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Application of spatial technology in malaria information infrastructure mapping with climate change perspective in Maharashtra, India

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सार - इस शोध पत्र में जलवायु परिवर्तन के परिपेक्ष्य में बादलों के स्थानिक डेटा अवसंरचना (एसडीआई) मॉडल का उपयोग करके भारत के महाराष्ट्र राज्य में मलेरिया सूचना इन्फ्रास्ट्रक्चर मैपिंग का प्रस्ताव किया गया है। *एम-क्लाउड* में, भू-स्थानिक स्वास्थ्य डेटाबेस को सकारात्मक मामलों के लिए विकसित किया गया है और महाराष्ट्र में 2001 से 2014 तक मलेरिया के कारण होने वाली मौतों की संख्या, ओपन सोर्स जीआईएस सॉफ्टवेयर का उपयोग करके; क्वांटम जीआईएस और मैप विंडो जीआईएस के द्वारा प्राप्त की गई है। तापमान, वर्षा और आर्द्रता के जलवायु डेटा का उपयोग करके राज्य के सभी 35 जिलों के मलेरिया के ट्रांसमिशन विंडो (TW) महीने की पहचान की गई थी। क्लाउड मॉडल और तैयार किए गए विभिन्न ग्राफों का उपयोग कर आच्छादित विश्लेषण किया गया। मच्छर 20 °C और 34 °C तापमान के बीच सक्रिय रहते हैं। हालांकि, अत्यधिक संचरण 29 डिग्री सेल्सियस तक बढ़ सकता है। भारत में पिछले 100 वर्षों के जलवायु डेटा के अवलोकन, सतह के तापमान में 0.3 डिग्री सेल्सियस की वृद्धि की प्रवृत्ति दर्शाते हैं। परिणामस्वरूप, भारत के कुछ हिस्सों में वेक्टर जनित रोगों की संभावित वृद्धि, जैसे कि मलेरिया, के बारे में चिंता बढ़ रही है। CORDEX डेटा के आधार पर 2015-2050 की अवधि के लिए सिम्युलेटेड माध्य तापमान का प्रतिगमन विश्लेषण 2050 तक महाराष्ट्र में बढ़ते रुझान को दर्शाता है।

ABSTRACT. The present research paper proposes Malaria Information Infrastructure Mapping in Maharashtra, India using Cloud Spatial Data Infrastructure (SDI) Model with a perspective on Climate Change. In *m-cloud*, geospatial health database has been developed for positive cases and that of number of deaths due to Malaria from 2001 to 2014 in Maharashtra, using Open Source GIS software; Quantum GIS and Map Window GIS. Transmission windows (TW) month for malaria was identified for all 35 districts in the state using climate data on temperature, rainfall and humidity. Overlay analysis was carried using the cloud model and different graphs generated. Mosquitoes are active between 20 °C and 34 °C window. However, peak transmission can extend up to 29 °C. Observations of climate data during the last 100 years, over India, show a rising trend in surface temperature by 0.3 °C. As a result, there is a growing concern about the possible resurgence of vector-borne diseases, such as malaria, over some parts of India. Regression analysis of simulated mean temperature based on CORDEX data for the period 2015-2050 over Maharashtra show an increasing trend over Maharashtra until 2050.

Key words – Malaria, Transmission windows, SDI model, Overlay analysis, Climate projection.

1. Introduction

Spatial Data Infrastructure (SDI) Model is one of the important concepts which facilitate to share and exchange of geospatial data from various authorized users. This has been started with a platform which provides an extensive range of operators to analyses the geospatial and non-geospatial data. It has enabled the different variety of operators to optimize the time, effort and resources while acquiring innovative types of datasets by evading

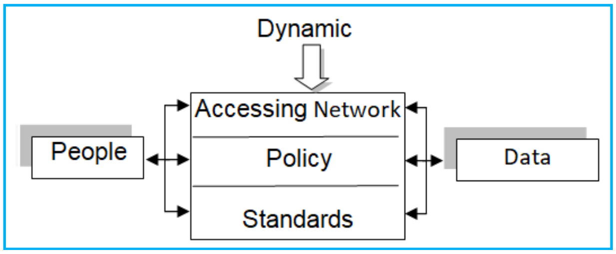

Fig. 1. SDI Model Components (He *et al*., 2015; Barik, 2017)

repetition of expenditures related to production and management of geospatial data (He *et al*., 2015; Barik, 2017). SDI Model is utilized for storing different varieties of geospatial data, decision making, fetching maps and data to mutual measure as required by users, analyzing and querying information, best owing absolute reports or maps to planners and administrators (Yue *et al*., 2013; Puri *et al*., 2007). SDI model covers five modules which have been derived and shown in Fig. 1.

SDI Model has played a significant role in various systems like monitoring of environment, management of natural resource, health-care, planning of land use & urban planning. It has integrated a mutual operation of database like creation of query, computations of statistical data & edge study with distinctive geographical & visualization features. These features extricate SDI Model from various data organizations and made it valued to private & public enterprises for elucidating happenings, forecasting results & scheming approaches (Paudyal, 2012; Barik and Samaddar, 2014; Mansourian *et al*., 2006; Smith *et al*., 2004; Rajabifard *et al*., 2002). For unified SDI Model development, integration is done with cloud computing to execute value added services leads to concept of Cloud SDI Model. In this model, geospatial data have sent to the cloud environment for advance analysis & processing (Barik, 2017; Yang *et al*., 2010; Yang *et al*., 2011). There are loads of open source/free software available as competitors with the variety of proprietary software for SDI Model development and implementation (Schäffer *et al*., 2010). Open Source Libraries and Plug-in have been created by the Developers to knob large geospatial data. Open Geospatial Consortium (OGC) wishes to fortify efficacy of expansion of community-led projects and Open Source GIS (OSGIS) Standards (Wu *et al*., 2010; Vaccari *et al*., 2009; Huang *et al*., 2013). The web services, database creation and modeling services in context to geospatial technology are required for unified SDI model development. OSGIS software is used to implement these services (Brovelli *et al*., 2016; Paudyal *et al*., 2014; Paudyal *et al*., 2012). In current context, SDI Model can be realized in cloud computing platform and articulated as Cloud SDI Model. It has high processing capabilities and infrastructures that up surge output & decrease potential near verge of geo-spatial clients. It also lessens storing desired for geospatial data in cloud with different Geospatial Web Services (GWS). Additionally, it diminishes the obligatory broadcast power effects in creating a general enhancement in efficacy. So, in the present study, Cloud SDI Model has used in the health sector. In this model, it has the ability to share the malaria information mapping in Maharashtra, India from 2001-2014.

Resurgence of Vector borne diseases like Malaria, Dengue and Chikunguniya in India has been on the rise. The present paper attempts to study the patterns and trends of the incidence of Malaria in urban landscapes of Maharashtra by analyzing the data of fourteen years from 2001 to 2014. The ‘spatio-temporal’ analysis highlights the incidence of high risk malaria affected districts in the state of Maharashtra. The Health data of both the positive cases and that of number of deaths due to malaria and climate data on temperature, rainfall, humidity have been collected for all the thirty five districts of Maharashtra from National Vector Borne Data Centre (NVBDCP) New Delhi and National Data Centre (IMD), Pune, respectively.

The findings of the study show that nine districts (25%) *viz.*, Pune, Thane, Greater Mumbai, Raigad, Gadchiroli, Nagpur, Bhandara, Gondia, Chandrapur have the highest incidence of positive cases and death due to malaria. The study also shows that the bigger urban centers report a much higher incidence of malaria over the smaller urban centers in the state, due to in-migration and rapid urbanization. The output of the results are presented in the form of thematic maps, which provide new insight into malaria epidemiology and the complexity of its transmission potential in endemic areas of Maharashtra. The study brings out few mitigative measures in the high incidence areas. In this paper, the geospatial data managed at the verge expending cloud computing platform. It highlighted the following contributions to Cloud SDI model in Malaria Information Infrastructure Mapping in Maharashtra, India:

(*i*) It proposed *m-cloud*, *i.e.*, Cloud SDI Model

(*ii*) It described to mend output and decrease latent for analysis & storing of geospatial data associated with the malaria information infrastructure mapping

(*iii*) It executed malaria information infrastructure (Case Study) as positive case, death trends and transmission window database due to malaria in the district of Maharashtra, India.

(*iv*) It designed the geospatial database creation of malaria data with the help of OS GIS (Quantum GIS and Map Window GIS); and also generated geospatial web services for mobile and desktop applications with Quantum GIS Cloud platform

(*v*) It also performed various data and overlay analysis for processing and visualization of geospatial data in *m-cloud* environment

m-cloud facilitates easy remark and use Malaria Information Infrastructure Mapping for public. This satisfies the anticipated requirement to synchronize entire health related information in a shared place to achieve properties of SDI Model. The clear effort of this developed system acts as catalyst for competent authorities to do suitable controlling and preventing malaria. This gives the main idea behind the design, development and implementation of *m-cloud* in health sector.

