[b] | 0.543 | 0.503 | 5.3286 |
| 3 | 0.816[c] | 0.666 | 0.620 | 4.6567 |

[a]Predictors (Constant), SD; [b]Predictors (Constant) SD, RF; [c]Predictors (Constant), SD, RF, Height

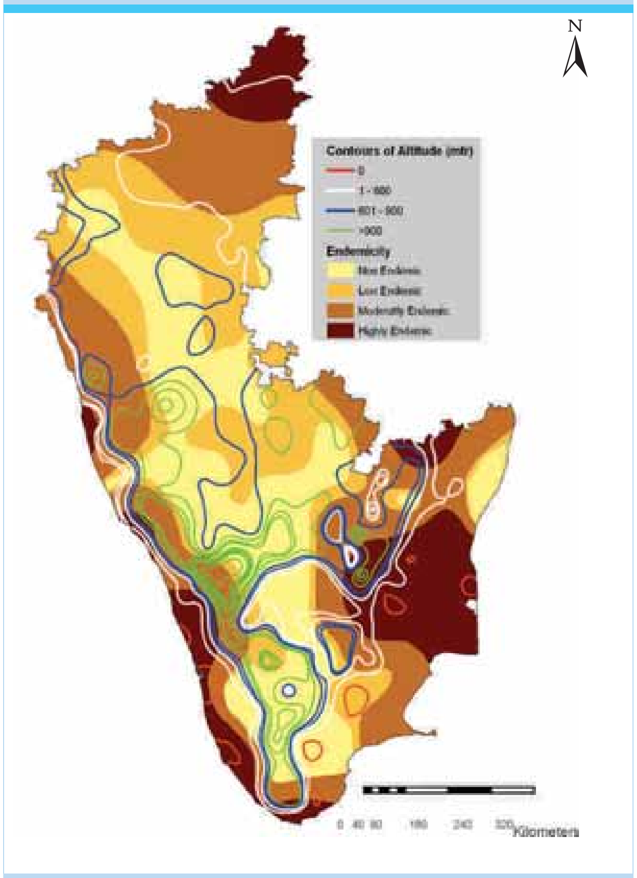


**Figure 38:** Map showing association between altitude and filariasis endemicity in southern India (contours of altitude overlaid on endemicity map)

was found to have a negative correlation with altitude ($r = 0.444$, $p < 0.05$) (Figure 38).

Multivariate (Multiple linear regression-stepwise) analysis revealed that among the seven possible risk variables, altitude, temperature, rainfall, relative humidity, saturation deficit, soil type and vegetation, included in the analysis, only three variables, altitude, rainfall and saturation deficit, emerged as significant variables contributing to 67% of the variation in the endemicity rate (Table 8a and b) at macro level. This regression model does not include other variables like vector breeding potential (land use/land cover etc.), socio-economic characteristics etc. of the area which may also be facilitating the situation conducive for the disease occurrence at the micro level.

The RS image files have been calibrated to produce NDVI, and also the land use/land cover pattern. The cultivable (moisture) and low vegetation zone with composite NDVI values ranging between 145 and 158 were the areas found to be endemic for filariasis. However, there was no significant association established between the NDVI and filariasis endemicity on a larger scale because the filariasis has more complexity in nature and is determined by many local phenomena.

### 3.1.3 Development of Geo-Environmental Risk Model (GERM) for Filariasis

To identify which combination of environmental factors are the best predictors, and to relate them to the risk of infection occurrence, a standard protocol developed by the National Remote Sensing Agency (NRSA) and National Natural Resource Management System (NNRMS) for geo-environmental key factors was accepted and adopted for the analysis.

The environmental factors that are influencing the disease transmission have been taken into consideration in preparing the model. The model customized the environmental parameters encompassing: altitude 0–2000 m mean sea level, temperature 8°C–37°C, rainfall 300 mm–1500 mm relative humidity 40–90% and soil type for deriving filariasis transmission risk index (FTRI). To accomplish this, each value of these geo-environmental variables was given scores for different geographical areas. Summing up the scores of these geo-environmental variables was done for a particular area as follows:

FTRI for a region = Sum of the scores of these geo-environmental variables and mathematically given as follows:

$$FTRI\ for\, a\ region = \sum_{i=1}^{5} Y_i \text{ where, } \sum Y_i = Y_1 + Y_2 + Y_3 + Y_4 + Y_5$$

$Y_1$, $Y_2$, $Y_3$, $Y_4$ and $Y_5$ are scores for altitude, temperature, relative humidity, rainfall and soil type respectively.

