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Multispectral Satellite Data and GIS for Mapping Vector Ecology, Monitoring, Risk Assessment, and Forecast of Vector Borne Disease Epidemics: A Systematic Review

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Abstract The vector borne disease (VBD) epidemics trend have been gradually increased in the world, especially in India for several decades. Mapping the vector breeding habitats, spatial distribution and seasonal variation of vector density, epidemiological survey, and mapping the thematic layers of bio-geo-environmental risk variables, VBD occurrences with respect to space and time, disease surveillance, spatial analysis and spatial modeling for prediction of epidemic risk assessment, and forecast are herculean task, and are involved huge expenditure, man power, and long duration, by the time, then the situation would have been changed, whereas, remote sensing, GPS and GIS are the finest technology which have been used for achieving the task in time with high accuracy, reliable, and low cost. The earth environmental remote sensing of multispectral satellite data are readily available to process the past and present condition of the vector ecology based on the data derived from visible to Infrared (Near Infrared, Middle Infrared, Infrared, and Thermal infrared) i.e. 0.0.45 µm-0.52 µm (Blue), 0.52 µm-0.60 µm (Green), 0.63 µm -0.69 µm (Red), 0.76 µm -0.90 µm (NIR), 1.55 µm -1.75 µm (Infrared), Thermal IR bands 10.41 µm -12.5 µm, and 2.08 µm -2.35 µm, and spatial resolution ranging from 30 meters to less than 1 meters, and SAR (Synthetic Aperture Radar), AVHRR (Advanced Very High Resolution Radiometer), MWR (Microwave Radiometer), microwave remote sensing of various earth resource satellites have been used for the study of weather parameters and climate determinants, and were used to analyze spatial topology with vector abundance and VBD epidemics. The results could thus provide a new basis of guidelines for the control of mosquito vectors as well as disease epidemics early in advance. Mostly, the situation, when the diseases occurrences are strongly related to geo-ecological risk variables, viz; weather parameters, climate season, agriculture, vegetation, land-use / land cover, water features, and physiographic landscapes, and therefore, the data pertaining to bio-geo environmental variables have been included in the spatial prediction models. Remote sensing, and GPS have been used for data collection of vector data (mature and immature), epidemiological site specific information, geo-environmental parameters, and vectors breeding habitats, subsequently, GIS have been used to analyze and mapping epidemic hotspots of VBD based on climate determinants are provided the key elements for depicting thematic layers concerned in both the vector control, prevention measures, and epidemiological management processes in advance.

Keywords: *Remote Sensing and GIS, spatial and temporal analysis, risk assessment, malaria, dengue, chikungunya, Japanese encephalitis, leishmaniasis, filariasis, vector borne diseases*

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1. Introduction

Vector-borne disease transmissions are being restricted by complex interactions between the parasite, the presents of vector population, and people [1-75]. Vector borne diseases are major public health problems caused by contagious pathogens transmitted by biting of blood-feeding vector species and causes of disease morbidity and human mortality largely in the tropical and sub-tropical countries in the world [1-75]. Rational control of these diseases requires an understanding of the links between various biological, meteorological, geographical, environmental [20,21,22], agricultural [14,15,23] and socio-economic factors [1-6]. The increasing of vector-borne diseases epidemics have been the key important public health dilemma in worldwide for more than 100 years and still it has been continued for a long continuous and severe risk to a great part of the world [1]. Remote sensing data were used [14,15,20,21] for mapping environmental parameters [3,5,12-16], including land use/land cover changes [12,19], agriculture crops [12,14,15,23], soil types [58] and its characteristics [15,58], type of vegetation [14,15,19], water features [23,24], vector breeding habitats [25,18,19]. GPS has been used for systematic and reconnaissance field survey [39], and subsequently, data were pooled in to the Geographic Information Systems (GIS) platform to organize, create thematic layers of maps [3-9], and to analyze the spatial and temporal aspects of mosquito breeding habitats [5,8,10,14,15] and predict the hot spot regions of VBD epidemics [52,54,55] leads to control disease epidemics [23,24,35]. Multispectral and multi-temporal remote sensing data were used for analyzing the longitudinal variations in immature vector abundance [3,5,63,65]. The integrated remote sensing and GPS has been utilized for mapping of vector abundance in various seasons with respect to space and time. A limited known ground survey data could be used to predict the value for unknown or inaccessible areas with aid of remote sensing and geographical information system (GIS) [18-25,27,51], and thus, to identify vector distribution and seasonal variations in the country, and consequently, result leads to delineate the vulnerable areas under the risk of infection and to assess the susceptible community and associated health risks. GIS was used to construct a buffer zones around vector breeding habitats to delineate the areas under risk of disease transmission [18,25], based on the flight range of the adult vector mosquitoes of malaria, filariasis, JE, and dengue 2.5Km and 0.4 - 0.5km respectively [1].