2. Description and details of the model

2.1. *Need of SDI model for malaria information infrastructure mapping in India*

Malaria is a major global health problem and part of Vector Borne Diseases (VBD). Worldwide malaria affects 3.5 to 5.0 billion people. At least one million deaths occur annually due to malaria. And 70 to 90% of the risk of malaria is considered due to environmental factors which largely influence the survival of the vectors. Rapid and uncontrollable growth of urban landscapes puts an immense pressure on the quality of urban environment, contributing to poor health to people living in towns/cities. Among the multiplicity of health problems affecting the urban population today, malaria probably is of prime importance, in terms of morbidity and outbreaks. The resurgence of malaria in the country in the early seventies touched a peak incidence of 6.4 million cases. Since then, the cases of malaria have shown a marginal decline and were largely confined with the rural pockets for the country as a whole. But, since its resurgence the disease largely spread to urban landscapes and emerged as a dominant health menace (Rai and Nathawat, 2017; Internet-1, 2017). Climate intensely influences the occurrence and distribution of VBD, such as Dengue and Malaria. Climate change is a major concern today as it leads to renaissance of vector borne disease. Despite, available malaria vaccine by 2006 worldwide; approximately malaria cases of 247 million have been seen & malaria-related deaths figure is around 0.88 million being reported universally. The World Health Organization (WHO) estimated malaria is accountable for 2.9% of world's total Disability-Adjusted Life Years (DALYs). A severe degradation of sanitation conditions in rural and urban landscapes could resurrect malaria, dengue and Chikungunya very rampantly. Variations in temperature & precipitation outlines affect straight to the '*pathogen host-vector interactions*' and by indirect manner *via* variations in water temperature, salinity/acidity, humidity, soil moisture, etc. the pathogens are also sensitive to '*climatic and ecological shifts*' allied with climate eroticisms. Long term climate changes have greater influence on incidence & broadcast of numerous vector borne diseases. Similarly, they may decline in specific areas as habitats become fewer fit for the host or vector populaces for continued broadcast (Saxena *et al*., 2009; Rai and Nathawat, 2017).

The 'malaria' word originates from European colonists who settled in African highlands in 19th century flying from lowlands that were known as 'mal arias' (Epstein, 2001; Kazembe, 2007; Rai and Nathawat, 2017). Dhiman *et al.* (2008) reviewed the synergy between incidence of temperature and transmission of mosquito vector. As the mosquito vectors subtle to climate logical circumstances, temperature verges limit the geo-graphic distribution of mosquitoes, upsurges their reproduction degree, stinging action & the degree at which pathogens developed inside them (Epstein, 2001), Anopheles mosquitoes are malaria carriers & alive for limited weeks only and their malaria transmission proceeds when temperatures surpass 16 °C (Wang *et al*., 2001, 2015; Bhattacharya *et al*., 2006).The increasing number of Malaria, Dengue, Chickengunia cases across urban centers of the country has once again re-generated active interest to study the incidence of urban Malaria among the researchers (IPCC, 2007). The scope of present study is to throw light on the nature of incidence of Malaria over the last one and a half decade in Maharashtra. By the amalgamation of web, mobile & spatial technology greater prospective has been realized for frequent functionality in context to geo-spatial data allotted over internet. It delivers real time &dynamic method to signify data *via* maps. A crucial need arose to launch a well-structured SDI Model geo portal where all stakeholders can utilize, interchange and retrieve spatial data for social, environmental and economic system (Barik *et al*., 2014; Leidig & Teeuw, 2015). One of the key technologies is GWS required for SDI Model development and implementation (He *et al*., 2015). SDI Design and implementation is used in Cloud Computing to share the information about Malaria Information Infrastructure Mapping in Maharashtra, India. It enables the end user or data analyst to rapidly gaze at the problem and gets the info as per the need. Thus, next section describes the details of related works which has been done with the Cloud SDI model.

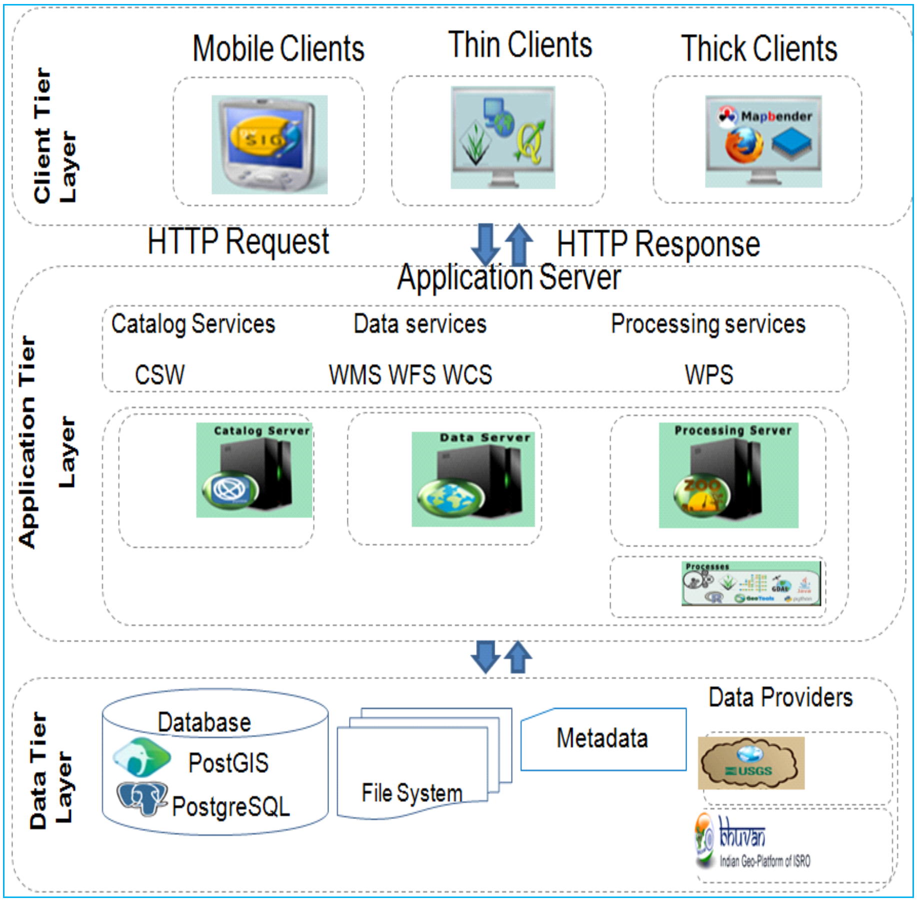

Fig. 2. System architecture for Cloud SDI Model (Evangelidis *et al*., 2014)

2.2. *Cloud SDI model - General system architecture*

Cloud computing provides enormous store and computable asset for implementation of geo-analysis prototypes. Here, the original model provides a transition from PC to quantifiable servers. Cloud computing and supplementary web processing architectures delivers an open environment in web to share various assets (Buyya *et al*., 2008; Chen *et al*., 2012; Huang *et al*., 2013). It brings a platform where organizations inter-relate with tools & proficiency to cherish performances for creating and managing geographical statistics. It describes the aggregate of plans, guidelines, technology, principles & manpower vital to reach, assign, endure, procedure, practice and spare spatial data. The elementary components of SDI are perceived as statistics, community, procedure, principles & networking (Rajabifard *et al*., 2002; Puri *et al*., 2007). Additionally, it can be realized through Service Oriented Architecture (SOA) or Cloud Computing technologies for enhanced and effectual use. SOA attempts to build active, disseminated & supple capability system over web that see data and service necessities for SDI development. SOA based SDI modules are Geospatial Web Services (GWS) which are well-organized set of actions which are exiled, self-confined and independent upon state of other services (Barik *et al*., 2014). Likewise, this model installs a multi-tenant design &unique-instance; authorizing many clients to add assets without upsetting each other. This incorporated method aids installing patches and applications improvements for user's placidity. Another feature of Geo-Spatial Cloud is hold of SOA & web services, a solely recognized architectural approach in engineering (Vaccari *et al*., 2009; Xiaolin, 2005). Numerous Cloud platforms discover the statistics of application & features *via* web service. This authorized a client to inquiry/apprise dissimilar cloud services and applications data in programmatic manner with delivery of normal tool to espouse diverse cloud applications with enterprise SOA infrastructure (Morris, 2006; Leidig and Teeuw, 2015; Yang *et al*., 2010; Wu *et al*., 2010; Yue *et al*., 2013) (Fig. 2.).

The client tier layer consists of thin, thick & mobile clients for abilities of envisaging geospatial data. Mobile clients run over mobile devices. The operator who works on simple web-browsers is demarcated as thin clients;

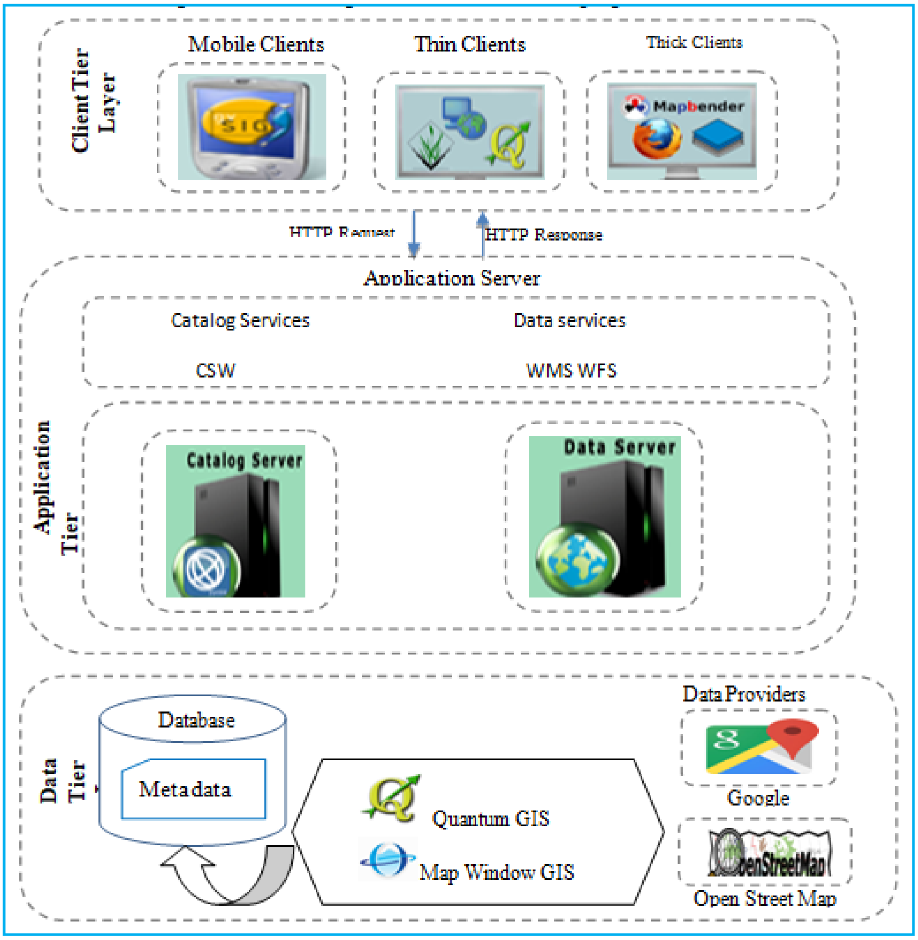

Fig. 3. Proposed system architecture of *m-cloud*

they do not need any extra software for the operation. Thick client operator are handling or envisaging the geospatial data in separate system which needs extra software for full phase operation (Evangelidis *et al*., 2014; Barik, 2017; Gkatzoflias *et al*., 2013).

