Applied GIS: Critical Cartography and Geovisualization Methods and Techniques in Public Health Epidemiology, Arthropod Vectors Ecology and Surveillance

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Abstract

Better understanding by mapping picturesque thematic information, and visualizing the actual burden of arthropod vector borne disease vertically and horizontally, using GIS, analytical cartographic and geo-visualization methods guide to select an appropriate methods for control and management of the disease. Both, the site specific public health epidemiology and entomological reality information on the grounds could be collected with GPS, and could be mapped under the GIS techniques. Different type of field survey methods and techniques could have been functional for the study of arthropod vectors surveillance, especially, mosquitoes, ticks, and mites vector abundance, and ecology, must have been essentially needed revision and updates for the achievements of goal move towards the betterment of vector borne disease control and management. Probability sampling (random sampling, systematic sampling, stratified sampling), and Non-probability sampling (convenience sampling, snowball sampling, quota sampling) existing conventional survey methods have been replaced with GIS scientific methods, used for public health epidemiological studies, and arthropod entomological study as well. Applied GIS contains the methods and techniques used for different field survey, such as; a systematic grid sampling techniques, GIS and GPS based reconnaissance survey methods, cluster sampling, stratified sampling, multistage sampling pilot sampling and random sampling survey with i) physiographic landscapes, ii) climate zones, iii) socio-economic structures, iv) settlement structures, v) land use / land cover categories, and vi) sampling survey in the buffering zones, etc., provides the accurate geo-coordinates site specific approach to portray the diversity and reliability of arthropod vector presents, and geovisualization of the vertical and longitudinal pattern of vector profusion, and thus, researcher and planners could be formed a datum of guidelines for arthropod vectors surveillance, and hence, preparing the indispensable prevention measures to vector borne disease control and management for sustainable health.

Key words: *GIS mapping, vector ecology, public health entomology, survey methods, spatial epidemiology, surveillance, mosquitoes, ticks, mites, arthropod vector borne diseases*

Introduction

Applied GIS is the structured spatial engine to include the range of techniques for amalgamation of collected entomological information, in which analyse vector profusion, diversity and its association with local environmental conditions, using geostatistics, and digital cartography and geovisualization methods [1-7]. Arthropod vectors include mosquitoes, sand flies, ticks, mites, bugs, lice, fleas, and biting midges, and other arthropod vectors which carry the pathogens, and act as an agent to transmit parasites mainly to animal and human host either by injection into the bloodstream directly, or through their salivary glands, or transmit by forcing parasites into a pool of blood which develops when masticating the body skin[8]. The neglected tropical diseases transmitted by arthropod vectors have public health importance, parasites causing fever by transmitted pathogens have obvious records reported all over the world and significance. Choosing an appropriate sampling technique for field survey to collect vectors, disease ecology, and the epidemiological information has the most important role in visualising the real situation of the ground perfectly, further leads to plan accordingly to make proper choice for both vector and the epidemic control [9,10].

The combined cartography and geo-statistical methods are mandated to bring the information on the health planners table instead of keeping a bulk of records in the file, which provides the burden of epidemics, perpetrator behind in it, and their hidden risk factors including natural and manmade. Cartographic visualisation has been applied to trace the reason for the impulses of the tropical infectious disease epidemics from 18th Century onwards, and arrived to draw a conclusion scientifically [2-4]. The modern GIS techniques have replaced the classical cartographic visualization methods with high accuracy, speed, and comparatively low cost. Beyond mapping techniques, GIS has inbuilt combination of cartography, geo-statistics, cartography, computer science and engineering, mobile online database connectivity (ODBC), geodesy civil engineering (surveying and mapping), web mapping and real time embedded mapping, structured query language (SQL), decision support with spatial analysis and spatial modelling techniques, etc.,[1-16] The modern cartographic visualisation methods has been aid to shape for scientific conclusion on disease epidemics for several decades [3,9,10]. The state /national public health planners have made scientific thought about the vector and vector borne disease epidemics based on the single frame map on their table at a glance. The spatial and temporal aspects of disease prevalence provide guidelines about the disease burden, spatial extent, and diffusion trend. During and after the world war-II, prolonged famine, natural calamities and disasters including floods, tsunami, cyclone, terrific Toronto weather, landslides, monsoon failure and droughts are fuelled to many fold increase of infectious diseases including vector borne diseases. The advanced GIS mapping critical cartographic techniques, and geo-visualization methods aided to plan for the prevention and control in the appropriate manner lead to appreciate level [1-7].

