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Contribution of Remote Sensing for Estimating the Impact of Environmental Change, in the Detection of *Japanese encephalitis* Disease in Gorakhpur District, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Case Study

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ABSTRACT

It is an important consideration of any area to be distributed spatially. *Japanese encephalitis* (JE) is a Vector Borne Disease (VBD) that is widespread in Asia. It results in severe illness, death, and hence in economic damage to households. In health planning and management, it is important to demonstrate the land use planning, and water resource planning in order to formulate the vector accumulation around the surroundings. The potential larval habitats of JE were identified using integrated remote sensing and Geographic Information System (GIS) analysis. Remote sensing is a technique to provide data and relate the factors of disease mainly vegetation and water. The objective of study is used remote sensing technique to relate and monitor the predictive area for infectious diseases. Remotely-sensed data have generally been used in two ways, namely (i) for the identification and mapping of land cover associated with host and/or organism habitats, and (ii)

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for the use of NDWI techniques to find out the vegetation and water content. Land cover classes, vegetated area, and presence of soil surface water content are high in growing seasons and the disease susceptibility also occurs in the areas and seasons. The results represent spatial maps of 2006 and 2009, interrelate the JE disease factors with remote sensing. It is used for depicting the area that significantly predicts the higher spread of disease. In future planning, these spatial maps of two different years appear as a promising and delineating strategy for the further JE disease study.

Keywords: Remote sensing (RS); vector borne diseases (VBD); Japanese encephalitis (JE); NDWI.

1. INTRODUCTION

Vector-borne diseases (VBD) have emerged as a serious public health problem in the countries of the South-East Asia, including India [1]. *Japanese encephalitis* (JE) is the leading cause of viral encephalitis in large parts of Asia with temperate and subtropical or tropical climate. The encephalitis mosquito transmits JE virus and breeds in areas of shallow surface water that are suitable for mosquito and parasite development. These environmental factors can be detected with satellite imagery, which provide high spatial and temporal coverage of most of the earth's surface. Since 2000, the JE occurrence has been reported in 16 States and Union Territories and among them Uttar Pradesh, Assam and Karnataka have accounted for more than 90% of the total incidence in India.

An epidemic of viral encephalitis was reported from July through November 2005 in Gorakhpur. It was the longest and most severe epidemic in 3 decades; 5,737 persons were affected in 7 districts of eastern Uttar Pradesh, and 1,344 persons died [2]. The incidence of JE infection is relatively high during monsoon, period and it strongly depends on rainfall, humidity, and temperature as well as the paddy cultivation [3].

Disease mapping is used to understand the geographical distribution and spread of disease in the past or present [4]. In disease mapping, using remote sensing analysis of land cover is an essential element of most remote sensing analysis [5]. With land cover classification, the role of remote sensing is the role of land cover in disease mapping [6], and environmental studies [7].

Remote sensing techniques are used to measure near-infrared and short wave infrared radiation observations derived from satellite-based data. A ground resolution threshold of 30 m was used to strike as the relationship between vegetation type and disease vectors, reservoirs, and hosts [8].

The present study evaluates the JE disease factors with Landsat ETM data of year 2006 and 2009. Vegetation type and growth stage of paddy along with the extent of water availability are reported to be the important factors in determining vector abundance. Mosquito larval habitats in this area are diverse and change with the season. During the dry season some rivers and streams become completely dry, while others have reduced flow and numerous isolated, residual pools of water in the main riverbed. Flooded area predict seasonal swamp area used or rice cultivation during rainy season. The classified land cover types are particularly conducive to mosquito breeding.

Landsat spectral data, particularly band 4 (infrared) and band 5(mid-infrared) are well suited for vegetation and water content analysis. For these reasons Landsat ETM data were chosen as the base imagery for larval habitat assessment [9]. Different approaches have been implemented to extract the vegetation and water using ERDAS Imagine remote sensing Software. These approaches are: (1) Supervised Classification (2) Normalized difference Water Index (NDWI). The result hypothesized that areas of the landscape will exhibit higher NDWI and paddy-crop in spring which is particularly an important target for spread disease.

2. STUDY AREA

JE disease cases were reported in the Gorakhpur district, Uttar Pradesh, India. It has an area of 3483.8 sq. km. The district lies between 27º6´57˝N–26º28´45˝N latitude and 83º7´3˝E - 83º40´5˝E longitude. The location map of study area is shown in Fig. 1.

3. DATA USED

The details of data collected and sources are described in Table 1.

The JE disease cases data of years 2006 and 2009 were collected from the district hospital of Gorakhpur. The population data was collected from census of India, 2001 [10]. The pig population data was collected from the statistical booklet of Gorakhpur. The focus of this research is on the usefulness of LANDSAT data for monitoring and mapping of disease. The collection of satellite images of LANDSAT ETM, which are freely available on U.S. Geological Survey (USGS) website and downloaded with path and row 142/041 and 142/042. These two multi-temporal data were acquired with a nominal spatial resolution of 30 meters from years 2006 and 2009, and used for mapping and monitoring of disease.