2.3. *The system architecture of m-cloud – modified for application in the present study*

The system architecture of Cloud SDI Model is categorized into three vital layers. The main phase among these three layers is data tier layer. In the data layer, geospatial database has designed and developed with the help of Quantum GIS (Q GIS) and Map Window GIS. There are several free data service providers, *i.e.*, Open Street and Google map have used with the developed geospatial database. In application layer, catalog services have been maintained for searching of desired available WMS and WFS services in common browsers in desktop and mobile environments. Data server has maintained through QGIS Cloud Provider for invocation of WMS and WFS GWS services. QGIS Cloud Provider has the ability to manage the application layer. Finally, client layer is the layer with the three categories of users. Fig. 3 has illustrated the proposed architecture of *m-cloud*.

2.4. *GWS for cloud SDI model*

The basic concept of GWS is to geospatial data visualization in SDI model by simply plotting the geospatial information of several group and servers in web. Plotting on web comprises the appearance of common plots for display of geographic backdrops and locations in collaborating and customizable mapping tools. The web service allows geospatial data and features in sharable computable platform in an efficient manner (Yang *et al*., 2010). Specifically, GWS applications access database in GIS server and delivers information in geographic components to end-users *via* web. GWS receives and processes requests for geographic information. Various client applications can be built after web services get deployed with availed services. Multiple geospatial & non-GWS helps to create each client application. With this regard, service chaining can be an important part of developing customized client applications (Yang *et al*., 2011,2010).

The OGC Web Map Services (WMS), Web Coverage Services & Web Feature Services (WFS) & interfaces are approved standards for data transfer of GIS *via* web. Web Catalog Service (CS-W) presents several meta-data consists of topological analysis, geographic operation and data format transmission and invoke many services. Web Coverage Services return the coverage data to user. The OGC Web Coverage Services (WCS) return actual raster data. The WCS standard offers interface to allow geographical coverage request *via* web with platform independent call. WCS interface returns both images and objects in geographical area, in other hand WMS interface returns only an image. WMS provide the files in image form & graphic languages like geotiff and SVG. It generates maps of referenced information in geospatial vigorously from geographic data. It permits formation of link for map server allocation by which clients structured customized maps. The operation in WMS invoked by standardized browser in request submission with Uniform Resource Locators (URLs). WFS return actual vector data. The WFS standard facilitates platform which allows request of geographical phenomena *via* platform-independent calls in web. The provisions of OGC WFS outline edge for access of data and operation in manipulation with geographic functionalities in HTTP or HTTPS (Xiaolin, 2005; Yue *et al*., 2013; de Abreu Freire and Painho, 2014).

The Application Tier contains the key geospatial services accomplished by servers. It allows intermediary between different service providers and authenticate clients. In uppermost of application tier, devoted server has been functioned for dissimilar services, *i.e.*, WCS, WFS, CSW and WMS. The devoted application server is accountable for requests to & from client to application server. Furthermore, application services comprise of server application namely catalog servers, data servers & processing servers. Catalog servers are used to pursuit the metadata info apropos stored geospatial data. Catalog server is the system modules for monitoring geospatial information in cloud computing environment. Catalog service is standard publish-find-bind service framework implemented & proposed by OGC web service architectures. Data server deals with the WCS, WMS and WFS (Yang *et al*., 2011,2010). Numerous OS projects are managed on cloud platforms with OGC WPS specification standards. OpenGeo, QGIS cloud is functioning in Amazon EC2, Skygone Cloud platform for various GWS. The viable and ascendable environments in cloud are constructed by using Docker which actsas open-source lightweight technology in cloud container in Linux environment. Open-source software deployed is NumPy,

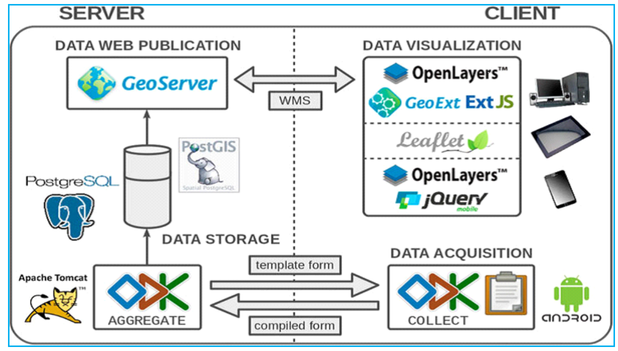

Fig. 4. General system architecture for mobile and other devices (Brovelli *et al*., 2015)

IPython, Grass GIS and GDAL *etc*. (Internet-3, 2017, Internet-4, 2016; Internet-5, 2016).In the era of mobile cloud computing with spatial technology, numerous architectures are proposed for conception of geospatial data in extensive series of application zones with OSS resources. Mobile-GIS applications are involved with an effectual association edge for web services in mobile SDI model applications (de Abreu Freire and Painho, 2014). Mobile Data Service (MDS) architecture is for executing web services of geo-spatial data in mobile client (Athanasis *et al*., 2015). Numerous designing architectures realized in SDI model based on Mobile. The general architecture for managing the field-collected data reports of road pavement damages through mobile and desktop shown in Fig. 4. System architecture displays that the Android based APP developed for the data acquisition and better visualization of spatial and non-spatial data (Brinkhoff, 2008; Brovelli *et al*., 2016; Boonchieng *et al*., 2014).

It has perceived that the cloud computing with mobile devices has prodigious prospective for geospatial data conception and assemblage in varied fields. In the forest information infrastructure, mobile mapping with high resolution remote sensing images, inventory management, grid & vector maps are used for data processing and surveying; those are vital tools for forestry science workers (Kang et al., 2007; Dong *et al*., 2010). Air pollution mobile app developed with aid of OSS for air greenhouse gases, emission of air pollutants & quality management by United States Environmental Protection Agency and California Environmental Protection Agency (Gkatzoflias *et al*., 2013). Mobile computing enabled SDI Model is one of the significant supplies for geo-scientist for precise raw data collection (Chen and Xiao, 2011). Creek Watch and EpiCollect are two instances of mobile apps and popular for SDI models in Mobile in arena of watershed management and environmental monitoring (Aanensen *et al*., 2009; Tang and Liu, 2016). It is profited for universal people in health sector. M-health is developed & realized as mobile app for public health information collection (Boonchieng *et al*., 2014). With the aid of earth observation data, an android based mobile app also developed for precise dispersion of rainfall approximations (Mantas *et al*., 2015). From these numerous swatting of research works, it is précised that SDI model in thin, mobile and thick, is the need of the hour.

3. Study area

Maharashtra is a state in western area of India. It is one of the second most populated state after Uttar Pradesh and third largest state by area in India. Maharashtra is surrounded by Gujarat and the Union territory of Dadra and Nagar Haveli to northwest, Arabian Sea to west, Karnataka to the south, Madhya Pradesh to the north and northeast, Chhattisgarh to the east, Goa to the southwest and Telangana to the southeast (Internet-2, 2017). The state covers 9.84% of the total geographical area of India and an area of 307,731 km^2. There are nearly 378 urban centers and 41000 villages in Maharashtra. Maharashtra has one of the highest levels of urbanization of all Indian states.

4. Objective of present study

The aim of the current work is to develop and implement prototype based *m-cloud*, *i.e.*, Cloud SDI Model for Malaria Information Infrastructure Mapping in Maharashtra, India. It has also projected the system architecture of cloud SDI model mainly on web browser, desktop and mobile environment. It has also proposed a vigorous step by step methodology for geospatial database development for *m-cloud* with the assistance of Open Source GIS; Quantum GIS Ver 2.14.3 and Map Window GIS Ver 4.8.8. By developing the proposed *m-cloud* model, it can easily analyze the Pattern and Trends in occurrence of malaria and also identify the high risk malaria prone districts.

5. Database and methodology

5.1. *Data procurement*

Data collection is the most important task of any research work. The climate data including all surface parameters like rainfall, maximum and minimum temperature, morning and evening relative humidity, wind speed, sunshine hours etc. for the period of (2001-2014) for the all thirty five districts of state of Maharashtra were collected from Indian Meteorological Department (IMD), Pune. The secondary health data comprising positive cases of malaria and number of deaths due to malaria are collected from National Vector Borne Disease Control Programme (NVBDCP), New Delhi. The climate Projection Data was collected from (IITM), Pune.

5.2. *Trend analysis*

Linear regression model (LRM) was applied for temporal trend analysis. The test has been widely used for several climatological studies for assessment of long term tendency in climatic parameters (De and Rao, 2004) Magnitude of trend was obtained from the slope (value of 'b') of the regression line.

