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A web based application study for integrated land management and administrative planning for East and South districts of Sikkim, India

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Abstract: Sikkim is a small hilly state in the eastern Himalayas with a rich biodiversity and formidable physical features with a total area of 7096 km^2. Sikkim has 26% of India's biodiversity. Any developmental activity necessitates accurate information about the lands and updated inventory of resources including natural resources and infrastructural facilities. For this purpose, as a pilot study, up-to-date comprehensive geospatial information on natural and man-made resources for East and South districts of Sikkim on 1:10,000 scale using high resolution satellite data was generated for developmental and managerial requirements of the government. Further, a web based solution was developed for dissemination and decentralized access of geospatial data by various user departments of Sikkim. Quick Bird satellite data for parts of East and South districts of Sikkim was procured and geo-referenced with DGPS data. Cartosat-I satellite data was procured for these two districts and ortho-rectified. The cadastral maps and administrative boundaries were collected from respective departments and digitized. Base layers like roads, bridges and culverts were digitized and updated using Quick Bird satellite data. The entire drainage network was digitized and updated using Cartosat-I satellite data. Onscreen interpretation of land use/land cover map was carried out on 1:4,000 scale for urban areas using Quick Bird satellite data and on 1:10,000 scale for rural areas using Cartosat satellite data. Soil map prepared by NBS&LUP on 1:2,50,000 scale was procured and digitized. Slope map was generated using Aster DEM on 1:10,000 scale. Point of Interest (POI) data on amenities and infrastructure facilities with corresponding photographs was collected with the help of GPS and plotted on 1:4,000 scale for urban areas and on 1:10,000 scale for rural areas with the help of high resolution satellite data. The entire geo-database was geo-referenced to the high resolution satellite data and Survey of India topo grid. The geo-database thus created was customized and a web based e-governance application was developed. This web based GIS application caters the needs of all government departments in the developmental programmes of the state.

Keywords: Administrative boundaries, High resolution satellite data, Land use/land cover, Point of interest, Slope, Web based GIS application

1. Introduction

Sikkim is a small north-eastern Indian state lies between 27° 04'46" to 28° 07'48"N latitudes and 88° 00'58" to 88°55'25"E longitudes with sharp altitudinal gradient and complex topography. It is bounded by vast stretches of Tibetan Plateau in the north, Chumbi valley of Tibet and Bhutan in the east, Nepal in the west, and West Bengal in the south. The state of Sikkim has a total area of 7096 km^2. Sikkim has a rugged topography and the flat lands are scarce and as a result create a barrier to efficient agriculture. The climate of the state is divided roughly in to tropical, temperate and alpine zones. The general trend of decrease in temperature with increase in altitude holds good in this state. For most of the period in a year, the climate is cold and humid as rainfall occurs in each month. Rainfall is heavy and well distributed during the months of May to early October. July month is the wettest month in most places. The intensity of rainfall during south-west monsoon season decreases from south to north, while the distribution of winter rainfall is in the opposite order. High intensity of rainfall causes extensive soil erosion and frequent landslides.

The nature of the terrain with varied micro-climatic conditions influence agriculture in Sikkim. Paddy is a summer crop and it is grown everywhere in the state except very higher areas. Most of the paddy is raised on un-irrigated fields because of copious rainfall during its growth period. Under horticulture, large quantities of oranges and apples are raised. Vegetables, pineapple and banana are other cash crops of Sikkim. Agriculture, horticulture and animal husbandry constitute a mainstay of the largest segment of Sikkim's population. Any developmental activities necessitate accurate information about natural resources and infrastructural facilities and updated inventory of these resources. Hence, there is an urgent need for cadastral based land information system. For this purpose, appropriate technology for developing cadastral based land information system was developed with a vision of Integrated Land Management and Administrative Planning (ILMAP). For this purpose, as a pilot study East and South districts of Sikkim (Fig.1) were selected.

Figure 1: Location map of the study area

1.1 Biodiversity of Sikkim

India is recognized as one of the twelve mega diversity centres of the world. Out of the eighteen biodiversity hot-spots in the world, India owns two, namely the Western Ghats and the Eastern Himalayas. Sikkim covering just 0.2 % of the geographical area of the country has tremendous biodiversity and has been identified as one of the hotspots in the Eastern Himalayas. The unique terrain, climate, biogeography of the state have resulted in the sustenance of varied eco zones in close proximity. Also the harmonious presence of several ethnic groups, having their distinct identity and practicing their traditional livelihoods add to the treasure house of knowledge related to this biodiversity. Biogeographically, it is enriched by both west and east Himalayan biogeographic provinces. In a landmass of just 7,096 km^2, it houses elevations ranging between 300 to 8,598m. The Mt. Khangchendzonga (8,598m) globally the third highest peak and highest in the country which creates a unique ecosystem is located in Sikkim. The state is endowed with rich floral and faunal diversity. The state possesses 31% of the mammals, 45% of the birds and 50% of the butterflies of the country (Arrawatia and Tambe, 2011). Sikkim also has 28 mountains/peaks, more than 80 glaciers, 227 high altitude lakes/wetlands and 104 rivers and streams. Broadly there are four eco-zones of vegetation according to altitude variations namely 1) Tropical, 2) Sub Tropical 3) Temperate & Alpine and 4) Trans Himalayan. But in some stray areas, altitude alone may not define a zone as exposure to other physical properties of the terrain can result otherwise.