Applied GIS: Cartography and Geovisualization

Geographical Information Systems (GIS) is a modern cartographic technology which could provide the answer to the many of public health or spatial epidemiological questions, such as; what is present (disease or vector)? Where is it (location)? How they are present (spatial patterns, diffusion direction, and vertical trends)? Which magnitude (vector abundance or number of disease)? Why it is there (reasons for vector presence or disease epidemics)? Raw data compiled in a file could not make any sagacity, and incredibly difficult to interpret the actual ground situation [3]. The huge numbers of commercial GIS software are available with comparatively low cost in the public market, and therefore, the GIS user experts have to choose the right software for their needs to accomplish the purpose [9,10]. At a glance, raw data could not provide the details of vectors [11], and vector borne diseases presence with have no site specific location with a particular shape, size (area), diffusion trend, and pattern, whereas, GIS analysis and mapping have fulfil the expectations of researchers and programmers [12-16]. Spatial analysis could be answered to find the disease origin or epic centre, magnitude, direction, trend of its spatial diffusion. As for the environmental pollution concern which affects nature, as a result, imbalance or deteriorating nature leads to human health issues, such as; physical illness, mental health, profusion and propagations of vectors, parasite development, and disease epidemics. Cartographic visualisation and GIS techniques are applied to endow with solutions for the environmental management to vector control, and prevent the vector borne disease epidemics. Cartographic results shows the disease burden of the community visualise the prospect risk of neighbours with infectious disease in a definite time point. The applied GIS has no limit in its applications, and used to conduct a field survey, choosing a sampling techniques, to develop a database information management, answer the structured queries, portray of the vector density, mapping the ecology, disease epidemics, guidelines to public health personnel about the disease magnitudes, spatial disparity or ubiquitous of the health services, beyond all, it could be provided the visual pictures of the epidemics, vector ecology, enlist the causative risk factors of the diseases (man made causative risk factors, socio-economic inequalities, climate, and environmental determinants), lead to predict the disease transmission in the newer areas, and address the difficulties through map guidelines to use as investigation apparatus to draw the new insights to good public health management. Spatial and temporal analysis of diseases, using GIS has been addressed to standardize the both vertical and horizontal structure of the communicable disease patterns with site specific at a particular time point, and as a result, the public health administrators choose a required control strategy to maintain sustainable health.

Survey Methods and Techniques

For both vector ecology and disease epidemiology, survey methods and techniques are varied with its purpose. Probability sampling (random sampling, systematic sampling, stratified sampling, buffering, multistage sampling, cluster sampling, pilot sampling), and Non-probability sampling (convenience sampling, snowball sampling, quota sampling) are used to collect the field sample primary data relevant to vectors and the patients.

Probability sampling: A systematic grid sampling techniques are applied to collect the fixed number of field data within the lattice boundary limits. Random sampling is used to ascertain the predicted value of vector abundance or risk of epidemic transmission or predicted map value using Kriging spatial interpolation methods (Simple Kriging/ Co-Kriging, Universal Kriging, Indicator Kriging, Probability Kriging, Disjunctive Kriging, Empirical Bayesian Kriging, and Areal Interpolation) used to assign the continuous spatial value for the unknown points in an area or not easy access point or data is not available, using a set of mean tendency of values in neighbouring grid segments or global means, applied within geo-statistical methods [3,15]. Buffering technique has been employed to fix the trap to collect the immature and the adult vectors, as well as the collecting the epidemiological information within the fixed radius boundary limit to assess the spatial agreement between the vector breeding surroundings, vector profusion, and vector borne disease epidemics. Buffering have made along the rivers, lakes / pools / dams / water reservoirs, rice fields, human settlements, roads, railway lines, forest land covers, , etc., [14]. Multistage sampling is applied to study the disease epidemiology in the different age group at a particular community or conveniently, in different locations / area codes [14,16]. Cluster sampling is employed to collect samples in the different unique clusters (for example- vectors: low density, moderate density, high density or disease- low risk, moderate risk, high risk). Pilot sampling is used to collect samples in a fixed radius, size, and shape boundary limit randomly fixed in number of sample sites in different land use / land cover categories/ different ecosystems/ physiographic landscapes/ different climate zones [14,16].

Non-probability sampling: Convenience sampling methods is not fixed or restricted to collect samples, and it depends upon the researcher / field investigator convenient [16] (for sample: i) Socio-economic inequality and human health based on the field quantum sampling techniques, ii) Knowledge, Aptitude, and Practice of prevention methods and control of vector borne diseases among the different community). Snowball sampling is used to recruit the people for testing the newly developed vaccine or medicine, if the test is proved positive results, the researcher has to keep on increasing the sample test. Quota sampling is a stratified sampling employed to collect the samples within the administrative boundaries (for example: Recruit the patient's quota samples to study the education level and health status in the different community or different age groups of the different districts/ state/ country).