Remote sensing has been served as an efficient method of gathering data about larval breeding sites [14,15,23]. Remote sensing (RS), Global Positioning Systems (GPS), and Geographic Iinformation Systems (GIS) have collectively been created effective resourceful tools by which the acquired data are analyzed for mapping of temporal dynamics of mosquito breeding sites, and continuous monitoring effectively [3-75]. Mapping of vector ecology and breeding habitats sites and its spatial and temporal longitudinal variations in both immature and adult vector abundance have been assessed and delineated using multispectral and multi-temporal satellite imagery with in GIS expert engine [23,24,25,57]. The mobile GPS instruments were used for the limited field survey to collect the data pertaining to the vectors and are integrated with multispectral satellite data with GIS expert engine to group the mosquito breeding habitats [18] for the both known and unknown areas in different parts of India [5,51,54]. The present attempt is made for the systematic review of the use of RS, GPS and GIS for mapping vector ecology [57], risk assessment [57], and spatial prediction of VBD epidemics [57] in the world for the past 3 decades, and thus, the map could be a base line leading to more effective application of vector control measures [57] and choose the appropriate control strategy to make successful move towards the sustainable health.

1.1. Remote Sensing, GIS, and GPS for Vector Surveillance

Geographical Information Systems (GIS) technology contains the specific location (geo-coordinates) of an object on a map, and to capture, accumulate, analyze, edit, and display the thematic information on a map [73]. GIS is a complete suite of the subjects of cartography, geo-statistics, computer science and engineering, database management, and the spatial intelligence. A Global Positioning System (GPS) is a mechanic, electronic and geodetic civil engineering surveying tool used for reconnaissance and systematic field survey to collect vector ecological information, breeding sites location and disease epidemiological information including the patient house hold locations [39,43]. Remote sensing techniques are being allowed to collect the information relevant to atmospheric, land, ice, and sea surface, information with high accuracy, reliable, and repetitive [73]. Remote sensing under the GIS expert engine, extract the witness of the details of land use / land cover changes, water surface features, land surface temperature, sea surface temperature, cloud density and pattern, dry and wet cultivation areas, crop types, vegetation covers, soil types, fertile soils, barren lands, shallow lands, mangrove forest, forest degradations, forest dynamics, urban settlement growths, urban transition, urban sprawl, urban agglomeration and environmental transition, land degradations, land pollutions, air pollutions, water pollutions, vector breeding ecology as well environmental epidemiological information, etc., [2-75]. Spatial information technologies, and in particular, GIS and GPS, are used to articulate a clear picture of spatial reasoning of VBD epidemics of the reality of the area where the epidemic situation was very critical [39,43,73]. On the other hand, these technologies by themselves are could not be interpreted and forecast mosquito vector distribution, species composition, or vector abundance [3-72]. It requires appropriate subject knowledge and the multidisciplinary subject's expert skills including medical entomology, health geography, vector biology, remote sensing and GIS, biostatistics, geostatistics, cartography, urban and rural landscape ecology, and computer applications skills.

GIS based map topology analysis could provide the information on the vector density patterns [73] and their spatial characteristics of breeding sources [14,15,18,19,23,25,58], biting behavior and time duration, adult vector resting places, and resting vector mosquito populations and the unbiased estimates of adult mosquito population density [1-75]. The unbiased estimates are required to assess the presence, abundance, and dispersion characteristics of adult mosquito populations with respect to space and time [25,73]. GIS spatial model provides the information on the environmental transition over a period of time duration [51,54,64], and the information on multiplier effect of developmental activities, land use/land cover dynamics, climate seasonal changes, landscape changes, etc., and altogether impact on change in the vector mosquitoes (*Aedes*, *Anopheles and*, *Culex sp*.) life cycle, particularly, on the fecundity, fertility and survival of the vector mosquitoes [1-75]. Vector surveillance system is a periodical monitoring of the geo-referenced vector data with respect to space and time [39,43]. GIS could be provided and depicts the reality of the past, present, and future vector breeding locations, appropriate site selection for fixing adult mosquito trap in the human settlement areas in the urban as well as rural areas to control the mosquito nuisance and mosquito abundance, and thus, the public health authority could proficient to prevent the epidemics.