In order that this FTRI for a region is given as a standardized quantity, it will be represented in terms of percentage as follows:

$$\text{Standardized FTRI of a region } = \frac{\sum_{i=1}^{5} Y_i \text{ of a region}}{Max\left(\sum_{i-1}^{5} Y_i \text{ in the study area}\right)} \times 100$$

The standardized FTRI will be used to predict the risk and non-risk areas for filariasis.

This approach was used to identify the areas to assess the potential for risk of filariasis transmission in Tamil Nadu, India. Using this model and GIS techniques the filariasis risk map was created for Tamil Nadu region (Figure 39).

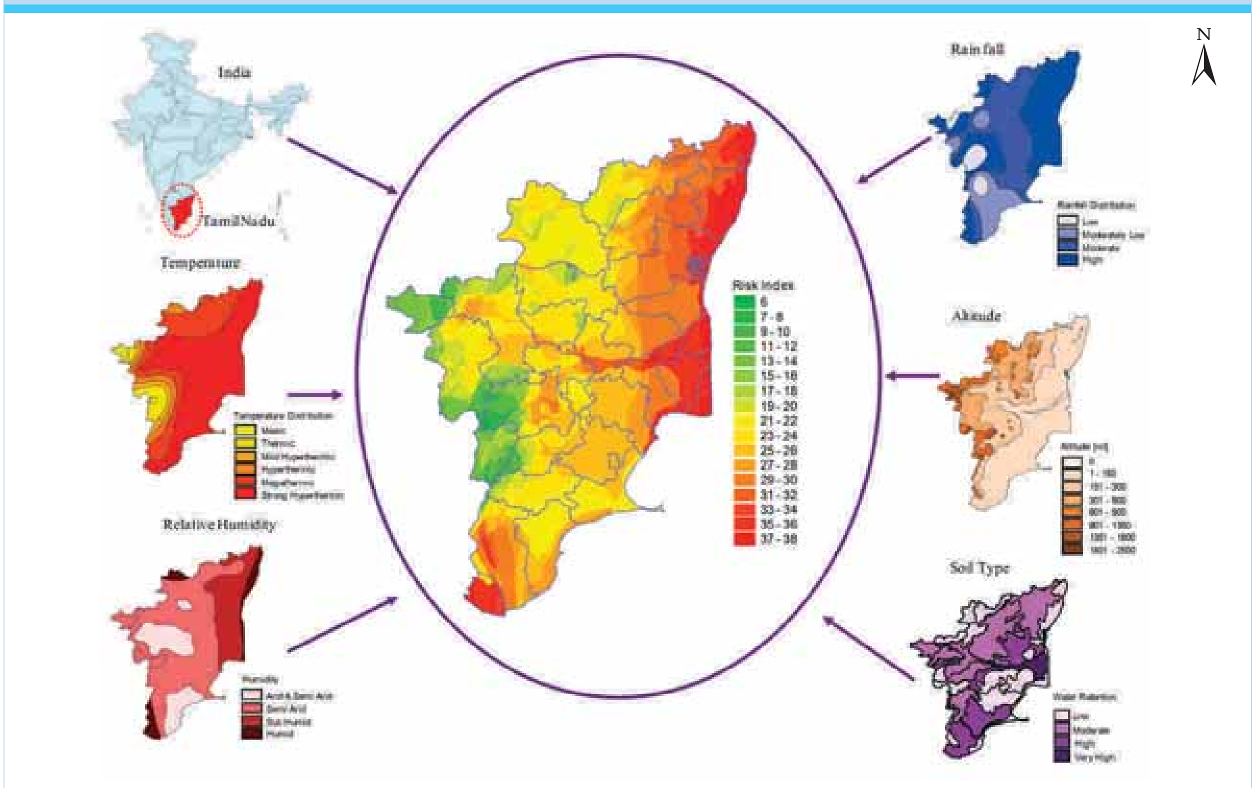


**Figure 39:** A geo-environmental risk map showing areas potential for LF transmission in Tamil Nadu

### 3.1.4 Development of Decision-making Tools

Updating information is important in all fields, but it is vital for health in case of beneficiaries as well as providers/planners. The health issues are always related to space and time, and therefore it is ideal to link Geographical Information Systems (GIS) with Health Information Systems (HIS). Since a global programme for elimination of lymphatic filariasis is going on, a decision support tool (HIS) has been built-up using GIS and network technologies, with user interface facilities for browsing, spatial structured querying, thematic mapping, data editing and drawing information (demographic features, infection/disease prevalence, filariasis environmental risk status and the ongoing control operations) of each district/region (Figure 40). Besides the visualization of site characterization, this system allows