3.1 Environmental Data

The life of JE virus was influenced by vectors namely *Culex vishnui* and *Culex tritaeniorhynchus*, influenced seasonally and their occurrence depends not only on the temperature and rainfall but also on the accumulation of water in the rice fields and animal population (pig, ducks). These factors influence the survival and reproduction of the JE disease, and relates in Table 2. The largest and most suitable water-logged areas occur in the early months of the rainy season mainly July to August. Therefore, the number of mosquitoes

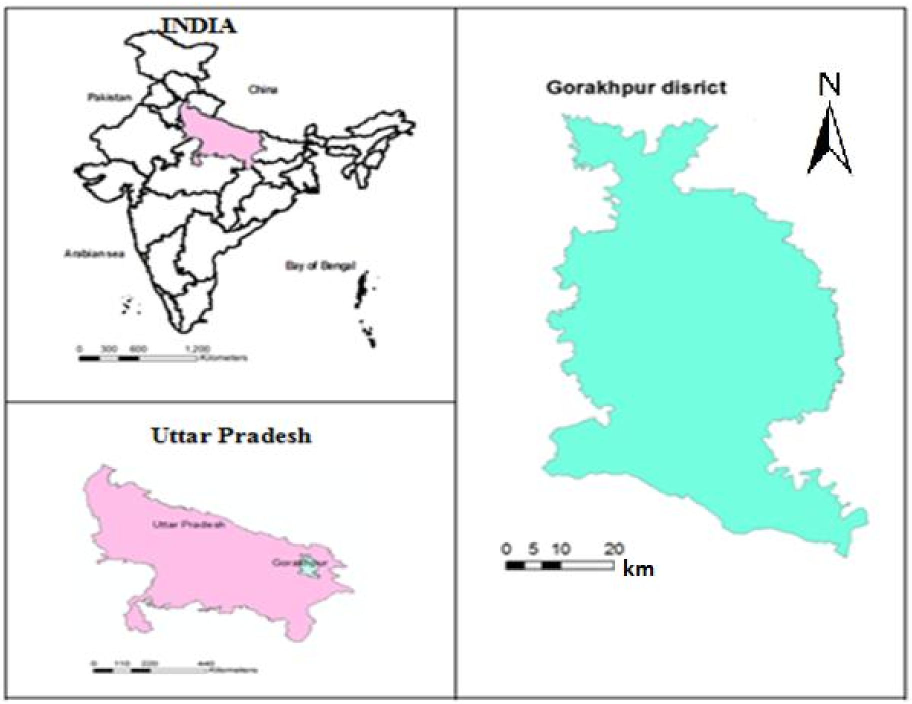

Fig. 1. Location map of study area

Table 1. Detailed of data collected for study

S. no.	Data collected	Details of data	Source of data
1	Topographical maps	63M/4,63M/8, 63/N1,N/2,N/3, N/5, N/6, N/7, N/9, N/10, N/11	SOI, Dehradun
2	Satellite images	Landsat ETM	USGS website
3	Statistical data	Census of India, 2001	Census of India
4	Pig population data	Year 2003,2007 and 2010	Statistical booklet of Gorakhpur district
5	Health data	JE disease data monthly and yearly	Health Department of Gorakhpur
6	Rainfall data	2006, 2009	IMD, Pune
7	Mosquito data	Three sites	BRD, Medical college.

in each year is dependent largely on the conditions of this season. Major factors that influence the occurrence of JE cases are temperature, rainfall, and rice field area, as they are breeding place for mosquitoes.

The average monthly rainfall was obtained from the meteorological stations, collected by the (Indian Meteorological Department) IMD website. The average monthly rainfall is 22.2 mm to 473.0 mm that occurs with high rainfall in June-August. Rice fields areas (km^2) in the study area are terraced rice fields of small size that are predominant that were extracted block wise from the classified image of satellite data.

3.2 Mosquito Vector Sampling

In Gorakhpur, there are 19 blocks that specify the collection of mosquito disease data. The mosquito data was collected from medical college of Gorakhpur. The data was collected from three sites and mode of vector trap on a 15 days difference. Sampling sites are shown in Fig 4. The period of collection being 6 p.m to 6 a.m.

4. METHODOLOGY

The Landsat ETM data of years 2006 and 2009 were downloaded and extracted the study area boundary map. The stacked and clipped images of both years are used for study. Seven bands, in layers, of satellite data, thermal infrared band 6 were removed from dates of imageries. The overall methodology of work is explained in Fig. 2.

The thermal band was not included in stacked images with all six images, as it measures the amount of infrared radiant flux emitted from surfaces [11]. While other bands provide a measure of reflected energy, band 6 measures transmitted energy. The remaining bands, 1 to 5 and 7 were a subset of each individual scene, clipped and mosaic. The range of satellite band 4 is 780 µ to 900 µ, and is primarily used to estimate biomass, although it can also discriminate water bodies and soil moisture from vegetation. Band 5 has a spectral range of 1550 µ to1750 µ and is particularly responsive to variations in biomass and moisture.

Originally, all the remotely sensed data are geocoded to the Universal Transverse Mercator (UTM) projection, but to attain precise result, all the satellite imagery were rectified using ground control point (GCP). Geometric correction was run to rectify the satellite scenes to UTM map projection. Rectification corrects the distortion within the scene as well as georeferences the scene to the UTM co-ordinate system. The first and second scenes to be geocoded by using base map data with Root Mean Square (RMS), are equal to ± 0.2 and ± 0.8 for which map co-ordinates were known. The points were precisely collected on the road network intersection points. The polynomial transformation model was adopted due to its simplicity and because such a model is highly recommended for flat areas.

Table 2. The factors that influence the survival of JE disease

Parameter	Condition of rice fields	
	May to July	peak July to early August
Rainfall (mm/month)	67-98	160 – 298
Area of breeding place	Small	Dense
Density of rice plant	Sparse	Sparse/dense

The classified images are validated using vegetation water map, they and predict the area of risk density by using mosquito density data.

5. SOFTWARE USED

This is spatial data integration software is used to map the blocks information geospatially in the GIS environment. The population data, piggistic data, mosquito density and disease case of present study area were prepared using the ArcGIS 10 ESRI software. Satellite scenes were loaded into the ERDAS Imagine software (2010), by pre-processing images, their classification and model makers.