GIS for mapping vector ecology and surveillance

Disease ecology and epidemics have been mapped and spatial autocorrelation was well documented by a physician John Snow who traced the cholera occurrences which claimed 616 deaths toll associated with a selective drinking water pump supplied contaminated drinking water in London, UK, during 1854 [1-5]. Vector borne disease epidemics control and management could be achieved by one of the ways is a systematic regular real time vector surveillance [6,11]. GIS has been used to mapping vector ecology, and categorize the vector profusion for the purpose of site specific vector control target with right method for the effective vector control and prevention of epidemics transmission in different locations where the probability of arthropod vector borne diseases viz; malaria, dengue, chikungunya, yellow fever, West Nile Virus, Japanese Encephalitis, Zika virus (ZIKV), Lyme disease, filariasis, Leishmaniasis, etc., become high risk [7,9,10]. GIS has been applied to execute spatial analysis and develop an ecological niche modelling to study the spatial relationship among the ecology, vector abundance, and outbreaks. Previous studies were carried out to study the rice agriculture fields and *Anopheles* mosquito's malaria vector abundance, household's access to streams / water pools located within buffer zone 2.5 Km. *Aedes* mosquitoes breed in containers in and around households, rubber and pineapple plantation, dengue vector abundance, dengue epidemics and ZIKV [11]. Japanese Encephalitis and West Nile Virus (WNV) vector habitats are associated with aquatics environment, wild migratory birds, wild animals, mollycoddle animals, and human accessibility, and *Culex quinquefasciatus* vector mosquitoes transmit parasite *Wuchereria bancrofti* causes lymphatic filariasis, avian malaria, and vector abundances are closely associated with coastal belts, river plains, and alluvial soils distributed in the sub-tropical regions, and *Mansonia* mosquitoes causes brugian filariasis which are breeding in a aquatics floating habitats like *Pistia stratiotes* and *water hyacinth* [8,912,14]. The study of public health entomology, vector ecology, spatial topology, and environmental epidemiology has momentous insights to practise appropriate prevention measures to reduce or control outbreaks in the right time. Reveal and ranking the causative risk factors spatially associated with hierarchy of epidemic risk zones, based on the functional categorization of ecosystems, and their suitability for both immature and adult vector survival, and profusion. Global Positioning Systems (GPS) have used to collect the both immature and the adult vector data in the field with exact geographical locations, subsequently imported to the Geographical Information System (GIS) spatial expert engine which allows the collected data to map visualization of the data for the seasonal investigations [9]. Mapping of vector ecosystems and the vector borne diseases, using GIS accurately classified into endemic, non-endemic, epidemics, chronic suffering, morbidity, disability, and sporadic stigmatization of the infections have been prepared, as a result, both vector control and prevention of outbreaks could be achieved successfully [9,10].

Mapping Techniques in Public Health Epidemiology

Different quantitative mapping techniques were applied to portray the data perfectly [1-5,10]. Each quantitative technique has the significant effect on map illustration and visual impact on a frequency distribution of the vector as well as epidemiological data (equal interval, quantile, equal groups, equal density, log interval, etc.,) , and therefore, choosing a right quantitative method is highly important for mapping and analysing spatial epidemiological data [10]. Fundamentals of critical and analytical cartographic and geo-visualisation knowledge must be chosen to employ for correct pictorial representation of ground reality. Chorochromatic, choroschematic, and choropleth are applied to functionally classifying different themes with different colours, different symbols or pictorial representation on various scales; different colours or line shadings / size and number of dots per inch are used to distinguish the different infectious diseases distribution concentration respectively [10,13]. Digital Terrain Elevation Model (DTEM) in 3D pictures are created to analyse the landscape ecology, slope, vegetation cover, urban land use planning for choosing a sites for hospital, school, markets, residential dwelling, parks, auditorium, health hazard disposals grounds, construction of underground canal / drainage systems for proper discharge of industrial, hospital, and household liquid waste for betterment of environmental safety, and human sustainable health. Critical cartography in public health has main focus on mapping of infectious disease epidemiological data started with map representation, and followed by map generalization, map overlay, map interpolation, map topology, map query, and the rational map generation ready to exercise for the optimum health delivery services, disease epidemic control, and management of the crucial situations [1-5,10,13]. Mapping techniques have been used in public health over 160 years, and it has been further refined with integral part of multidisciplinary approach, as a result, spatial analyse, and spatial modelling have been used to move the next steps towards the decision making for betterment of human health [1-5]. The mapping concept has been gifted intelligent to fuse public health epidemiological information, and facilitated key elements of components scientifically, and to practice evidence based adequate strategy by collaborating multisectoral and multidisciplinary expert of different public health stakeholders including the researchers, pharmaceuticals investors, and medicine suppliers for better improvement human illness leads to move towards the national sustainable health.

Conclusion

The distribution of vectors and disease outbreaks are determined by complex phenomena, and it is much more difficult to understand the problems and their spatial cognitions with available raw data on the round table discussion. Applied GIS for mapping, spatial analysis, and geospatial modelling aided to visualise the spatial and seasonal variation of the both vector density and disease epidemics to pinpoint, and to appreciate the key risk factors force in functional behind the public health issues. Map prophecy provides the guidelines to understand the key elements of vector ecology, locality of patient's house hold locations, risk of neighbourhoods, hospitals sites, transport networks and health service facilities. Therefore, the public health entomologist, and communicable disease salutary officials have been integrated in course of action arrival to making final decision to plan a choice of operational targets to vector control and surveillance to prevent the outbreaks early in advance successfully.

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