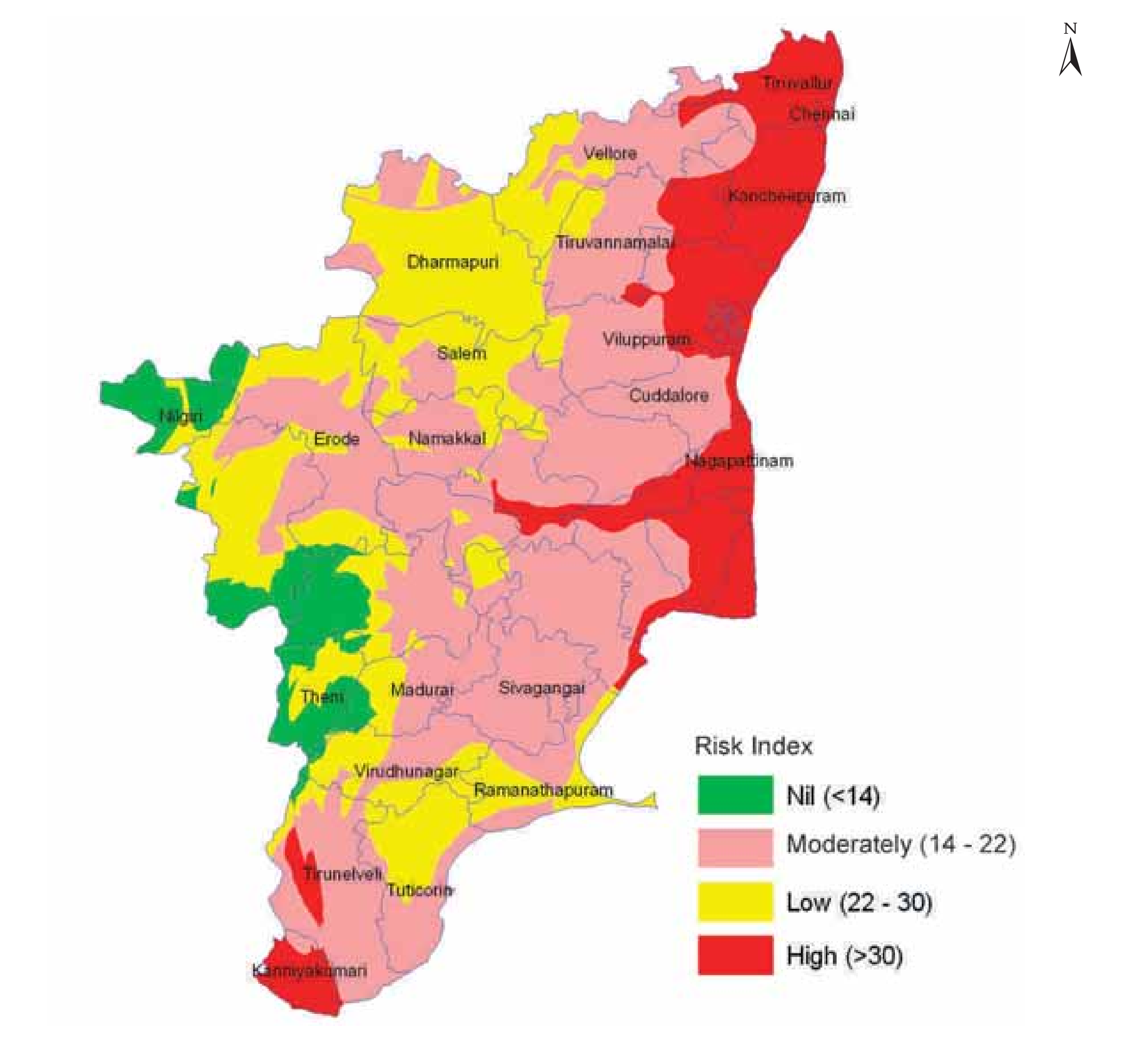


**Figure 40:** Filariasis transmission risk in Tamil Nadu

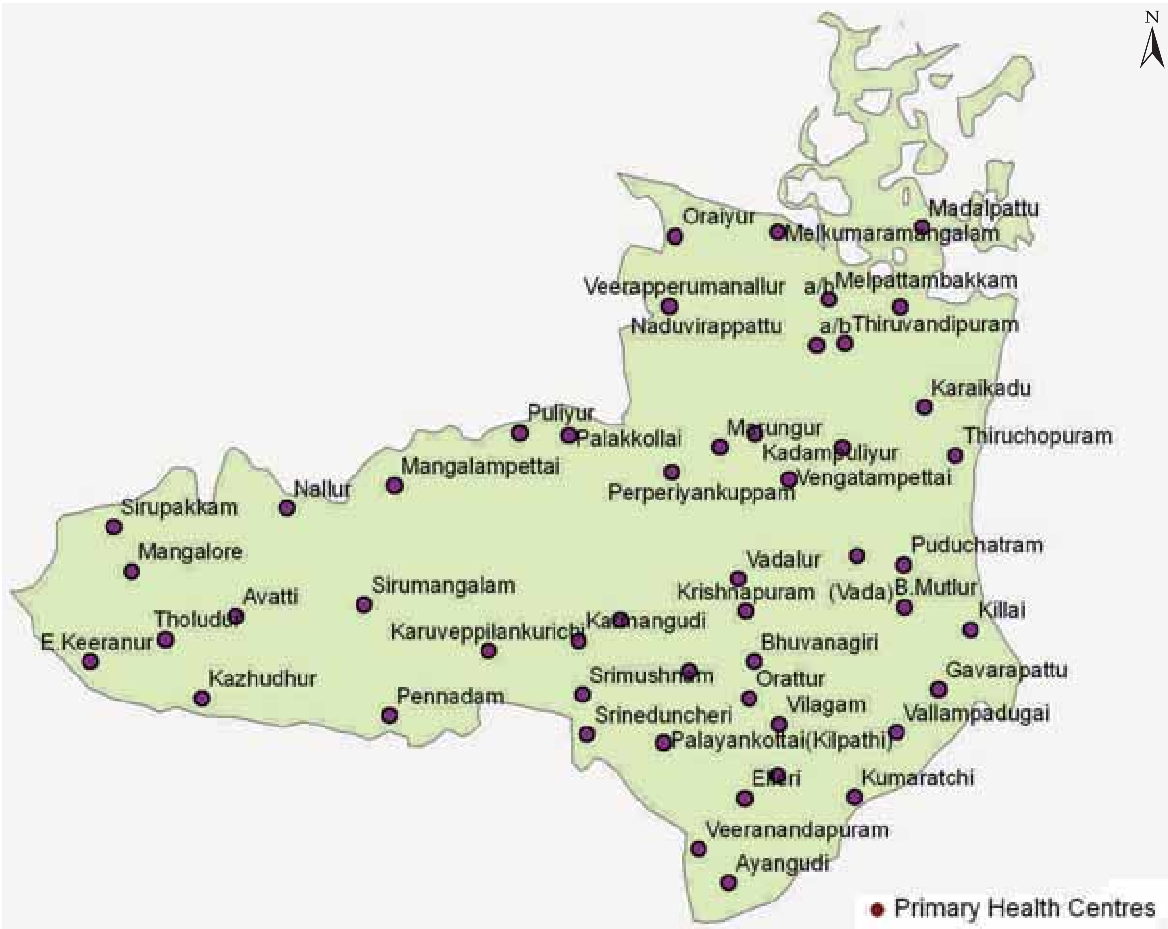


**Figure 41:** Primary Health Centres in Cuddalore district in Tamil Nadu. FIMS has the facility to update from each centre

integration of data from any desktop data base software or worksheet. It has facilities to update the data from different nodes or centres (Figure 41). The tool designed here as a model can function country wide, with all the desired data and queries. Further, the critical level of different components is required to be defined in the system, before it is taken to the real time situation.