1.2. Mapping Vector Ecology

Mapping of breeding habitats and vector ecology of malaria, filariasis, dengue, chikungunya, JE, and leishmaniasis have been done for the control and management of the disease epidemic situation using remote sensing data and GIS for the past 3 decades [3-75]. Land use / land cover analysis has spatially associated with vector density and as well VBDs epidemics statistically significant [14,15,19]. Malaria vector mosquito's profusion of most important 30 *Anopheles* species are found in the rural, urban and hilly highland regions associated with water features, rice fields, dense settlement urban areas, and river tributaries and sub streams [3-25,28-33]. In India, 6 major *Anopheles* vector mosquitoes namely; *An. culicifacies, An. fluviatilis, An. stephensi, An. minimus, An. dirus, An.Annularis* are transmitting malaria [6,9]. JE vector mosquitoes i.e. *Culline* mosquitoes mainly *Cx. vishnui* group viz., *Cx tritaeniorhynchus, Cx. Vishnui, Cx. whitmorei, Cx.epidesmus, Cx. pseudovishnui, Cx.fuscocephala, Cx. bitaeniorhynchus* and *Cx.gelidus* are spatially correlated with rice filed wet irrigation agriculture land [23,46,47,48,49]. *Aedes* species (*Ae. aegypti*, and *Ae. albopictus)* density are mostly found in the domestic discarded containers in and around the domestic and peripheral human settlement areas [36-39,41-45], and also has spatial auto correlation with a specific land use / land cover categories [34], different climate seasons [34,45], and environmental variables [36-39,41-45]. Filariasis vector mosquitoes are found ubiquitous and abundance in the entire region of the country [50], however, the disease endemic regions are associated with landscape, soils, and human urban settlements [51]. The environmental variables corresponding to leishmaniasis vector breeding specific ground characteristics were studied and demarcated the risk borne areas for both visceral leishmaniasis and cutaneous leishmaniasis based on the breeding landscapes [58-72], settlement housing structures and roof types, soil type's water holding capacity, alkaline and salinity, and crop types [58-72]. These bio-geo environmental variables have been included in the spatial and ecological niche modeling [64,70,71,72] process, and thus, geo-spatial and ecological niche models were developed [64,70,71,72] for forecasting leishmaniasis transmission risk using remote sensing and GIS [70,71,72]. As a result, these fundamental risk factors of vector breeding sources must be understood to demarcate the site specific high risk regions of past, present and future trend of geographical variations in the breeding habitats, and thus, enable to prepare the maps of changing trend on vector borne disease epidemics.

1.3. Environmental Risk Factors and Vector Borne Diseases

The hybrid of remote sensing and GIS have been used for monitoring and management of natural resources including the fields of meteorology, ocean resource evaluation, glacier and ice, agriculture, forestry, water resource, energy, ecology and environment, urban planning, rural development, transport and civil engineering, land use / land cover studies, human health, birds and animal health, pollution control, and health delivery services in public health sectors [73]. Most importantly, remote sensing and GIS are used to evaluate the natural resources, and to have a spatial model describe the relationships between environmental factors / indicators and vector ecology, vector profusion and vector borne diseases [3-75]. Remote sensing could be used to reveal the types of environments of nature, and to portrait the spatial phenomenon; and GIS could be used to link between spatial data and their associated explanatory information (Non-spatial data): socio-economic, cultural and human health [3,4,5,6,7]. The National Aeronautics and Space Administration (NASA) was commenced the biosphere observation and spatial forecast of infectious diseases during 1985, the aim of which was to determine if remotely sensed data have been used to identify and monitor environmental risk factors that influence malaria vector populations across the third world and other countries [7,8,28,29]. Particularly, GIS was used for the revision of associations between vector location, surroundings, and disease incidence, and was used in the surveillance and monitoring of vector-borne disease [7,39,41,43]. Multispectral satellite data have been used in the studies of vector borne diseases and its environment [9,28,29,30]. The integrated remote sensing and GIS techniques were used to identify villages at high risk for malaria transmission [28,29,30]. Temporal analyses of Landsat Thematic Mapper (TM) Satellite imagery were used to substantiate the guinea worm in association with changes in agricultural production were statistically significant [22]. Multispectral Satellite imagery are well suited for examine the VBD endemic risk factors. GIS [25,27] and GPS are facilitating for comparisons of the longitudinal investigations [42,43], and based on the results, the national level VBD control program could be promoted [25,27,35], particularly, in the epidemic hot spot regions through multisectoral approach in collaboration with local block level or ward level administration might be feasible public health management in the control of VBD endemic diseases. The increase of mean annual and monthly precipitation and monthly number of rainy days could be the risk of VBD epidemics. Land use / land cover classification dynamics have been conducted using multispectral satellite data product of visible to near infrared (NIR) band ranging (0.45 µm to 0.72 µm), and pilot sampling vector data were overlaid on land use/ land cover categories [14,15,23] are having functional relationships between field-sampled mosquitoes and land cover parameters enable for determining risk of vector borne disease epidemic transmission [14,15,23].