6. SUPERVISED CLASSIFICATION

Land cover mapping from remotely sensed data is used in the steps of classifying technique. The steps in classifying the imagery are used in statistical algorithm, which are quite different from each other. As for supervised classification: the training stage, the classification stage, and the output stage [12]. Image analysis was performed using ERDAS Imagine 2010 - a classification analysis package that uses an approach rather than the traditional pixel-based routine. Image data is classified based on image brightness values and extracts the homogeneous regions as individual objects. A supervised classification involves collecting training samples, preliminary classification, and comparison with the field data.

Training, classification, and comparison are then performed several times until the classification achieves a desired accuracy of above 85% for the initial classification [13]. The maximum likelihood classification rule is used to assume that the probabilities of class are equal for all classes, and it also takes into account the variance of each of the signatures. This variance is important when comparing pixels to signatures.

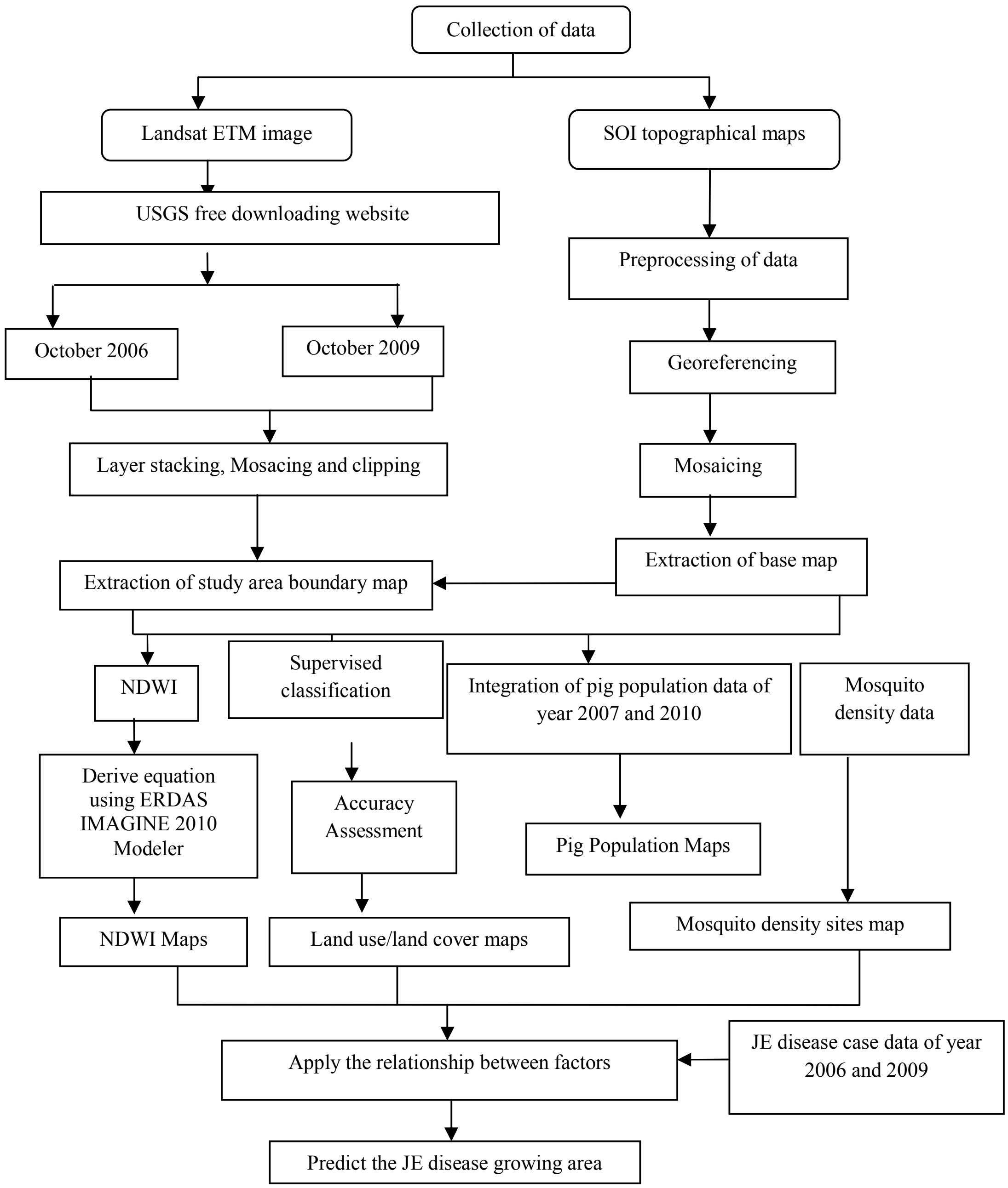

Fig. 2. Flow chart of methodology

7. ACCURACY ASSESSMENT

Accuracy assessment is the final stage of image classification process. It is a post-classification method like computation of class statistics, accuracy assessment, and map preparation. Factors that limit the application of post-classification change detection techniques include cost, consistency, and error propagation [14]. This study focused on relatively small geographic units as compared to health studies. Hence, much variability is not expected within a short distance and some of changes might not be captured due to image resolution. To assess the accuracy of the classified maps, the ground truthing coordinates of the corresponding reference points with their reference ID was imported in ERDAS accuracy assessment tool. The classification accuracy is achieved by comparing the ground truth data points of the eight themes with the classified image.

The overall accuracy of year 2006 and 2009 data are derived 89%, 88% and Kappa statistics are 0.8305 and 0.84.

8. NORMALIZED DIFFERENCE WATER INDEX (NDWI)

The suitability of habitats for mosquito larvae breeding is dependent on the presence and distribution of specific variables *i.e.*, surface water, water- related vegetation and distribution the amount of precipitation [15]. The abundance of vector larvae and adults is directly linked to the presence, distribution and persistence of water bodies (puddles, ponds). The NDWI technique to use two near-IR channels centered approximately at 0.86 µm and 1.24 µm for remote sensing of vegetation liquid water from space is proposed [16,17].