Tropical zone lies between the 300m low river valleys to the mid-hill heights of around 1200m. The topographical features are deep valleys and gorges with well-drained slopes. Beneath canopies of tall evergreen and semi-deciduous trees, the dense undergrowth in this belt includes various species of orchids. Lowland forests of Sikkim are home to several endangered species of birds.

Sub Tropical region has a range from about 1800 m to 3000 m and the physical features associated with this belt are the upper portions of high hills. Rainfall is heaviest in this zone and conditions remain humid throughout the year. In the upper reaches, dense tall evergreen forests with oak and rhododendron predominate. This area is also hosts different bird varieties. Plantations of large cardamom beneath canopies of tall trees in forest patches, terraced farmland, and a tea estate at Temi are the dominant features of the landscape. Most of the human population of Sikkim resides in the sub-tropical and tropical zones in an agricultural setting where terrace cultivation of rice, ginger, orange, cardamom are commercially grown while guava, banana, squash and marigold are common along with vegetables and herbs in homestead gardens. Stall fed livestock is another feature in villages.

Temperate and Alpine region extends from 3000m to 4000m with mixed coniferous forests of hemlock, spruce, pine, fir and juniper with shrubby undergrowth of Rhododendron and dwarf bamboo. Subsistence farming of wheat, barley and maize is carried out while beans, peas, some apple, peach and pear are grown on homesteads. Potato and cabbage are grown as cash crops. Some amount of cattle and yak rearing is practiced with grazing in forest pasturelands. The Alpine forests and scrub extend up to 4,500 m with small crooked trees and large shrubs interspersed with fir and pine. The stunted forest is mainly of rhododendron of many species. Several plants found in this region attract interest for use in traditional medicine. This region has a very small resident human population, mainly Bhutias and mostly pastoral, herding livestock such as yaks and dairy cattle.

Trans-Himalayan region lies between 4500m and 5500m and is characterized by cold desert vegetation, a feature exclusively restricted to the north of Sikkim. This eco-region has not yet been included in the protected area network of the state and is perhaps the most threatened as it contains a host of endangered species. The region has a short four-month growing season during which grass, flowering plants and herbs grow abundantly supporting a host of insect fauna as well as wild and domestic herbivores, larks and finches. There are no permanent settlements. Human population consists of a small number of nomadic herders of Tibetan origin called 'Drokpas'.

Sikkim is a veritable nature's Noah's Arc teeming with biodiversity, housing nearly half of the country's wild trees, orchid and Rhododendron wealth and one third of the country's flowering plants (Arrawatia and Tambe, 2011). Nature has been particularly generous in her gift of sylvan treasures to the state of Sikkim.

2. Scope and objective

The objective of the study is to prepare up-to-date comprehensive integrated geospatial information for natural and man-made resources for East and South districts of Sikkim on 1:10,000 scale using high

resolution satellite data. This geospatial database is used for developmental and managerial requirements of the government by developing a web based solution for dissemination and decentralized access of geospatial data by various user departments of Sikkim. For this purpose, the geospatial information required include, drainage, transport network, utility network, Point of Interest (POI), cadastral maps, administrative boundaries, land use/land cover map etc. Information available from respective departments was collected and integrated with the geospatial database. After integrating all the information with all attribute data, a web based application was developed for dissemination and use of various departments in all developmental programmes.

3. Remote sensing and GIS based studies

There are some scientific studies published on this area in terms of natural resources and disaster management. Based on the petrological and geochemical studies of strata bound zinc-lead-copper mineralization around Rangpo in Lesser Himalayan belt, it was revealed that the sulphide ore body and its host rocks including the metavolcanics were involved in at least three different phases of tectonic deformation, achieving green schist facies of regional metamorphism (Rai and Madhusudana Rao, 1993). Mishra and Basuroy (2001) studied Sikkim from seismology point of view. According to them the East Sikkim area recorded a large number of shallow focus micro-earthquakes which was included under zone IV of seismic zoning map of India. Krishnaiah et al. (2010) carried out seismic refraction surveys around proposed Rolep hydropower project and found that no major shear zones/weak zones were found in the area and the seismic results were in conformity with borehole data. Application of remote sensing and GIS is useful in identification of fractured aquifers based on lineament studies, detection of alluvial aquifers using geomorphological features, demarcation of glacial boundary and lakes and site selection of artificial recharge structures (Roy, 2009). The drinking water quality of the area was in conformity with the standards described as per Bureau of Indian Standards specifications in terms of its physicochemical characteristics (Khadse et al., 2010). Use of remote sensing and GIS technology helps to overcome the problem of conventional method of estimating rainfall run off by employing Soil Conservation System model which considers parameters like slope, vegetation cover and area of watershed (Pradhan et al., 2010). From tourism point of view, Das et al. (2012) estimated that approximately 7.6 to 10.4 lakhs of tourists would visit Sikkim during 2017, which would also have implications on the infrastructure, environment, natural resources, culture and ecotourism of the state. They further stated that a proactive planning involving optimal use of management options is required for a viable symbiosis of tourism and environment for sustainability of tourism in the state.