1.4. GIS for Mapping Vector Abundance AND Control

GIS has been used for mapping geographical distribution, seasonal variation of vector profusion and VBD epidemics [25,27,42,45,73], and a big data analysis of the environmental determinants [35] of VBD epidemics for a long periods provide the vertical and horizontal structure of the epidemic changes [25,27,42,45,73]. GIS could allow the health geography, vector biology, medical entomology, spatial epidemiology, environmental health researchers to analyze the presence or absence of both immature and adult vector populations, and hence, to construct a map topologies [73], geo-statistical analyses [52], and spatial analyses to develop spatial model [51,54], and ecological niche model [54,64] GIS based ecological niche model(s) link habitat features and mosquito presence or absence, and are used to develop the appropriate control strategy [2-75] including; 1) identify schemes for deployment of mosquito traps, (2) test the existing and new traps in the endemic regions through the health deployment schemes, (3) forecast and predict the vectors spatial distributions and abundance, and to estimate the future hotspot epidemics based on the past and present scenario, (4) link environmental parameters in a control or development sites to assess the adult presence in a specific space and time, (5) and to evaluate and assess the relationships between the climate factors, environmental determinants variables, and immature and adult vector development productivity sites, 6) to analyze climatic variables and host availability patterns, and vector distribution, (7) to identify containment and buffer zones for mosquito control and to evaluate mosquito control efficacy.

1.5. Remote Sensing Application in the Mosquito-borne Disease Distribution

The occurrence of vector borne diseases is found ubiquitous in the 142 tropical and subtropical countries in the world [1]. The applications of remote sensing have been widely used to study the spatial epidemiology of VBD, in particularly, for the risk assessment of mosquito-borne disease epidemics for the past 3 decades [2-75]. Information derived from the satellite imagery [54,55,58] to develop a method to map mosquito ecology and their breeding habitats are statistically significant [66,72,73]. Initial studies largely focused on identifying mosquito breeding habitats [14,15,16,23,32] such as marshes and wetlands, wet cultivation rice fields [14,15,23] through mapping land use / land cover dynamics, using satellite data [12,19]. Several approaches including remote sensing (RS), global positioning systems (GPS), and geographical information systems (GIS), spatial statistics, big data analysis, web mapping GIS, and digital map visualization were addressed to analysis the progress made with the application of geo-spatial techniques on mosquito vector borne diseases, vector borne parasitic diseases, vector borne zoonotic [40] parasitic diseases, soil-transmitted [7] and waterborne helminthes infections [7], as well as arthropod-borne diseases [3-75] such as leishmaniasis [58,59,61-70], malaria [3,9,12,14,23,24] and lymphatic filariasis [50,51,52,54,55,56]. Limited mosquito ground surveys were combined with remote sensing and geographical information system (GIS) technologies to identify mosquito breeding habitats in India and to delineate associated health risks. Mosquito *Anopheles*, *Culex* could be found breeding in water-associated habitats with dense vegetation cover and has spatially associated with water features including existing lakes. Satellite image interpretation key elements are used for classification of the spectral signature [15,23,53,73], and image analysis was used to predict, potential mosquito breeding sites [5,14,15,17,23] of the study sites. Remote sensing has been used to visualize our environment nature and its dynamic processes. Multispectral satellite images were used for epidemiological processes, and the results has been largely endorsed to conclude the diseases distributions [6,46,50], and their variations during the past 3 decades. Most of the circumstances, when vector borne diseases are effectively related to geo-ecological risk factors [10,24,25,27,45,56] viz; climate, vegetation or land-use / land cover, water features, human settlements, cattle sheds, forest cover, etc., and therefore, remote sensing of multispectral data could be included in forecast models. In other cases, satellite data could be utilized to obtain information for drawing thematic layers concerned in the epidemiological processes, which might have vary depends upon the different ecotypes and ecosystems [3,8,9,12-33,74]. According to the research aim and objectives and its final targets, the users could be selected the panel of available spectral radiometers with specific characteristics including spatial resolution and frequency of data. For examples, most important vector borne diseases, animal host population, land use /land cover changes in association with JE, climate factors and land use / land cover impact on malaria cases, environmental parameters and land cover with dengue epidemics illustrate these applications.