The normalized difference water index [16] is calculated by using this formula:

$$\textbf{NDWI} = \mathbf{NIR} - \mathbf{Green} \div \mathbf{NIR} + \mathbf{Green}$$

The data sets for classes were created to use supervised classification to individual eight land use class types in the image data. The land use/land cover map used for this study was obtained by analyzing the temporal behavior of vegetation greenness and soil moisture from vegetation indices (NDWI), derived from the same. Mosquito breed habitat was represented as dense, open forest and other-crop, paddy field were immediate adjacent of water bodies. The areas for assessing the risks of JE infection are based on the maximum distance from where an encephalitis carrying mosquito can travel these areas from its breeding ground to infect human hosts. The initial NDWI values that varied from –1 to +1 were linearly stretched between zero and 255, by assigning the least NDWI value in each image cube a value of zero, and the maximum NDWI, a value of 255 [18,19].

The models are developed in Model Maker tool in ERDAS Imagine 2010 software. The resulted image was shown the area which is highly water area. The NDWI models were run using both two images of Landsat of year Oct 2006 and Oct 2009 is shown in Fig. 3. for Oct 2009 data as well as Oct 2006.

9. RESULTS

The carried work explained the disease rate from the months of October in years 2006 and 2009, and using remote sensing technique included the factors that are responsible to the spread of the disease. From the survey and collection of JE data from the district hospital of Gorakhpur, JE disease highly occurred during the mid seasons *i.e.* August - November. Fig. 4 displays the disease cases of years 2006 and 2009 for the months October.

9.1 Block Wise Spatial Generation of Data

The collected disease data are integrated in the GIS environment at block level division.

9.2 Spatial Mapping

Data related to JE disease at block level was geocoded in the GIS environment. The total population in blocks of district and total pig population in blocks of district for years 2007, and 2010 are geocoded and shown in Fig. 5, 6, and 7. Mapping incidence of JE disease is the step to analyze block levels for of years 2006 and 2009, which needs to be done carefully. Blocks in high number of population have more incidences, which closely reflects in the statistical variability and is shown in Figs. 8 and 9. Mosquito density site map is shown in Fig. 10.

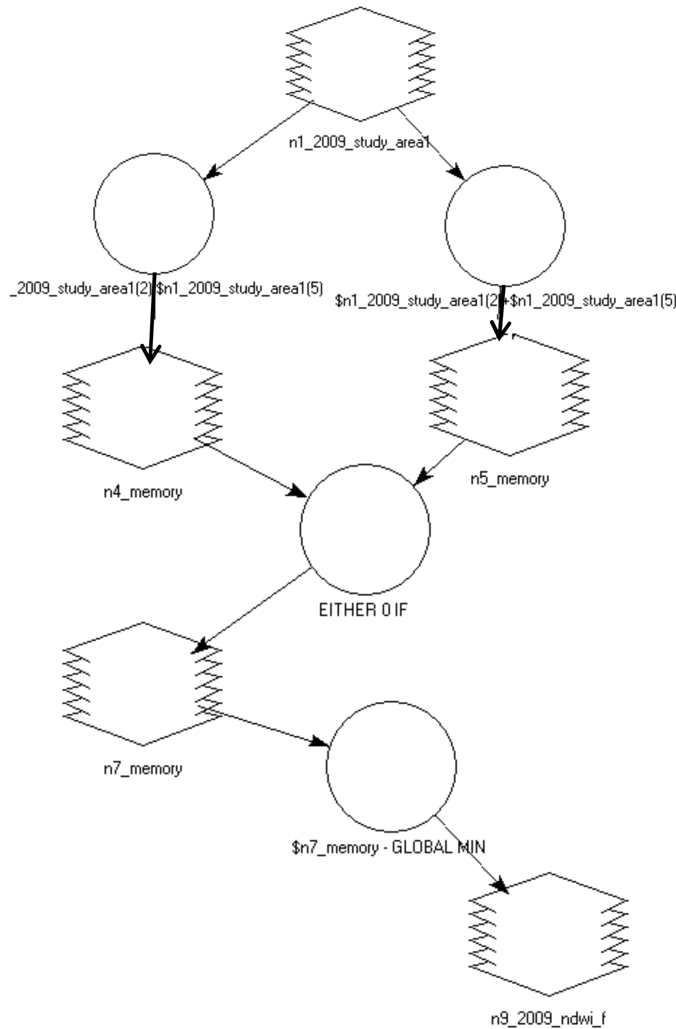

Fig. 3. NDWI model for Oct 2009 Landsat data

9.3 Remote Sensing Data Integration

The extraction of land use classes for years 2006 and 2009 are shown in Figs. 11 and 12. The vegetation-water for different years are shown in Figs. 13 and 14. This represents that in the month of October, cases of deaths were on peak due to the vegetation and water distribution. A comparison of two different time imagery with the disease data was done for different years and the same month; the classes were compressed into distinct classes, namely water, forest, fellow land, water sand, other-crop, paddy crop, pond and settlement (Figs. 11 and 12). Forests in the study area are predominantly herbaceous materials associated with high soil moisture that consequently have higher values in the NDWI. Other crops occupy portions of the image that are more typically open and dry landscapes, where the soil moisture content is lower.

Their presence is indicated by higher brightness value and lower values in the NDWI (Figs.13 and 14).

Rice field areas are breeding places, where water provides habitats for mosquito vectors. However, there are several factors that were not included in this study, such as JE virus in a human population, socio-economic data e.g. population knowledge, pesticide, insecticide, vaccination program etc.