5.3. *Transmission windows*

Transmission windows (TW) of Malaria determine, keeping in view the lower cut off temperature as 18 °C and upper cutoff as 32 °C (Chan *et al*., 1999; Parry *et al*., 2007) and RH from >55%. Keeping in view the climatic suitability for the no. of month's transmission may remain open; Transmission windows were categorized as follows:

Category I : Not a single month is open

Category II : 1-3 months open

Category III : 3-6 months open

Category IV : 6-8 months open

Category V : 8-12 months are open continuously for malaria transmission.

Transmission of malaria is possible if TW is open for 3 months continuously, therefore, for analysis at the regional level a new category, *i.e*., TW open for 1-2 month also created to differentiate it from 3 continuous months. TW open for 6 months or more indicate stability of malaria transmission. Transmission windows have been determined based on temperature alone as well as with combination of temperature and RH. The inputs were fed in ARC GIS software for generation of region / area wise maps with district boundaries.

5.4. *Climate projection*

Future changes in climatic variable particularly rainfall and temperature, for this projected Coordinated Regional Climate Downscaling Experiment (CORDEX) data were acquired from the Indian Institute of Tropical Meteorology (IITM), Pune. CORDEX South Asia data include simulations performed by the Swedish meteorological and hydrological Institute (SMHI) Rossby centre RCM Rossby centre Atmospheric model version 4 (RCA4). The yearly projected mean temperature and monsoon rainfall values for the period between 2015 and 2050 were obtained by averaging the monsoon rainfall

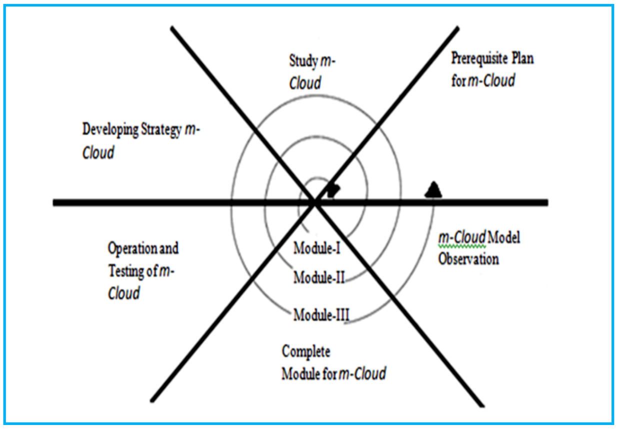

Fig. 5. Spiral process model for *m-cloud* development

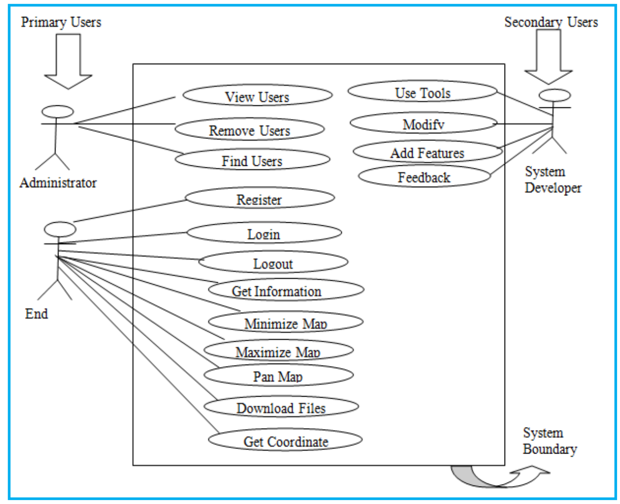

Fig. 6. Work flow chart of use case diagram for *m-cloud*

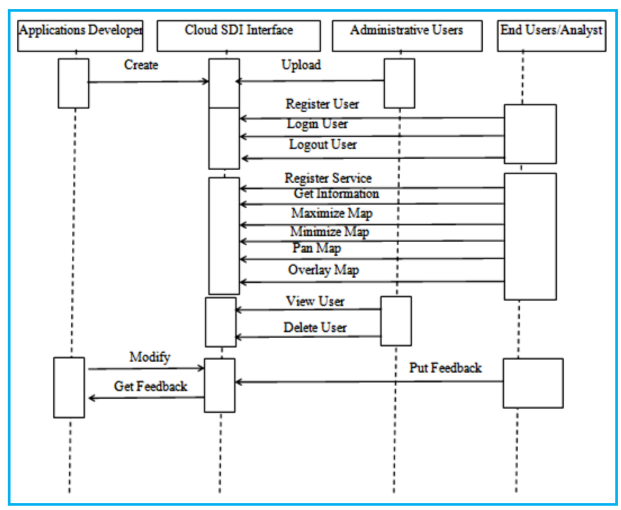

Fig. 7. Sequence Diagram for *m-cloud* (Best Case Scenario)

values of pixel (0.25° × 0.25°) sizes which covered Maharashtra. The linear regression analysis of annual mean temperature carried out to see the future changes in climate variability.

5.5. *Methodology adopted for m-cloud*

Geospatial database creation emphasizes on the methodology to discover and extended in health sector. The established geospatial database provides a dexterous means of distribution of geospatial & non-spatial data in *m-cloud*. The prototype based on Object Oriented Software Engineering (OOSE) projected by Jacobson's method to conglomerate strong user focus and the time critical nature. Fig. 5 signifies the completely win-win procedure model for creation of geospatial database creation.

The model of spatial database creation is regular in nature and each process improves the study and strategies of various steps through testing of completed module design. In complete module, Q GIS software sets up the database for Malaria Information Infrastructure Mapping in Maharashtra, India by the assistance of Indian political map. QGIS is used for cohesive spatial database formation. The geospatial database is designed to exemplify the database for Malaria Information Infrastructure Mapping in Maharashtra, India. The competences of developed framework and are prepared by QGIS Ver. 2.14.3 and Map Window GIS Ver. 4.8.8.

m-cloud entails three key functional phases. Phase I provides the geospatial database created for database of Malaria Information Infrastructure Mapping in Maharashtra, India application cases in GIS environment. Primarily provides the basic information about the Malaria Information Infrastructure Mapping in Maharashtra, India by taking different parameters and is expected to be beneficial to the stakeholders such as end users and government organizations etc.

Phase II accentuates on development/design of numerous OGC compliant services for WMS, WFS and WCS. It defines the integration of different services in QGIS Cloud Providers. Phase III defines the addition of developed model with thin clients, thick client and mobile users. In this phase, it also performs some overlay operation in cloud environments. From above analysis and designing phase, the central issue is to select the augmented acceptance of OS GIS for comprehensive development of Cloud SDI Model. Further, it is predictable that each phase would divulge with unique features connected to requirements of underlying infrastructure GWSs and allow survey of interfaces between SDI modules.

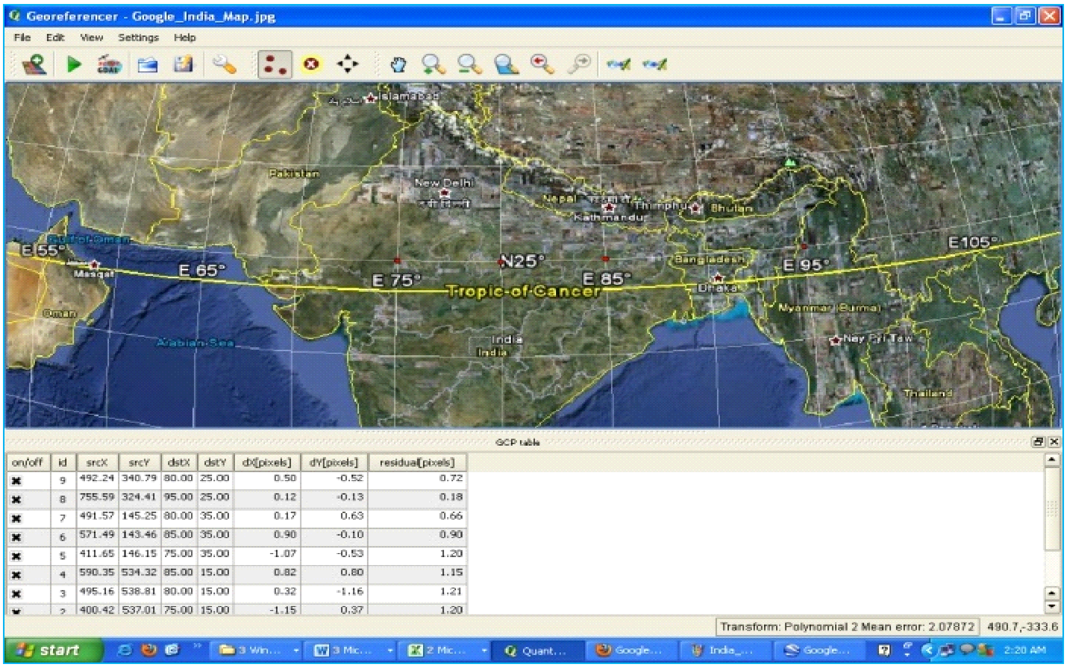

Fig. 8. Geo reference map of India

The flow of processes in system is caught in state chart that require to be decoded into design element of software designed process. In the design phase, use case and sequence diagram are labeled the workflow conduct of Cloud SDI Model and are illustrated in Figs. 6 and 7 respectively.

So, from win-win spiral model, use case diagram and in the sequence diagram, it has been observed that geospatial database creation and related geospatial analysis are the prime focus in Malaria Information Infrastructure Mapping in Maharashtra, India.