1.6. Mapping, Monitoring and Risk Assessment

The occurrences of VBDs are major public health problems in the poor economy countries [1], mostly affected people living in the regions of sub-tropical and tropical countries in the world [1], especially, South East Asia, Africa, and Pacific regions [1]. The epidemiological aspects of huge volume of VBD confirmed cases, and mortality records are stored in the records. Vector borne disease prevalence are associated with different landscape, climate conditions (winter to mild summer, vegetations, altitudes (mountain to plain, and also socio-economic differences (rich to poor) [1-75]. Socio-economic [10], environment [45,56], climate factors [9,30,58] are highly influenced over changing the geographical distribution pattern of VBD prevalence [3-75], and the risk factors are vary to different vectors and the occurrences of VBD [3-75]. Vector profusion are highly associated with different climate, environmental determinants and change over the different seasons [34], and therefore, mapping of VBDs epidemiological characteristics and vector ecology, monitoring periodically, forecast or early warning [30,31] or spatial prediction of VBDs using multispectral remote sensing data [30,31,73,75-79], and other socio-economic determinant variables are giving spatially very fine and accurate could be used for health planning, decision making, drug delivery, and targeted areas for vector control intervention measures.

2. Malaria

Malaria is transmitted by the Anopheles species mosquitoes, and caused approximately 251 million clinically confirmed cases, and 585,000 deaths across the world [1] and approximately 90% of deaths are in the African countries [1], and in India, 162.5 million cases, and 16,700 deaths (WHO 2018). Despite the indoor spraying and distribute the insecticidal nets as we know these are identified as effective prevention control method to malaria transmission by mosquitoes, the country has the furthermost burden of the disease and also struggle to organize control measures adequately. Malaria vector abundance is geographically distributed in highland elevated areas, coastal, urban, and rural plain regions, and it is seasonally varied with monsoon [9]. Wet irrigation rice fields provides the ideal ground for abundance of malaria vector mosquito's larval habitats [14,15,23], and followed by the perennial and semi perennial streams, and water ponds, or lakes are supporting for *Anopheles* vector breeding [9,18,19,20]. In urban areas, over head water tanks are the ideal grounds for vector breeding [18,19,20], and in the coastal areas, water chess pools are supporting for mosquito breeding [9,18,19,20]. Remote sensing and GIS were widely used to map the malaria vector mosquito density [18,19,20]. Malaria epidemics are highly associated with vector density [3,4,5,6,18,19,20], and based on these multiple environmental factors in estimating disease risk by using multi-criteria decision rules, and thus, mapping of malaria transmission risk [9], the risk assessment by areas and by communities have been completed focusing the elimination process in the specifically identified locations with high risks [9]. GIS and remote sensing of environmental determinants using multiple regression analysis predict the malaria API index for the endemic region [9], and hence, model based prioritizing areas for malaria vector control [18,19] as well as disease control measures could be done where the spatial risk of potential vector density exposure and malaria transmission hazard occurred continuously [18,19].

A multi-criteria decision analysis approach (MCDA) was applied in Africa and South America and produced malaria risk maps [26,74]. GIS technique has been used to design a nationwide surveillance system for organize and control of malaria and it was brought declining trend of API index in India for the past 7 decades [2]. GIS based system could be included data on the locations of breeding sites of *Anopheles* mosquitoes [9,18,19,20,73], imported malaria cases [2,9,19], vector population research centers, and surveillance system could also be provided the guideline and appropriate technique [2,9,18,19,42] for the executive collaboration and a countrywide network systems to mobilize localities in the malaria outbreaks. A major role of the malaria control program was to categorize ecological risk factors that affect the patterns of disease transmission risk [9,73] based on the predictive models of vector population changes and vector borne disease transmission epidemic risk using multispectral satellite data and GIS.