Using statistical data of district data and satellite image for October 2009 can render a better developed model for JE.

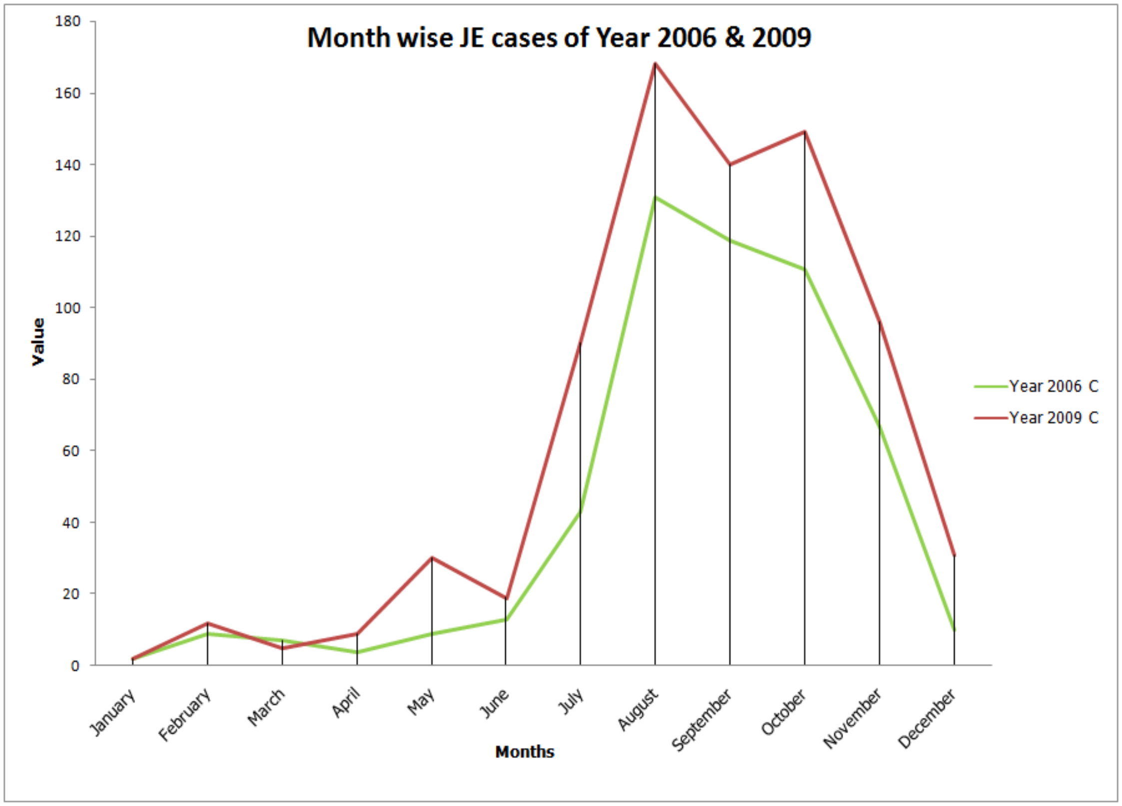

Fig. 4. JE Disease case distribution month wise from year 2006 & 2009

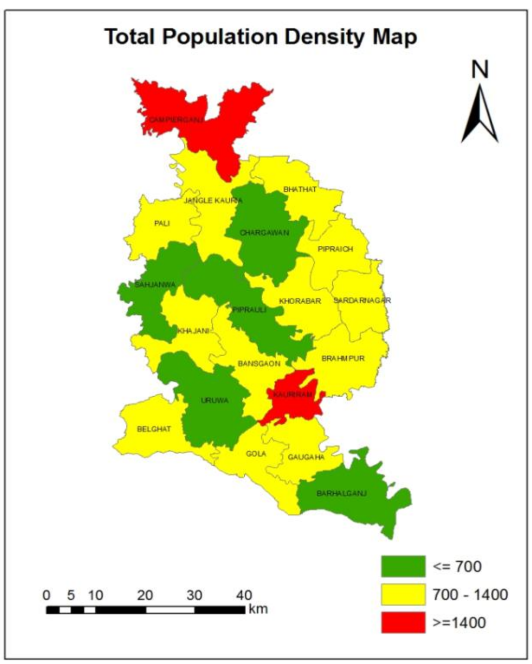

Fig. 5. Total number of population density in year 2001

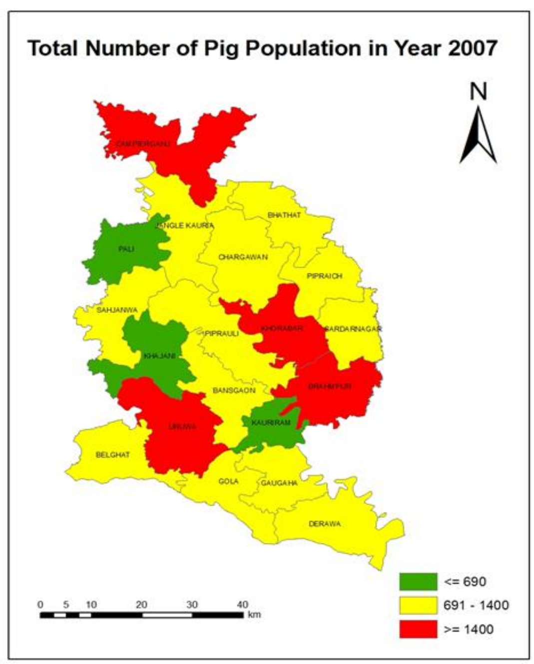

Fig. 6. Total number of pig population density in year 2007

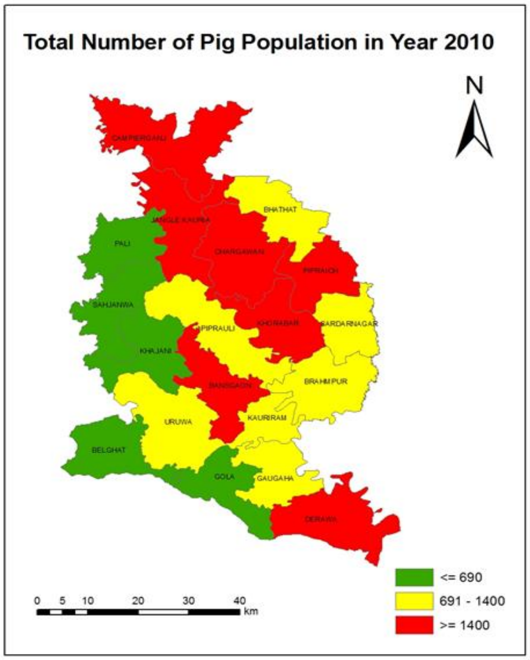

Fig. 7. Total number of pig population density in year 2010

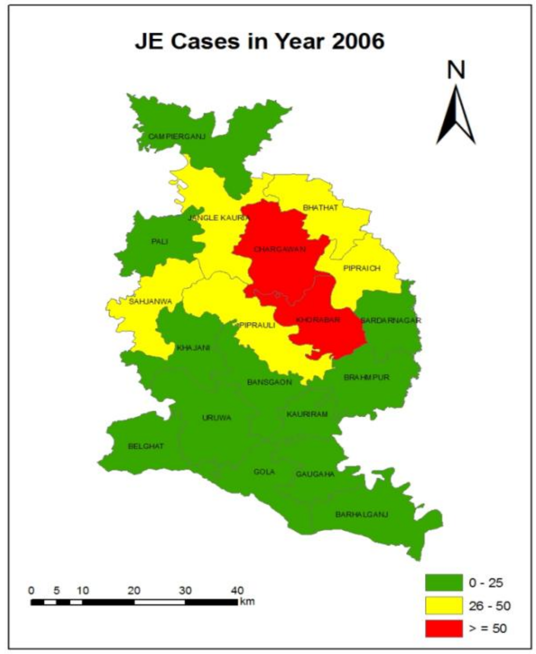

Fig. 8. Total number of JE cases in year 2006

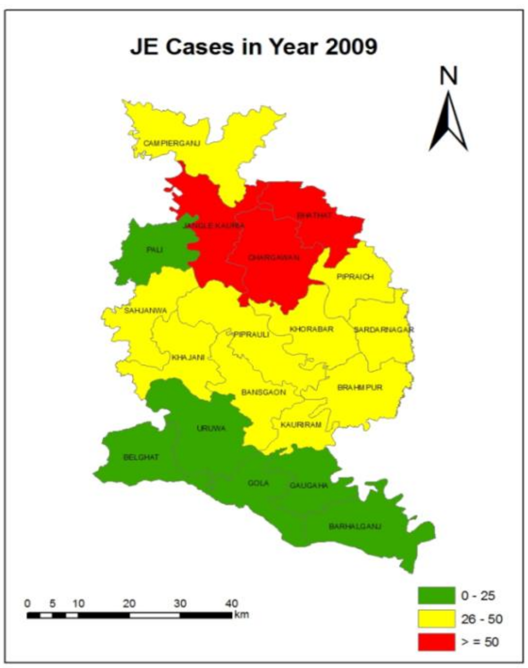

Fig. 9. Total number of JE cases in year 2009

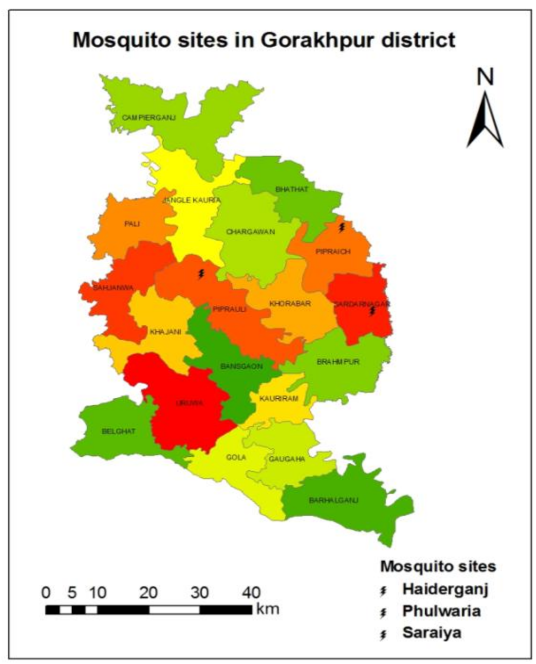

Fig. 10. Mosquito density sites

The relationship between JE cases and environmental factors (water-pixel value, paddy-crop, and pig-population) is listed in the following equation:

$$\text{Case} = f\,(x^1\,\text{water-pixel} + x^2\,\text{paddy-crop} + x^3\,\text{pig-population}) + c1$$

Here case is the number of monthly reported JE cases in the district of Gorakhpur. Rice is the monthly major rice field area in the study area (km^2) and mosquito density per trap from field observation. JE cases were the dependent of these variables whereas other environmental factors were independent.

There is no permanent mosquito monitoring station in the district which is known from the survey. The above relationship are between JE cases and environmental factors rainfall and rice field areas (km^2) and pig population. The prediction equation was selected as the JE model in the district fit with actual data (R^2= 0.407), and was validated with the 2009 disease case data with an R^2= 0.589. Water pool area extracted by NDWI is shown in Table 3.