5.6. *Geospatial database creation*

The creation/designing of smooth spatial digital database is quite tedious. Integrated spatial database design includes many stages as inputs of data on spatial and related attribute, its authentication with same set of data. Geospatial database can deliver unique platform in which numerous organizations interconnect with technologies/systems to look after different actions for spending, use and generating spatial data. Quantum GIS 2.14.3 and Map Window GIS Ver 4.8.8 are selected to examine the competences with creation of geospatial database. The route model for clean designing of geospatial database creation is frequent or recurring in nature and the policy of steps through testing and assessment. In complete component for database creation, Quantum GIS is used for malaria geospatial database with the help of political map of India. The malaria geospatial databases are nominated to exemplify the capabilities of developed framework. Initially, the base map of India downloaded from the Google Earth. The download image is geo-referenced with the help of Geo-reference tool in QGIS. The GCPs selected at the intersection of latitude and longitude lines. WGS-84 universal coordinate system with EPSG: 3857 coordinate reference system is elected for the primary setup of the geospatial database designing. After the processing of geo-referencing method, the generated image is ready for the extracting different kinds of thematic maps. Fig. 8 has shown the snapshot of geo-referencing of India map in Geo-reference Tool from QGIS.

In the present application case study, the entire districts of Maharashtra, India have been taken. These have been categorized into the different layers with schema definition. *m-cloud* has contributed enormously in considerate the epidemiological process of malaria and examples drawn has shown that the proposed model is now widely used for research and decision making in malaria control. Various statistical data analysis is one of the most consistent and established set of tools to analyze through geospatial datasets. Precipitation is either conducive to mosquito breeding and or flushing out of its larva. Excess rainfall increases the breeding grounds of mosquitoes and dry conditions eliminate them. Intensity and duration of rainfall affect the population of mosquitoes (Rai and Nathawat, 2017). Rainfall also increases the relative humidity and modifies the temperature which affects the longevity of mosquitoes and thus transmission of diseases. If relative humidity is below 60% the life of mosquitoes is shortened which in turn reduces transmission of the vector. Higher relative humidity between 60-80% is considered to be optimum for effective transmission of the vector. Thus, climatic conditions play an important role in breeding of mosquitoes, transmission and degree of endemicity of malaria. The epidemiology of vector borne diseases is complex and factors like construction of dams, increasing irrigation practices, health infrastructure and migration of people, education, behavior and socio-economic condition. Influence transmission of vector borne diseases. It is predicted that global warming will increase the geographical area of malaria transmission from 45% of the world's population to 60%. He further reiterates, as the average temperature of the earth has increased by 1 °C, plants, insects and insect-borne diseases are migrating to higher elevations (Epstein, 2001).

In this section, geospatial database creation has done with the help of digitalization process through QGIS tool. Particularly, for creation of point vector database, it used Map Window GIS. After geospatial schema definition, there are 2 number of thematic layers created. First layer is created for India state boundary. For this layer, WGS-84 with EPSG: 4326 coordinates' reference system is chosen. The second thematic layer designed with Spatial Converter Tool in Map Window GIS Ver. 4.8.8.

6. Results and discussion

6.1. *Geospatial data analysis*

Death due to Malaria from 2001-2014 is reported very high in Mumbai in the range from 98-980 persons because of high rainfall high humidity and uncontrollable growth of urbanization more slums and unhygienic conditions swampy areas all are favorable factor for the incidence. Death due to malaria and more population on Small Island Mumbai is shown in the Table 1 and Fig. 11. After this Thane and Nagpur districts shows high incidence and death due to malaria which range from 55-98. After this Gadchiroli, Chandrapur, Bhandara, Gondia these north eastern districts shows the death in the range of 28-55 because of heavy rainfall and high humidity. But Pune comes under rain shadow zone still it shows more incidence and death due to malaria it ranges from 28-55 and the causative factor is different that is uncontrollable rapid increase of urbanization which comes along with more slums, more unhygienic conditions and dumping ground swampy areas etc. All these conditions are favorable for mosquito breeding ground zone and the diseases. After this Raigad, Ratnagiri, Wardha and Ahmednagar shows the death in between the range of 16-28. Rest of all other districts shows the death in between 1-16 surprisingly Sindhudurg is coastal district still comes under this category and shows the incidence and death is very less. It is gratifying thing that Washim district reported not a single death due to malaria which is illustrated in Fig. 9. The highest Incidence of malaria from 2001- 2005 was in Mumbai and Bhandara districts followed by Thane, Raigad and Wardha districts has shown in (Fig. 10).

The inputs of positive cases and the deaths (number of persons) were fed in ARC GIS software and region wise maps with district boundaries were generated. It includes incidence of malaria with the interval of 2001-2005, 2006-2010 and 2011-2014 to see the trend and pattern of the incidence of Malaria in Maharashtra and finally find out the trend with the help of linear regression equation: $y = a + bx$ where b value shows the rate of change per decade thus the trend of malaria from 2001-2014 generated in the form of Map. Death due to malaria from 2001-2014 also shows in the form of map. Incidence of positive cases of malaria from 2006-2010 the data shows highest incidence was in Mumbai, then Thane, Raigad, Gadchiroli and Bhandara districts as shown in Table 2 and (Fig. 9). In (Fig. 10) shows that Incidence of malaria from 2001-2014 the data shows highest incidence was in Mumbai, Thane, Gadchiroli followed by Raigad, Chandrapur and Ahmednagar. In this period Bhandara district shows very less incidence may be because of some mitigative measures and awareness which is shown in Fig. 10. It has also visualized in Fig. 12 in geospatial maps. Finally the trend map shows the highest incidence is in the Mumbai, Thane and Gadchiroli districts followed by Raigad, Chandrapur and Ahmednagar districts. A negative trend shows in the Bhandara districts because from 2001 to 2010 continually it shows highest incidence of positive cases of malaria but in the period of 2011-2014 it shows negligible incidence because of awareness & other mitigative factors which is really gratifying thing which is shown in Figs. 9&10. Fig. 12 has also shown the positive cases of malaria in maps from 2001-2014.

Transmission Windows based upon threshold criteria of maximum and minimum temperature and morning and relative humidity.

According to Fig. 13, using the criteria of temperature and relative humidity for Transmission window months, as per epidemiological data (2001-2014) it reflected contrasting situation at Sindhudurg district though the situation is favorable for an incidence of Malaria there is less percentage of incidence and the death due to Malaria. Here the transmission window is much higher that is for 8-12 months continue open for transmission. After that Mumbai, Thane, Pune, Ahmednagar, Satara, Sangli, Kolhapur, Beed, Gondia and

TABLE 1

Death due to Malaria (Number of Persons)

District	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Thane	6	0	1	3	3	0	0	5	1	20	19	14	16	10
Raigad	5	0	0	2	1	0	0	0	1	1	2	1	8	0
Ratnagiri	0	1	3	2	1	4	0	2	4	2	0	0	0	0
Gr. Mumbai	18	18	14	23	75	107	122	98	198	145	69	45	30	18
Ahmednagar	0	0	0	0	0	0	6	1	7	4	5	1	4	0
Dhule	0	1	0	0	0	0	0	0	0	1	1	2	2	1
Nandurbar	0	0	0	1	0	0	0	0	0	0	0	1	0	1
Jalgaon	0	0	0		0	0	4	3	1	1	1	1	1	0
Nashik	0	0	1	1	1	0	6	4	0	3	0	0	0	0
Pune	0	0	3	0	2	2	8	7	0	4	4	5	1	1
PMC	0	0	1	2	0	0	12	0	0		0	0	0	3
Solapur	2	0	2	1	0	1	0	1	0	0	0	0	0	1
Satara	1	1	3	1	0	0	1	0		0	0	0	1	0
Kolhapur	0	0	1	0	0	1	1	1	1	0	0	0	0	0
Sangli	2	0	0	1	0	0	0	0	1	0	0	0	0	0
Sindhudurg	0	1	0	0	0	0	0	1	0	1	0	2	0	0
Aurangabad	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Jalna	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Parbhani	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Hingoli	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Beed	0	1	0	0	1	0	1	0	0	0	0	0	1	1
Nanded	0	0	1	0	1	0	1	0	0	0	1	0	0	0
Osmanabad	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Latur	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Akola	0	0	1	1	1	0	0	0	0	1	1	0	0	0
Washim	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amaravati	0	1	5	0	1	3	1	0	0	0	0	1	1	0
Yeotmal	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Buldhana	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Nagpur	0	0	2	0	1	3	0	0	0	3	0	1	0	0
NMC	7	9	16	17	10	5	5	0	0	0	0	0	0	0
Wardha	2	1	2	1	4	4	9	1	0	0	1	2	0	0
Bhandara	5	3	24	4	2	3	3	2	2	0	0	0	0	0
Gondia	0	1	3	0	0	0	1	7	4	4	5	7	4	9
Chandrapur	0	2	1	0	0	0	0	9	6	3	3	8	5	5
Gadchiroli	1	1	0	0	0	0	0	5	1	4	6	4	6	18
Grand Total	50	43	85	61	104	133	182	148	227	200	118	96	80	68

TABLE 2

Positive cases of Malaria (Number of Persons)