## 3.2 Validation of Geo-Environmental Risk Model (GERM) for Predicting Filariasis Risk Areas

One of the important outcomes of the earlier project was the development of Geo-Environmental Risk Model (GERM) for predicting the areas at risk of filariasis. Initially, the filariasis risk map has been produced for Tamil Nadu region, as a case study. It has become necessary to validate the model before attempting to take up the model for a larger geographical area, probably for the entire country.

The filariasis risk map produced for Tamil Nadu as a case study was validated using Immuno-Chromatographic Test (ICT) kits to test the predictability of the model. The Tamil Nadu region lies in southeastern part of India between 8° 5′ N–13° 35′ N and 76° 15′ E–80° 20′ E. For validation purposes from the whole of Tamil Nadu region, where the model prediction has been made, an area of 100 x 350 km was selected representing all the geo-environmental features. It was divided into 10 x 10 km grids, so that each grid contained at least one village in rural area/one ward in urban area (Figure 42).

From the no risk zone, all the villages/wards falling on either intersection points or nearer to them were selected for the survey, since the negative prediction in the model has been considered critical from the application point of view. Thus, a total of 35 geo-coded sites (intersection points) were required to be surveyed in the 'no risk' zone. In the 'at risk' areas, 10% of the total villages falling on the intersection points were selected on a systematic random basis, which could minimize the cost of survey while ensuring a fair spatial representation of the area. The number of sites surveyed by this method thus became 25 in the 'at risk' areas (Figure 42).

Altogether, there were 60 sites surveyed from the entire study area. In all the selected sites, children in the age class 9–15 years were screened for antigenemia (Ag), using ICT kits. This age group was chosen, as the likelihood of getting positive in this group is higher, as these children were born before the introduction of Mass Drug Administration with DEC, under the LF Elimination programme.