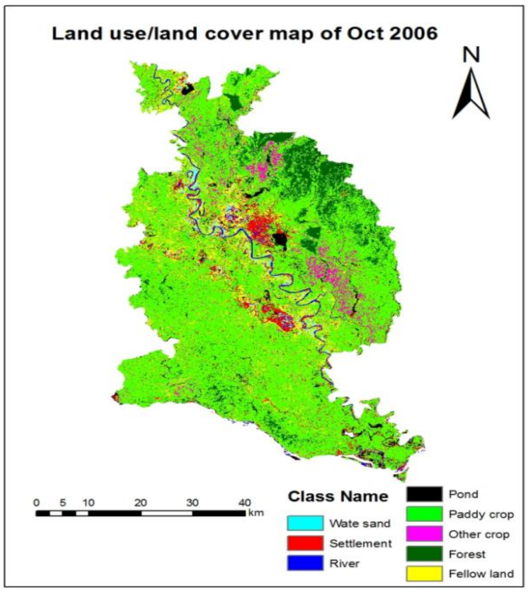

Fig. 11. Land use/land cover map of October 2006

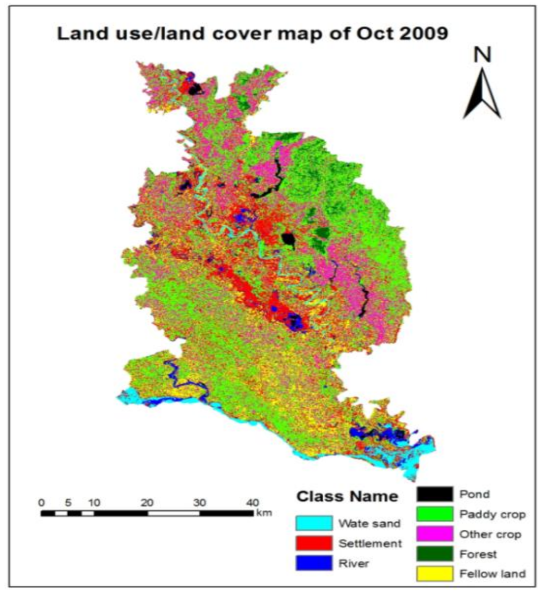

Fig. 12. Land use/land cover map of October 2009

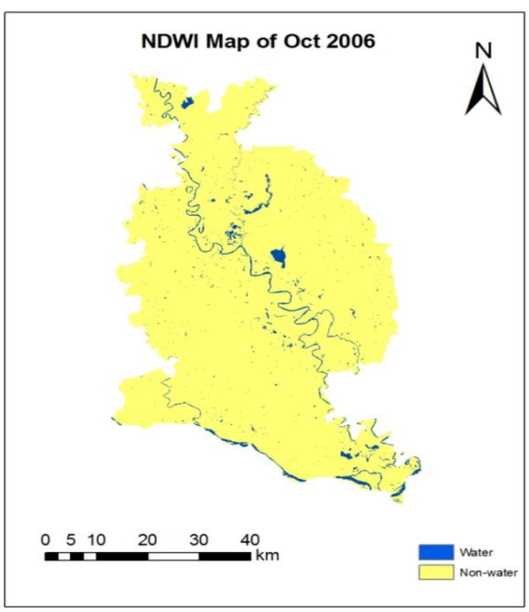

Fig. 13. NDWI map of Oct 2006

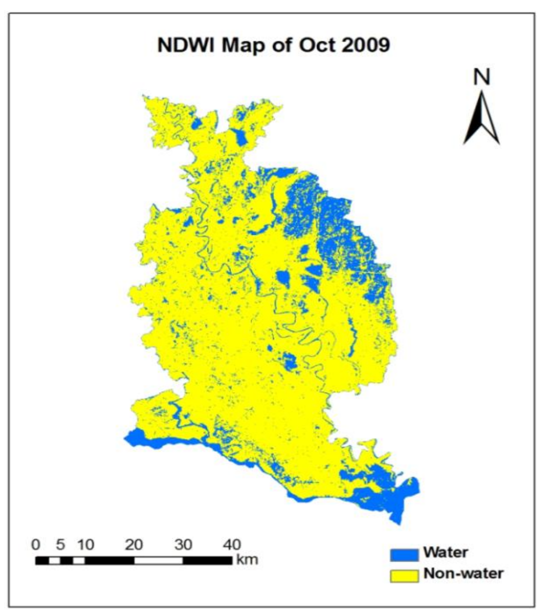

Fig. 14. NDWI map of Oct 2010

Table 3. The area extracted by NDWI analysis

S. no.	Types of image data	NDWI area (m^2)
1.	2006 October	406.62
2.	2009 October	892.81

Paddy field is considered as an indicators or suitable larval habitats. A high value of identified larval habitat was created to identify dense vegetation class immediately adjacent to water classes. Indeed, small standing water bodies have a greater potential for larval development than large open bodies of water, so identifying and classifying small bodies with adjacent dense vegetation is important but challenging, given the limitation of pixel resolution. An average value of NDWI, for each of the seven LANDSAT ETM images for the different months, was obtained for each of the temporally homogeneous NDWI regions. The NDWI (Figs. 13 and 14) show the seasonal dynamics within and between land cover types.

During the early growing season, the areas with shallow soils, high water table, or a large contributing area tend to saturate and are capture in the NDWI images. During May and June it is reasonable to assume that the increase in the NDWI in most land covers is due to the increase in the biomass, and subsequent leaf water content from maturing vegetation.