District	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Thane	4607	3694	3038	3551	3375	4583	7203	8987	17509	19524	15777	16141	11522	7503
Raigad	2105	2414	2611	4097	3812	6060	3051	1998	4368	4669	4211	4361	4989	3254
Ratnagiri	488	472	333	320	352	426	524	644	1703	2783	1962	810	604	309
Gr. Mumbai	12580	13542	13522	14756	13452	17826	25403	26021	44035	76755	39822	16086	10565	9068
Ahmednagar	449	192	101	108	135	228	381	2046	3729	4103	3652	2304	1015	408
Dhule	685	575	2245	1641	844	1754	2773	1885	1539	2403	1699	1047	605	410
Nandurbar	472	219	535	1283	802	939	1304	1272	1773	2094	1694	1073	736	644
Jalgaon	470	437	2684	2480	985	725	2086	792	759	1173	890	551	270	312
Nashik	158	75	150	121	208	463	1552	250	439	948	366	357	137	101
Pune	798	431	320	281	367	695	1199	819	1227	1308	949	512	329	231
PMC	103	177	228	203	117	112	139	104	137	137	94	78	47	22
Solapur	969	386	251	197	296	232	215	200	287	315	204	125	71	32
Satara	550	460	213	359	384	345	497	377	442	897	779	575	311	260
Kolhapur	259	154	141	103	158	185	219	161	176	225	177	99	82	94
Sangli	390	253	168	230	184	149	204	259	276	483	323	162	111	92
Sindhudurg	301	308	152	131	111	270	296	186	260	516	308	243	206	142
Aurangabad	477	405	297	230	179	215	270	128	214	296	213	148	106	91
Jalna	113	102	109	104	55	59	71	26	46	52	26	15	12	14
Parbhani	247	213	141	114	90	65	118	151	115	120	126	25	49	38
Hingoli	117	107	115	58	16	23	34	19	27	37	16	13	19	11
Beed	1275	851	348	339	252	324	295	134	202	246	227	108	69	57
Nanded	982	962	2177	2111	893	635	641	84	115	112	81	32	30	11
Osmanabad	267	132	93	91	61	33	51	274	189	250	195	88	56	48
Latur	432	279	168	163	157	174	94	537	424	974	592	303	197	110
Akola	367	357	479	334	301	273	246	216	178	252	240	218	149	196
Washim	259	215	227	136	177	312	166	267	126	172	144	96	71	76
Amaravati	1590	888	1424	1396	1222	1451	1114	916	549	856	770	721	767	578
Yeotmal	473	559	469	540	363	356	379	1234	913	1320	1141	1032	855	498
Buldhana	2694	2651	1960	2192	1565	2439	1547	232	240	399	348	210	175	208
Nagpur	482	403	415	460	290	245	226	647	571	969	860	515	355	285
NMC	2280	2043	3076	2745	1285	970	1105	84	95	188	147	125	79	48
Wardha	2269	2629	3330	4379	3424	2420	2832	898	500	637	788	712	456	242
Bhandara	14321	7703	19810	21928	10159	7737	9903	272	309	290	195	190	172	93
Gondia	990	553	724	720	629	569	568	1543	1039	1150	1425	754	594	1465
Chandrapur	193	142	86	86	63	75	73	2298	1409	1780	2466	2069	1429	1965
Gadchiroli	831	585	765	1001	845	1053	1071	11372	7898	10765	13670	6596	6436	24469
Grand Total	56043	45568	62905	68988	47608	54420	67850	67333	93818	139198	96577	58494	43676	53385

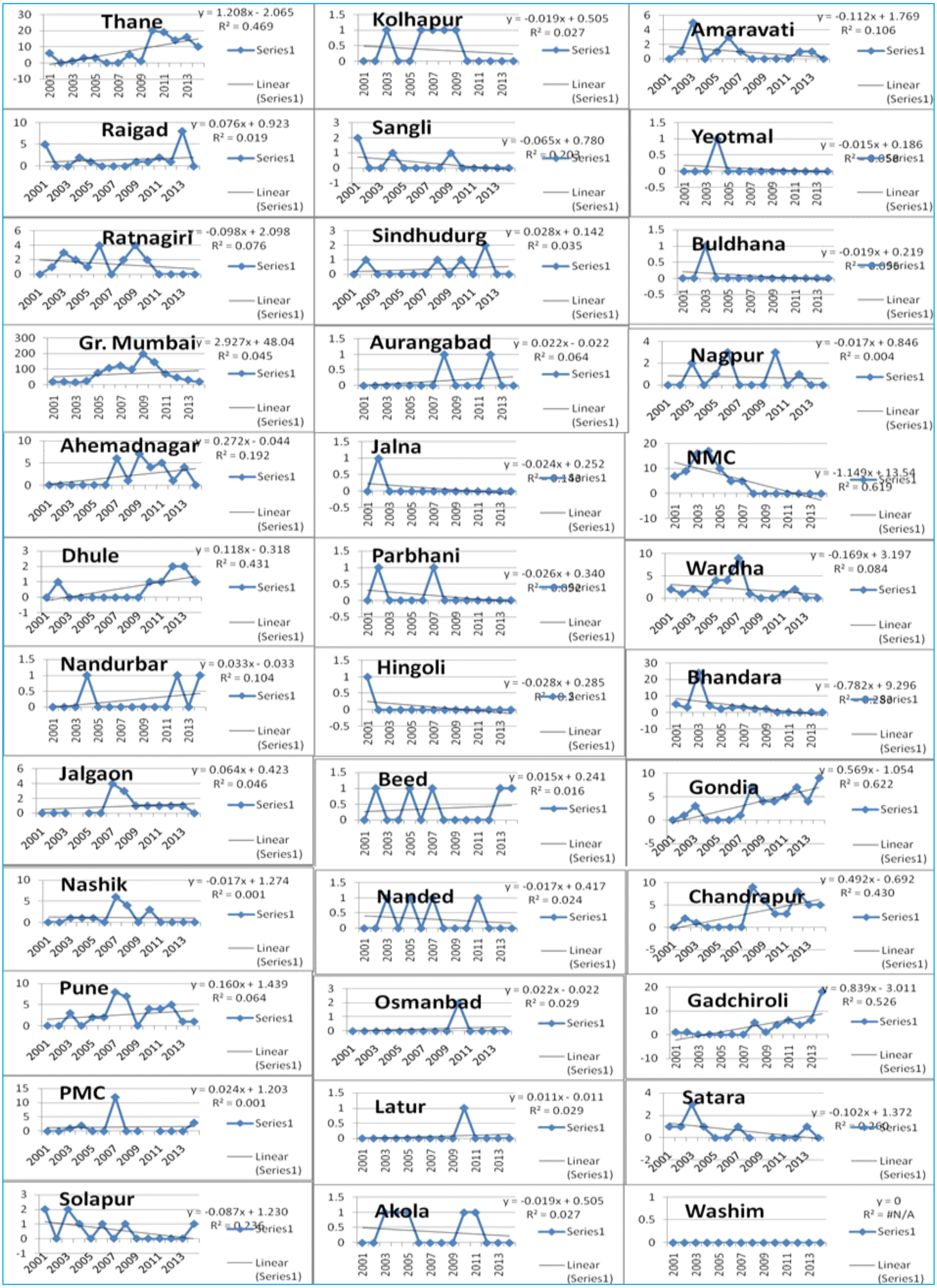

Fig. 9. Death trends due to Malaria (Number of Persons)

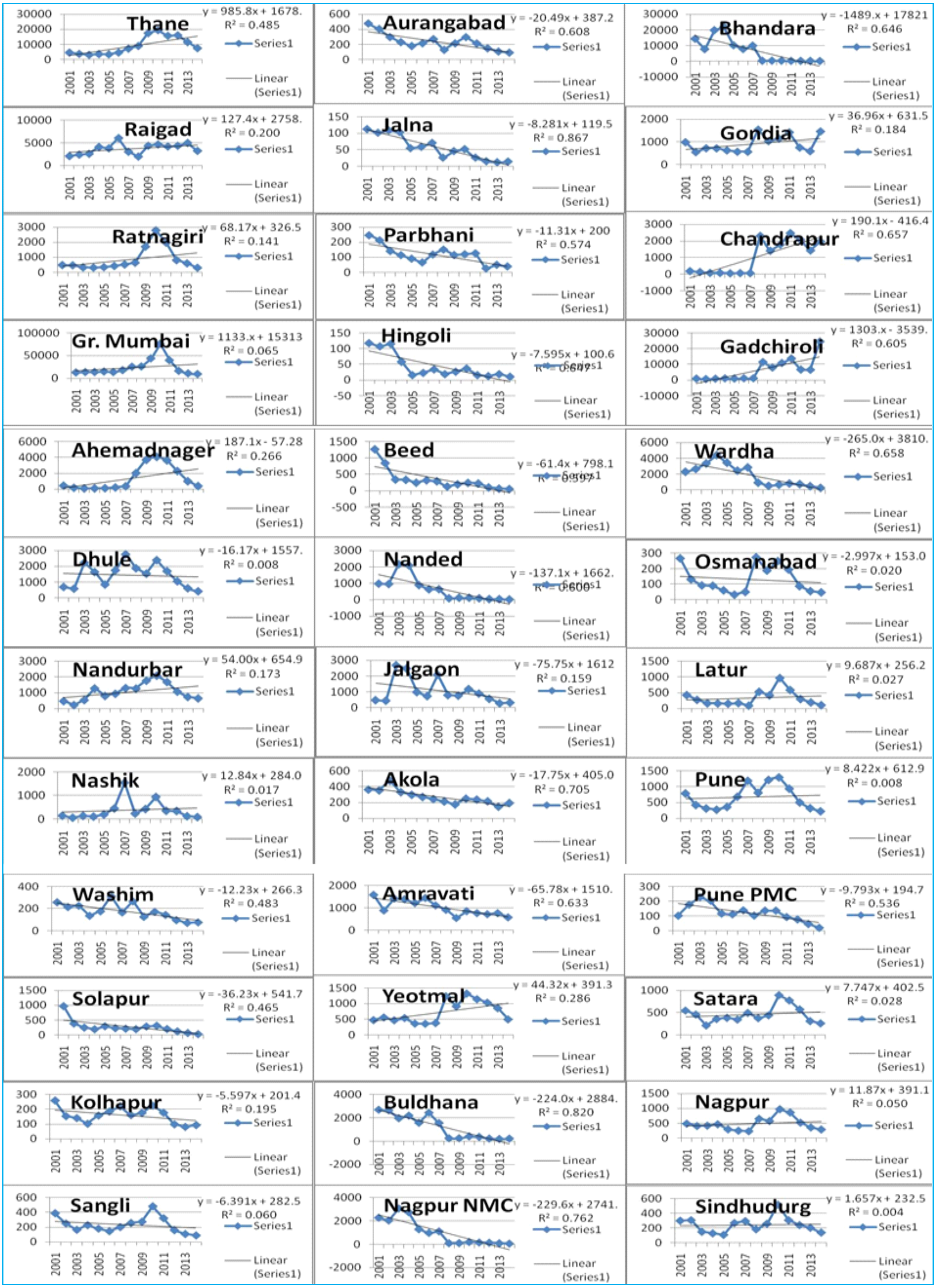

Fig. 10. Positive trends due to Malaria (Number of Persons)