Malaria transmission risk zones were delineated based on the geo-environmental risk variables and wet irrigation agriculture rice cultivation land increases the production of *Anopheles gambiae*, the main vector of malaria in India, Mali, and different part of the world [14,15,23]. The spatial variation of malaria vector mosquito's abundance is highly significance in the villages and it has been varied with seasons [3,9,17,20]. Multispectral remotely sensed data were examined for mapping of rice cultivation patterns and vector abundance and malaria API index account for this variance statistically significant. Land use / land cover categories based on two cropping seasons (Karif and Rabi) for some of the villages, the young rice canopy has 86% correlated with *An. Gambiae* profusion in the month of August before the climax in malaria transmission [14,15], and also it has significance with mosquito flight range buffer zones around the villages [14,15,23]. The relationship between *An. gambiae* profusion and rice cultivation could have been used to move towards the disease control and sustainable health [14,15]. The model could provide information on the ecological, meteorological and climatologic data so as to identify, assess the potentiality, and delineate the malaria vector mosquitoes breeding sources [14,15,18,19,20] could be integrated with malaria indices [1,2], such as; malaria prevalence, morbidity and mortality, and this valuable information could be used for targeted control measures in the malaria risk zones in advance.

2.1. Dengue and Chikungunya

Dengue is transmitted mostly by the bites of adult female Aedes aegypti mosquitoes in India [34], and followed by *Ae.albopictus* is contributed to some extent of epidemics in India [4]. Dengue viruses are 4 types DEN1-4 and all the four types of DENV1-4 were reported in different parts of the country [2,10,34,45]. Dengue fever (DF) and dengue hemorrhagic fever (DHF) is a constant and serious public health problem in the country [2,34] as well as in the world [1]. In India, dengue epidemics are reported from 24 States and 3 Union Territories of India [34,45], and highest report was recorded in the 5 States namely; Tamil Nadu, Karnataka, Kerala, Punjab and West Bengal [2,34,45] during 2019. Chikungunya was reported in Kolkata during 1963, and then, it was reported in Pondicherry during 1965, and followed by dengue confirmed cases recorded in the Southern States of India, namely; Tamil Nadu, Andhra Pradesh, Madhya Pradesh, and Maharashtra during 1973, and subsequently, were recorded in Maharashtra, during 1983 and 2000. After the 25 years period of interval, a major epidemic of chikungunya was occurred in 213 districts from the Southern States of India [2,34,45], such as; Tamil Nadu, Kerala, Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, and Gujarat, during 2006. Thereafter, it has been reported with a quantity of cases every year [2,34,45]. Chikungunya vector ecology, climate and environment al conditions are the same of dengue vector mosquitoes [34]. *Ae. aegypti* is ideally found in and around human settlements, preferring low vegetation, biting human for blood and primarily found indoors resting, while *Ae. albopictus* is found commonly outdoors human settlements and breeds in all types of natural containers [34,43,45]. However, gravid *Ae aegypti* female were presented both in indoor and outdoor without any significant difference, and therefore, it has been replaced with *Ae. albopictus* as an outdoor breeder [34,43,45]. Dengue epidemics are associated with dense settlements [10,34,39-43], where high quantity of vector mosquitoes of *Aedes* genus is most prevalent.

Spatial and temporal aspects of dengue fever were analyzed on the basis of vector population dynamics derived based on environmental parameters using a diffusion equation model [35,36,37,45]. A simulations model describe the artificial and natural landscapes shows the auto correlation with dengue epidemics [41] could be realized the advantage of remotely sensed data along with meteorological data for a forecast model to analyze a realistic way the geographic spread of a vector-borne disease including dengue fever [34,44,45]. The potential use and limitations of remote sensing data and GIS applications, spatial statistics have been analyzed for the past 30 years, and concluded that RS, GIS and Geo-statistics are as the applied spatial epidemiology [27], could be used for a dengue surveillance [39,42], control and management strategy and prevention [42]. A GIS based ecological niche models ascertain the urban growth, economic developmental activities, land use/land cover transformation, and the seasonal climate changes, and its impact on the environment that are most important concern with a sporadic epidemics in different ecological setups [34,36,45]. A Geographically Weighted Regression (GWR) method was used to analyze socioeconomic parameters, such as population density, population movements, standard of living, and the locality to create a prediction of risk map [35,39], and the model could identify degree of epidemic cases in association with socio-economic factors [10]. GIS methodology was planned to explore the influence of geo-environmental risk factors on dengue occurrences. Remote sensing of multispectral data provides the enough data about physical environment and have been used for spatial prediction of several vector borne diseases, including dengue [10,25,29,45], and a amalgamated investigation of the dengue incidences in association with climate factors were revealed using multivariate regression [25,29,45]. The spatial relationship between land use/land cover categories and dengue-affected areas was quantified [45] using GIS, and thus, health planners may perhaps able to choose a appropriate control measures and to priority for organize an appropriate preventive measures based on the risk levels.