10. DISCUSSION AND CONCLUSION

This paper has presented the relationship between JE cases and land use analysis. JE cases occur only in those areas where favorable rainfall and other environmental factors are found, such as rainfall, presence of JE mosquito vectors, and rice fields including close by pigsties population. A change in rainfall patterns can change the JE vector mosquitoes breeding potential. Both land use extracted paddy-field area and NDWI based methods were found to be higher extraction of vegetation and water body. The NDWI method was used to successfully map water for the watershed over the larger regional area. The concept of water-pixel used water areas that could predict the mosquito growth and degradation.

Based on field observations, it considered that the primary larval habitats have vegetation immediately adjacent to small water bodies.

The relationship between JE cases and environmental factors, JE cases occur only in those areas where favorable rainfall and other environmental factors are found, such as temperature, presence of JE mosquito vectors, and rice fields including occurrences of pigsties areas. A change in piggistic area and rainfall patterns can change the JE vector mosquitoes breeding potential. The impacts of these factors seriously influence vector survival rates by changing developmental periods.

Overall, the work fitted the well-suited place, where the generation of disease cases is significantly high. Remote sensing directly gets updated, which is a cost-effective, easily accessible source of data and is rapidly a powerful tool allowing for seasonal monitoring of vegetation growth. Moreover, preparations are well advanced for further fleets of satellites, designed to monitor a variety of rice fields, for a better understanding of the changing environment.

11. RECOMMENDATIONS

This work is discussed for JE disease at block level with two different years and the same season, by using remote sensing data at block level.

- High resolution of remote sensing data can be used for further study.
- The generated spatial maps at block level can be generated a village level.
- Disease cases used here are for two years with relation of two year satellite data of the same season and different years. It should be monitored with two different season disease cases and satellite data. Through this, it will be easy to validate the areas that are highly affected by the JE incidence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Saxena Rekha, Nagpal BN, Srivastava Aruna, Gupta SK, Dash AP. Application of spatial technology in malaria research & control: Some new insights. Indian J Med Res. 2009;130:125-132.
2. Parida MM, Santhosh RS, Dash KP, Tripathi NK, Saxena P, Ambuj S, Sahni KA, Rao VP. Lakshmana Kouichi Morita.

Development and evaluation of reverse transcription–loop-mediated isothermal amplification assay for rapid and real-time detection of *Japanese encephalitis* virus. Journal of Clinical Microbiology. 2006;4172–4178.

3. Mutheneni Rao Srinivasa, Upadhyayula Murty Suryanarayana, Natarajan Arunachalam. Prevalence of *Japanese encephalitis* and its modulation by weather variables. Journal of Public Health and Epidemiology. 2014;6(1):52-59.
4. Hay SI. An overview of remote sensing and geodesy for epidemiology and public health application. Advances In Parasitology. 2000;47.
5. Aplin P. Using remotely sensed data. Progress reports remote sensing: Land cover. Progress in Physical Geography. 2004;28(2):283–293.
6. Tran A, Gardon J, Weber S, Polidori L. Mapping disease incidence in suburban areas using remotely sensed data. American Journal of Epidemiology. 2002;156:662–68.
7. Kalluri Satya, Gilruth Peter, Rogers David, Szczur Martha. Surveillance of arthropod vector-borne infectious diseases using remote sensing techniques: A review. PLoS Pathog. 2007;3:1361–1371. DOI:10.1371/journal.ppat.0030116.
8. Beck R. Louisa, Lobitz M. Bradley, Wood L. Byron. Remote Sensing and Human Health: New Sensors and New Opportunities. Emerging Infectious Diseases. 2000;6(3).
9. Zou Li, Miller N. Scott, Schmidtmann T. Edward. Mosquito larval habitat mapping using remote sensing and GIS: Implications of coal bed methane development and west nile virus. J. Med. Entomol. 2006;43(5):1034-1041.
10. Available:http://gorakhpur.nic.in/gazeteer/chap4.htm
11. Jensen JR. Introductory digital image processing. Prentice Hall, Upper Saddle River, New Jersey; 1996.
12. Lillesand TM, Kiefer RW, Chipman JW. Remote Sensing and Image Interpretation. Fifth ed, New York, John Wiley and Sons; 2004.
13. Anderson JR, Hardy EE, Roach JT, Witmer RE, et al. A land use and land cover classification system for use with remote sensor data (revised), U.S. Geological Survey. 1976;964:28.
14. Muzein Sherefa Bedru. Remote sensing & GIS for land cover/ land use change detection and analysis in the semi-natural ecosystems and agriculture landscapes of the central Ethiopian Rift Valley. Ph.D. Thesis, Dresden, Germany; 2006.
15. Dambach. Peter, Machault Vanessa. Utilization of combined remote sensing techniques to detect environmental variables influencing malaria vector densities in rural West Africa. International Journal of Health Geographics. 2012;11:8.
16. Gao Bo-Cai. NDWI a normalized difference water index for remote sensing of vegetation liquid water from space. Remote Sensing. Environment. 1996;58: 257-266.
17. Cao Chunxiang, Chang Chaoyi, Xu Min, Zhao Jian, Gao Mengxu, Zhang Hao, Guo Jianping, Guo Jianghong, Dong Lei, He Qisheng, Bai Linyan, Bao Yunfei, Chen Wei, Zheng Sheng, Tian Yifei, Li Wenxiu, Li Xiaowen. Epidemic risk analysis after the Wenchuan Earthquake using remote sensing. International Journal of Remote Sensing. 2010;31(13):3631–3642.
18. Purevdorj TS, Tateishi R, Ishiyama T, Honda Y. Relationships between percent vegetation cover and vegetation indices. Int. J. Remote Sensing. 2010;19(18): 3519-3535.
19. DeAlwis DA, Easton ZM, Dahlke HE, Philpot WD, Steenhuis TS. Unsupervised classification of saturated areas using a time series of remotely sensed images. Hydrol. Earth Syst. Sci. Discuss. 2007;4:1663–1696.

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