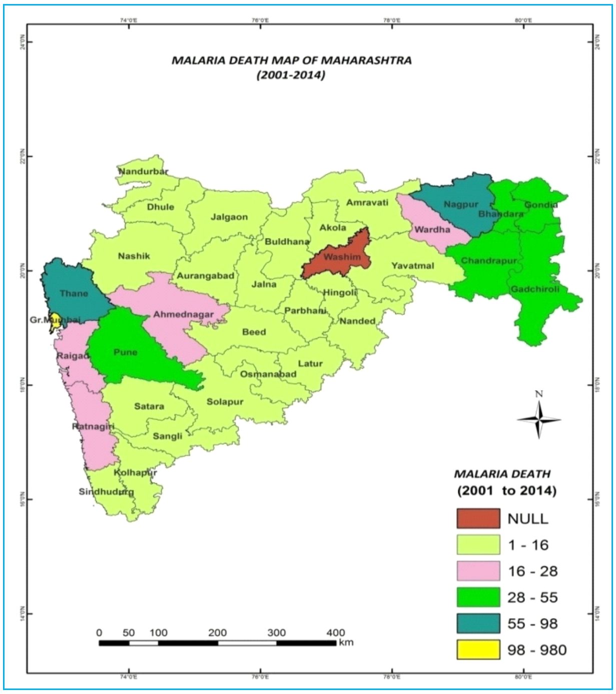

Fig. 11. Maps shows the number of death due to malaria from 2001-2014

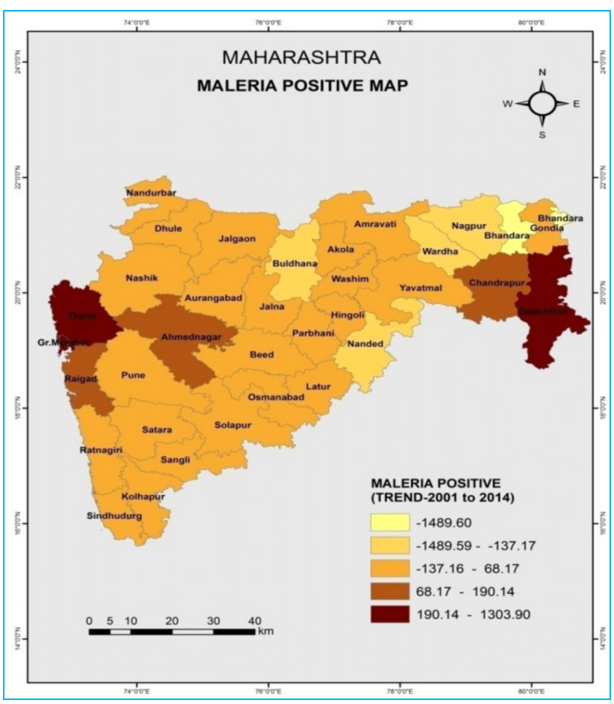

Fig. 12. Map shows the trend of positive cases (number of persons) malaria at the state of Maharashtra, from 2001-2014

Bhandara there 6-8 months are open for transmission and the incidence as well as death also more in these districts. Only five districts Washim, Latur, Nanded, Akola and

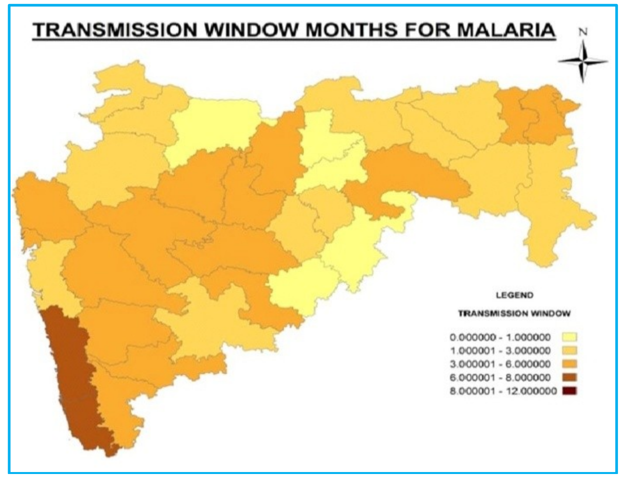

Fig. 13. Transmission window of Malaria based on temperature and humidity for the year 2001-2014

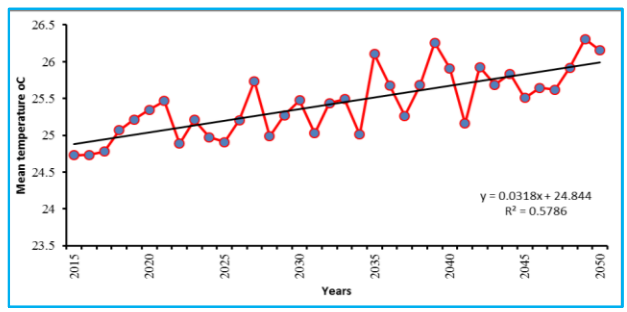

Fig. 14. Simulated mean temperature based on CORDEX data for the period 2015-2050 over Maharashtra

Jalgaon shows 0-1 month open for transmission and the incidences as well as deaths are less from all these districts.

According to Fig. 14, in the climate change scenario, simulated mean temperature based on CORDEX data for the period 2015-2050 over Maharashtra displays the near term future from 2015 till 2050 linear trend in projected annual mean temperature. The linear regression analysis shows an increasing trend over the study area until 2050. The rate of increase in mean temperature is found to be 0.03 °C per year.

6.2. *Geospatial overlay analysis in m-cloud environment*

Within this fragment, geospatial overlay geospatial data analysis is performed for robust locality type geospatial statistics of malaria information mapping in Maharashtra, India. It superimposes with vector and raster geospatial database which has been created by QGIS software. Primarily, the data are collected in excel format. The excel formatted data made into the

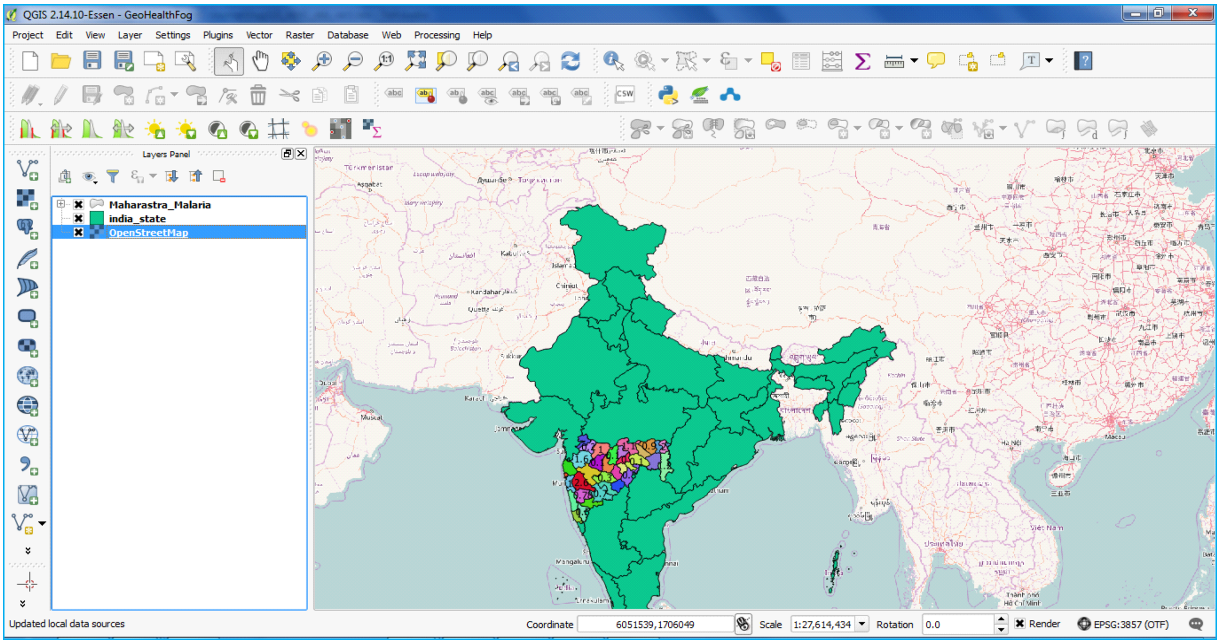

Fig. 15. Integration of malaria information infrastructure mapping in Maharashtra, India on thick client environment in *m-cloud*