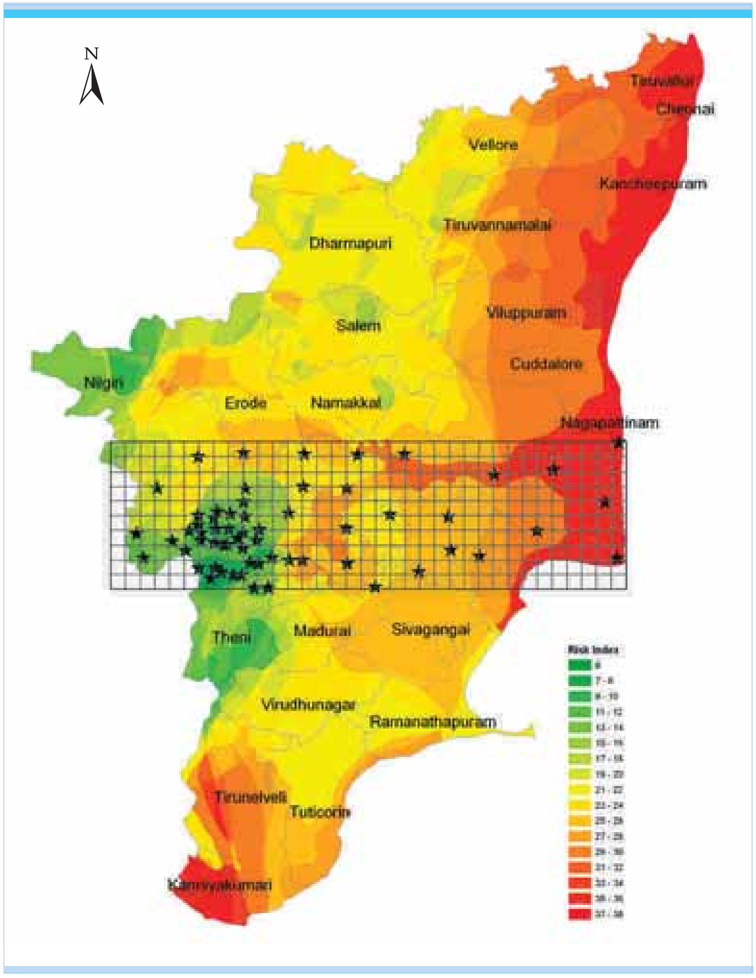


**Figure 42:** Sites selected for validation using Immuno-chromatographic test (ICT) for the detection of filarial antigen in children

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Assuming a minimum of 1% Ag prevalence in the age group of 9–15 years and allowing for an error of 2.5%, the sample size was estimated to be 58 in a population of about 1500 in a village. Thus, a minimum of 60 children had to be screened in each site. This was achieved by visiting either all or selected sections of the school, located in these sites (villages/wards), following a systematic random procedure.

Statistical analysis was done at two levels, at the first level prediction by GERM model was compared with the observed data and at the second level, the relationship between the FTRI and the occurrence of filariasis in an area was compared. For this, logistic regression analysis was carried out with FTRI as the descriptive/independent variable, and occurrence of filariasis as the dependent variable. The dependent variable is binary in nature indicating the presence or absence of filariasis in the community. This analysis was also useful to indicate how the risk of filariasis agrees with FTRI.

A total of 3600 children (boys: 2088, and girls: 1512) in the age class of 9–15 were examined for the presence of filarial antigenemia using the ICT kits in the selected 60 sites. Of the total children examined, 28 were detected positive for antigenemia, and among them, the boys and girls were 19 and 9 respectively. Of the 60 sites surveyed, only 8 were found to be positive for filarial antigenemia. It was observed that all the 35 sites selected from non-risk area did not record any cases with filarial antigenemia (i.e. among the 2100 children surveyed) (Table 9).

Among the 25 risk sites selected, only in 8 sites filarial antigenemia positive cases were found (Figure 43). A total of 28 individuals were found to have filarial antigen among the 1500 examined. The antigenemia rates ranged 1.67–10% in these 8 sites.