2.2. Japanese Encephalitis (JE)

Japanese Encephalitis (JE) is caused by a *flavivirus* i.e. Japanese encephalitis virus (JEV) that is transmitted by bite of female Culex genus mosquitoes, and it has accounted about 50,000 cases and 10,000 deaths every year in the epidemic countries of the Asian continent [1]. In India, 1500 - 4500 cases have been reported in every year [2]. Most of the infected JE cases are asymptomatic [45-49]; however, subsequently, it turns to significant amount of morbidity and mortality [45-49] below 15 years old children [1,2]. In India, JE epidemics are mostly associated with mega water resource projects, and great changes in land use / land cover categories across the nation for the past 7 decades [46]. The change in agriculture practice from dry land crop to wet irrigation rice cultivation crops have been probably source of conducing environments for vector abundance and survival of JE vector mosquitoes [23,46]. The spatial and temporal analysis of JE epidemics clusters in India for the past70 years could be provided the hotspot region of JE transmission across the nation [46]. Remote sensing data and GIS were used to identify and demarcate the wet irrigation crop cultivation [14,15,23], and suitable fertile soil types [46], and accordingly, to formulate spatial analysis of spatial auto correlation between the JE epidemics and determinant variables [46,47,48,49] (husbandry of amplifying host, seasonal migratory birds during the monsoon, and finally the abundance of vector mosquito populations). Remote Sensing and GIS were used for mapping of JE epidemics hotspot regions, the similar study was conducted by the author gives the clear pictures of susceptible regions of JE epidemics as well as endemic hotspot regions in India [46], and thus, could be used as the datum of baseline for the site specific target for control measures to prevent JE epidemics in the country.

3. Lymphatic Filariasis

India is known for the filariasis endemic country in the world account for more than 100 years [1,2,50]. In India, filariasis is caused by the parasite species namely; *Wuchereria Bancroft* 99.4 % and *Brugia malayi* 0.6%, and is transmitted by the bites of infected female *Culex quinquefasciatus*, and *Mansonia annulifera* species vector mosquitoes respectively [50,51,52,54]. The *Bancroft* vector mosquitoes are found ubiquitous all over the country [50,51,54], whereas the endemic districts are located in the along the coastal districts and the districts of major perennial river belts all over the country [50,51,54], and *Mansonia annulifera* species mosquitoes have been densely occurred in the western coastal region in Kerala state [50,51,54], and are delineated as filariasis hotspot endemic regions in the country [51,52,54]. The delineation of areas using the night blood examination survey method is useful for identifying the risky areas at the micro level only [50,52-56], concurrently, it is a time consuming, relatively inaccurate, heavy work load and huge labour consuming, and also it could be influenced by the human factors and it could reflects on the final results [50,55,56]. Therefore, spatial interpolation of infection state at macro level is not possible, auxiliary, the processes not underlying the pattern of filariasis distribution which are basically governed by the environmental conditions [51,52,54]. It exemplify that the risk of filariasis distribution are strictly associated with geographical risk factors of the micro climatic conditions and local landscape variation in the earth environmental conditions.

The geo-environmental risk factors are likely to influence the lymphatic filariasis prevalence [54]. Therefore, the author and his team members have developed a geo-environmental risk model to map the potential areas under risk of transmission of lymphatic filariasis transmission risk in Tamil Nadu region of South India [51,54], particularly the spatial model was used to identify and map the filariasis "non-risk" areas, statistically significant [54]. *W. bancrofti* transmission is strongly controlled by the geo-environmental risk variables, and hence it is possible to identify the areas where risk of transmission could be delineated on a macro-scale [51,52,54]. Remote sensing and geographic information system (GIS) were used to delineate and discriminate the risk of filariasis prevalence based on the mF data, and it was overlaid with land use / land cover and spectral indices derived from the IRS WiFS, and Landsat TM (Thematic Mapper) data is statistically significant [53,54,55]. The relationship between filariasis prevalence and multispectral image data vegetation indices has high association, and the results shows that filariasis prevalence was associated with water sources and vegetation cover, while wetness and moisture vegetation index were the most important indices, and thus, provides a hopeful outline tool for regional filariasis surveillance and site specific direct control efforts [54,55]. The integrated multispectral satellite data with GIS functions were used to identify high-risk village based on the indicators including the vector population density, human infection rate, vector species composition, mean life expectancy, and environmental variables (settlements, elevation, water features, soil types, vegetation cover., etc) as well as meteorological factors (temperature, relative humidity-RH, saturation deficiency-SD, and rainfall) in relation to filarial transmission risk [54]. The results indicate that the most important landscape elements associated with filariasis prevalence are soil, water and different vegetation [54]. GIS and remote sensing technologies were used to not only for mapping current spatial patterns, but also predicting it's both vertical and horizontal distribution corresponding with future developmental and environmental changes [75-79].