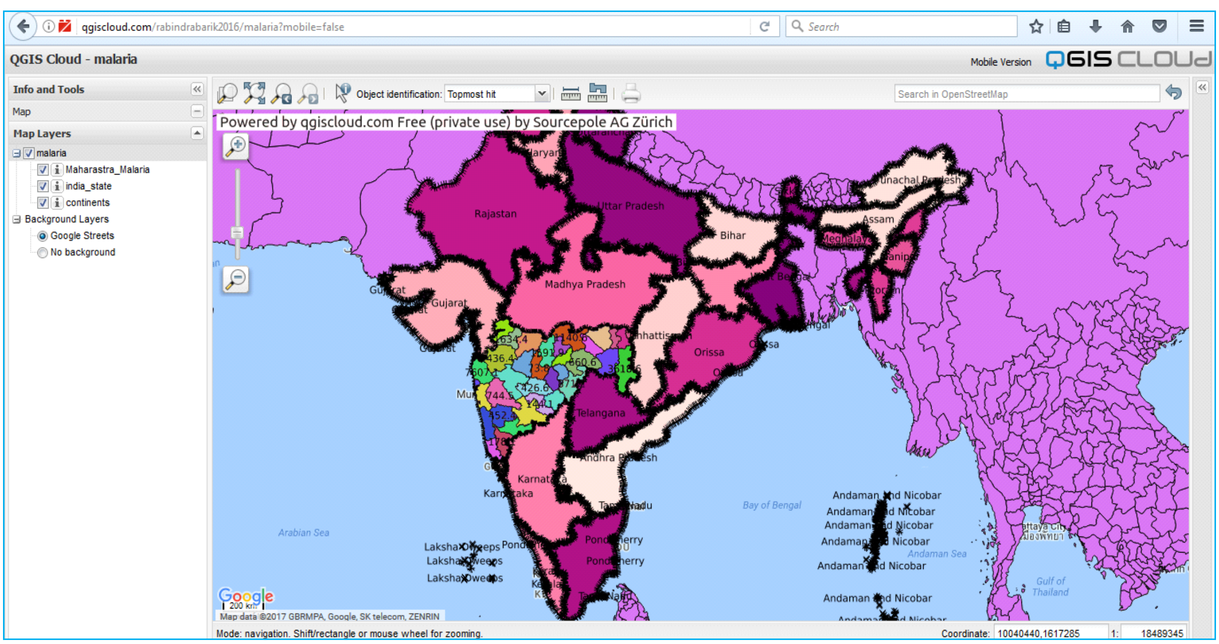

Fig. 16. Integration of malaria information infrastructure mapping in Maharashtra, India on thin client environment in *m-cloud*

trained data as in .csv format. The .csv format data again converted into the ESRI shape file formats with QGIS tools. In the current scenario, it designed the malaria information geospatial data for processing in *m-cloud*. After storing the data, overlay analysis has performed with raster and designed vector data. In QGIS, a plug-in named as QGIS Cloud has installed and made updated for storing of created geospatial database. This QGIS plug-in is responsible for the storing created geospatial vector data. These geospatial vector data are stored in the database of cloud layer. After successful uploading of the database, it automatically generated the link for mobile. Figs. 15-17 show the overlay operation on thick, thin and mobile client's environment in *m-cloud* (Internet-6, 2017; Internet-7 2017).

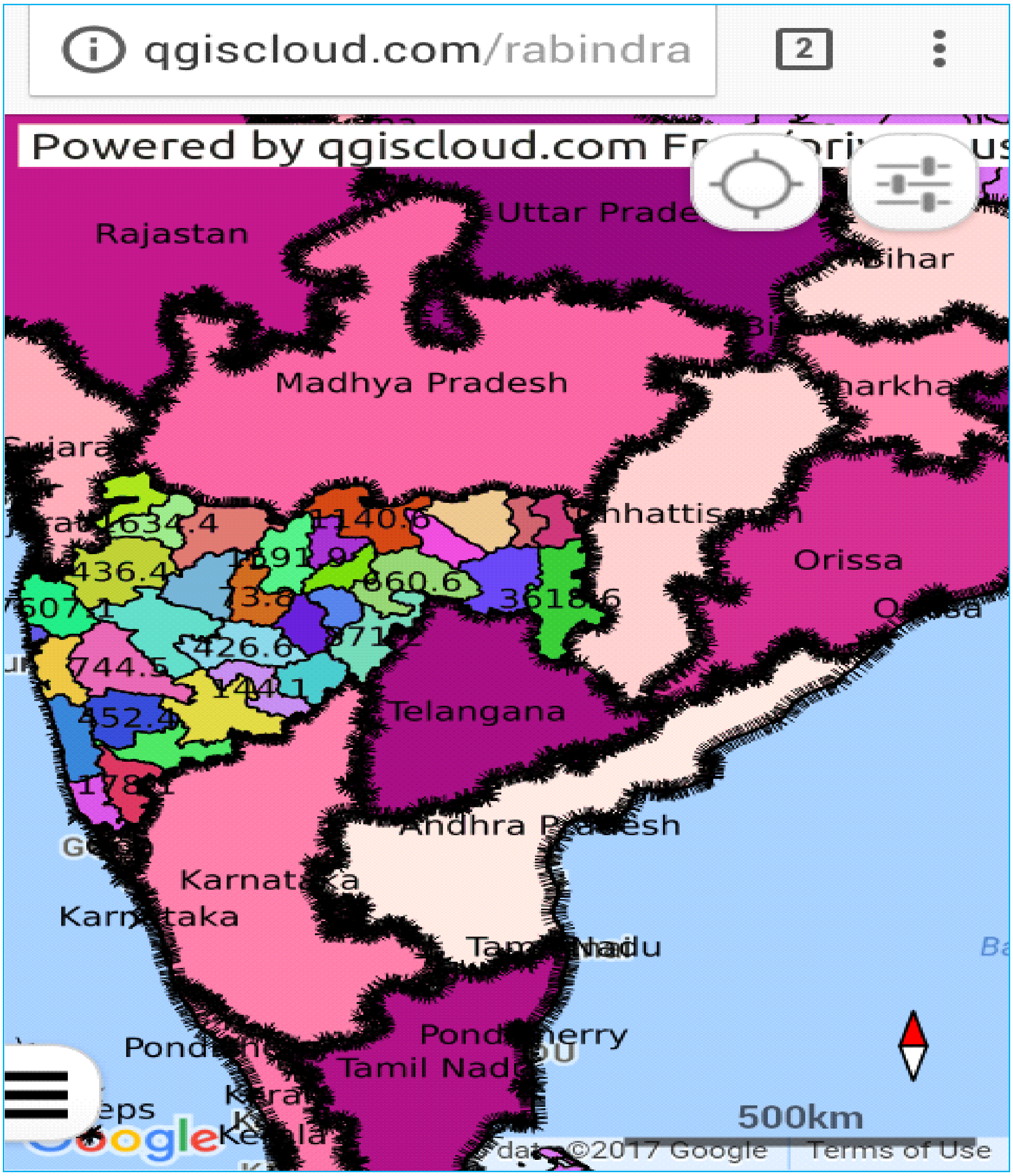

Fig. 17. Malaria Information Infrastructure Mapping in Maharashtra on mobile client environment in *m-cloud*

7. Model performances and concluding remarks

The above study has outlined the main features of incidence of malaria in the state of Maharashtra. The study shows that the problem of Malaria is highest in the coastal districts of Maharashtra such as Thane, Greater Mumbai, Raigad and in the north eastern districts of Maharashtra such as Gadchiroli, Nagpur, Bhandara, Gondia, Chandrapur because of heavy rainfall due to that more marshy land and favorable climatic conditions for mosquito breeding and survival. But Bhandara district shows negative trend in recent years because of awareness and other precaution like mosquito net, cleanliness and hygiene etc. Pune district also shows higher incidence and death due to malaria but the causative factor is different in this scenario causing Pune comes under the rain shadow zone hence scanty rainfall and urbanization and increasing slum areas around Pune are responsible for malaria incidence and death due to that. Even Ahmednagar also comes under rain shadow region hence experience scanty rainfall which leads to the higher incidence and death due to Malaria. As well as urban effect is also one of the causative factors for higher incidences of Malaria.

Risk mapping using spatial technology has clearly brought out the epidemiology of disease *vis a vis* environmental risk factors by identifying the spatial limits of the disease. The relationships between the prevalence of disease and distribution of vector could have never been so comprehensively studied without geo-spatial technology. Space based imagery has made it possible easy to collect information for vast and inaccessible areas and also in taking appropriate decisions effectively. GIS widely used in public health studies. Novel public health strategies of prevention and control of malaria, dengue and chikunguniya will benefit in their mitigation. It has also recommended that suitable best configuration of malaria information infrastructure with the help of Cloud SDI Model for each district of Maharashtra, India. The developed Cloud SDI Model can have great potential for the decision makers and planners to quickly look into the problems and resolute accordingly.

In this research paper, the proposed and developed *m-cloud* is used the cloud computing gateway for geospatial data analysis for malaria information mapping in Maharashtra, India. It gives the overall competence for processing of geospatial data by developed Model which has benefitted to decision makers or common people. The present study has taken Geospatial database of malaria information in Maharashtra, India as a suitable case study in the developed *m-cloud* framework. Here, it has presented the various data analysis and geospatial overlay approaches. It also validated the geospatial analysis techniques on malaria information geospatial database. The developed model can be widely using in public health studies. Novel public health strategies of prevention and control of malaria, dengue and chikunguniya will benefit in their mitigation by using this model. It has also recommended that suitable best configuration of malaria information infrastructure with the help of *m-cloud* for each district of Maharashtra, India. The developed *m-cloud* can have great potential for the decision makers and planners to quickly look into the problems and resolute accordingly. The developed system has added the more intelligence processing of geospatial data in cloud computing environment. In our future studies, we will add different variety of intelligent services and practicability aspects on SDI Model development and implementation of successful SDI Framework at international level in education, watershed management and energy management sector. It will also plan to execute to assist the cloud computing environment by implementing fog computing paradigm at the edge of the client. In order to check with projected value CORDEX data Fig. 14 clearly shows the scenario of increasing temperature over Maharashtra which may be favorable for spread of malaria hence may contribute to increase in the death rate. Therefore it is very relevant that decision makers of the concern departments of health and others have to take necessary prevention and control. Climate change and global warming resulted in sting to mosquito bites, in vector borne diseases.

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