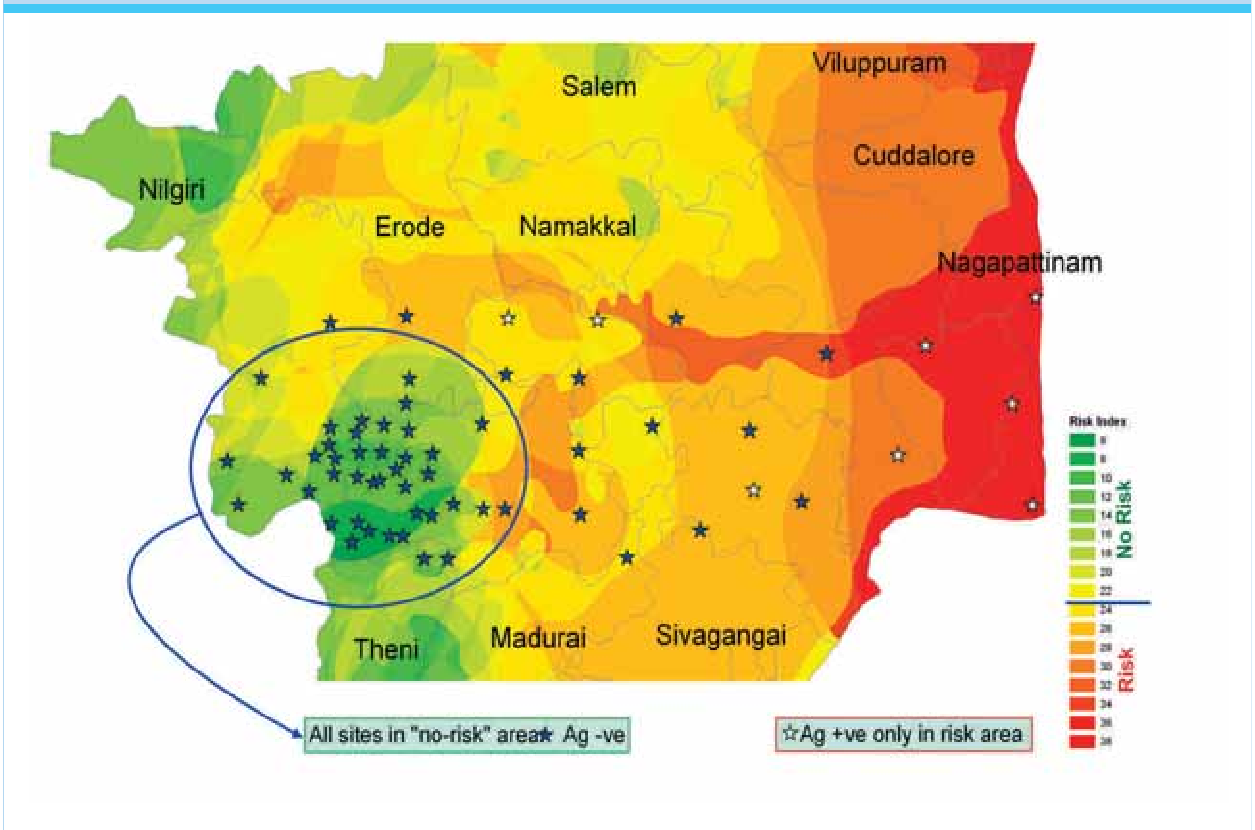


**Figure 43:** ICT survey results in Tamil Nadu

**Table 9. Results of the filarial antigenemia surveys using ICT**

| Filariasis risk status of the area | No. of communities selected | No of communities detected positive by the ICT | No. of individuals tested | | |
|---|---|---|---|---|---|
| | | | Positive | Negative | Total |
| Non-risk | 35 | 0 | 0 | 2100 | 2100 |
| Risk | 25 | 8 | 28 | 1472 | 1500 |
| Total | 60 | 8 | 28 | 3572 | 3600 |

The relationship between the FTRI and the prevalence of filariasis antigenemia was analyzed, using logistic regression and it was found that the model fitted well for the data ($\chi^2 = 2.27$, df = 6, $p = 0.892$). FTRI was a significant predictor contributing to the status of filariasis in an area. The model could correctly classify 93.3% of the data with a sensitivity of 100% (95% limits: 59.8–100%) and specificity of 67.3% (52.8–79.3%). The relationship between the FTRI and the prevalence of filarial antigenemia has shown that the model is fitted well with the data indicating that the FTRI is a significant indicator of 'non-risk' status of filariasis in an area.

It may be mentioned that through this model, it may not be possible to identify the positive cases from the potential 'risk' areas with any of the existing diagnostic tools. Also it may be noted that all people live at risk of infection may not be infective. But one can expect a relatively high risk of LF transmission with increasing FTRI in the 'risk' areas. The validation study has demonstrated that no transmission takes place in any of the 'non-risk' areas. Since the negative determination of this model is excellent, all the 'non-risk' areas could be omitted from LF elimination under mass drug administration programme.

## 3.3 Delimitation of Lymphatic Filariasis in India based on Geo-Environmental Risk Model (GERM) – Ongoing

The GERM model customized various environmental parameters that are directly or indirectly influencing the transmission of lymphatic filariasis transmission. The present study is aimed to produce a transmission risk map for the entire country based on the GERM model for the delimitation of lymphatic filariasis in India.

In this direction, various steps involved in determining the filariasis transmission risk index (FTRI) have been accomplished by using both geo-spatial and temporal details available with Shuttle Radar Topography Mission (SRTM), Survey of India (SOI), Indian Remote Sensing satellite images, and Indian Meteorological Department (IMD).

The team is in the process of creating the filariasis transmission risk map for the entire country, based on GERM, and this will also be validated. The demarcation of the areas, in terms of Filariasis Transmission Risk will be highly advantageous as a onetime process, particularly for the areas, where no survey has been carried out even once and their endemicity not known. Based on the degree of risk, the areas can be stratified and this will help prioritizing them for intervention.

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