4. Leishmaniases

Leishmaniasis is a neglected tropical disease transmitted to human by the bites of infected female sand fly family *phlebotomine* 90 species, and is endemics in the 102 countries [1] across the globe. It has been infecting approximately 2 million people around the world every year [1], and mostly prevalence in the low income group of countries in the tropical and sub-tropical regions in the world [1]. In Southeast Asia, it is reported from 119 endemic districts geographically distributed in the 4 countries namely Bangladesh, Bhutan, India and Nepal, and 90% of the global burdens of VL cases are reported from Brazil, Ethiopia, India, Somalia, South Sudan and Sudan [1]. VL is caused by the protozoan Leishmania parasites *L. donovani* are transmitted by the bite of infected female *phlebotomine* sandflies, namely; *P. argentipes,* P. papatasi. The lifespan of the female adult *P. papatasi* is increased with diminishing temperature between 18-32°C, and the immature *phlebotomines* are ecologically sensitive insects, and highly abundance in the cool and moist areas with high organic matter that serve as food for larvae [58-72]. The VL cases are reported from 54 districts of endemic region in India [58], and the most endemic states are namely; Bihar, West Bengal, Jharkhand, Uttar Pradesh, Gujarat, Kerala, and foothills of the Himalayan mountain range in the North Western sector of India [58-67]. Remote sensing (RS) of multispectral satellite data information and GIS techniques has been used for mapping land use land cover and soils most suitable to VL risk mapping and prediction of the areas vulnerable to epidemics where the areas are having surplus of irrigation sources tend to have extensive cultivation areas under edible shrubs and plants, alluvial soil regions, dark coloured soils alkaline in nature (pH 7.2–8.5), chief inorganic constituents of silicon, iron and aluminum, and its capability of retaining water, and thus, flourishing growth, wealth of edible shrubs, plants or agricultural crops during the southwest monsoon (July-October) in India [58,64,65,66]. Cutaneous Leishmaniasis by *L. tropica* and *L. major* occur in the West and North-western states of India viz; Rajasthan, Punjab, and Bikaner district in Rajasthan, and Kerala states of Southern India [67]. Both VL and CL transmission risk of hotspots clusters were identified, and were delineated using RS and GIS successfully [58,75,76,77,78,79].

5. Conclusion

The public health authorities make a move towards both vector control and epidemic management based on the final results of the spatial ecological niche models. In some circumstances, epidemics have been robustly related to geo-environmental parameters, viz; climate factors, vegetation cover or land-use categories, and multispectral radiation values. In other cases, multispectral satellite data provides information for depiction of thematic layers concerned in the epidemiological studies, which may differ according to the different landscape ecotypes and ecosystems. Moreover, the generated map shows the risk areas, and could be used by researchers to either re-site the epidemic areas or choose an appropriate mosquito control measures so as to prevent health risks and ensure health sustainability of their development. However, the utility and efficiency of the techniques are depends on the experts and accuracy of the available data., etc., Specific problem are including; 1) accurate data on the disease, and basic environmental data on vegetation, land uses, topography, rainfall, etc.; and demographic data on the population movement, and socio-economics of the people are also involved; 2) Computer hardware and software, GIS software and training, RS.GPS, and GIS experts, 3) Health administration personnel's, 4) Government health policy, 5) Founding sources, and finally, 6) there has no conventionality of standard methods of analysis, and the use of the techniques, and the techniques is highly depends upon the individual researchers. It is concluded that disease transmission risk mapping at the district/state/national level could be developed based on the field environmental characteristics, climate, landscape, and entomological data and it could be used by the multidisciplinary approach. The integrated team could be of health geographer, environmental epidemiologist, remote sensing and GIS engineers, and health personnel's including the health administration authorities choose an appropriate tool to perfect sustainable health by formulate an effective vector control strategies in the risk areas well in advance to avoid any major outbreak. It is concluded that the integration of multispectral and multi-temporal remote sensing data analyzed in the GIS expert engine could be a very effective method in combating vector control and vector borne diseases epidemic management.

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