Several studies were carried out on landslides of Sikkim. When probabilistic prediction maps are compared with the actual landslide map generated from the recent satellite data for accuracy prediction, it was found that the generated hazard maps agree with the observed landslide incidences (Ramakrishnan et al., 2005). The efficacy of the technique involving statistical indicators was demonstrated with a high prediction accuracy of 84% for landslide vulnerability assessment (Sharma et al., 2011). By integrating the influence of various soil attributes, landslide vulnerability status was studied in parts of East Sikkim which revealed 90% of agreement with the density of landslides in most vulnerable zones showing the efficacy of soil characteristics as a potential indicator of landslide events (Sharma et al., 2012a). The landslide inventory layer prepared through satellite image and several thematic layers integrated in GIS environment showed significant agreement with field occurrence of landslides that was further ascertained by the prevalence of vulnerability assessment accuracy (Sharma et al., 2012b). The Likelihood Ratio technique yielded significantly higher accuracy for landslide vulnerability assessment (77%) as compared to the Frequency Ratio Technique (71%) (Sharma et al., 2012c). When compared to the actual landslide history of the past, it was found that Shannon's entropy applied zonation model matched to real landslide events with higher value of landslide density as compared to the model developed without Shannon's entropy (Sharma et al., 2012d). Rawat et al. (2012) highlighted the importance of multi-disciplinary studies in estimating the landslide hazard zonation combining the subjects as diverse as geology, geomorphology, remote sensing and GIS.

4. Methodology

Quick Bird satellite data (from 9-12-2009 to 10-3-2010) for parts of East and South districts of Sikkim was procured and geo-referenced with DGPS data. Cartosat-I satellite data was procured for these two districts and ortho-rectified (Fig. 2).The cadastral maps and administrative boundaries like district, sub division, block, revenue block, constituency, gram panchayat, ward, police station, polling station were collected from respective departments and digitized (Fig.3a). Base layers like roads (National Highway, state Highway and other roads), bridges and culverts were digitized (Fig.3b) and updated using Quick Bird data. The entire drainage network was digitized and updated using Cartosat-I satellite data (Fig.3c). By onscreen interpretation, land use/land cover maps were prepared on 1:4,000 scale for urban areas using Quick Bird satellite data and on 1:10,000 scale for rural areas (Fig.3d) using Cartosat satellite data. As per the technical guidelines of Town and Country Planning Organization, Ministry of Urban Development, Government of India, (TCOP, 2006) urban land use and land cover categories were mapped on 1:4,000 scale using Level-5 classification while for mapping rural areas on 1:10,000 scale, Level-4 classification was followed. Soil map prepared by NBS&LUP on

1:2,50,000 scale was procured and digitized (Fig.3e). Slope map was generated using Aster DEM on 1:10,000 scale (Fig.3f). POI data on offices, hospitals, schools, colleges, banks, electric transformers, mobile towers, temples, places of tourism interest, religious places, water pumping stations, telephone exchanges, electric substations, bus stops, hotels etc. was collected with the help of GPS and plotted on 1:4,000 scale for urban areas and on 1:10,000 scale for rural areas with the help of high resolution satellite data. With the help of geo-database created, a customized web GIS based e-governance application was developed. This web based application was developed to cater the needs of all government departments in the developmental programmes of the state.

5. Resource GIS layers

Administrative boundaries like cadastral maps, gram panchayat ward boundary, gram panchayat boundary, revenue block boundary, constituency boundary, block boundary, sub-division boundary, district boundary were collected for these two districts, scanned, digitized and geo-referenced with high resolution satellite data. Further, these layers were also superimposed on Survey of India topo grid (Fig.3a).
Base map includes bridges, culverts, highways, other roads, settlements, district boundary were digitized, geo-referenced and updated with high resolution satellite data (Fig.3b). Drainage network was digitized using Survey of India toposheets and updated with Cartosat satellite data (Fig.3c). Land use/land cover map consists of built up land (urban), built up land (rural), crop land, plantation, Forest land dense, Moderate, open, forest plantation, vacant land, scrub land, snow covered land, lake, river (wet, dry), tank (Fig.3d).

Sikkim has a wide range of climate, physiography, geology and vegetation that influence formation of different kinds of soils. These soils were mapped and published by National Bureau of Soil Survey and Land use Planning (NBS&LUP) on 1:2,50,000 scale. This map was procured, digitized and geo-referenced (Fig.3e). There are 52 soil types mapped at family level in these two districts.

Slope map was generated by acquiring the Aster DEM, the first step towards the creation of the slope map. The digitized area of interest layer was superimposed over the Aster DEM data and used as the input raster for slope map generation. The Spatial analyst tools provide tools for generation of slope map with the classified symbology (Fig.3f).

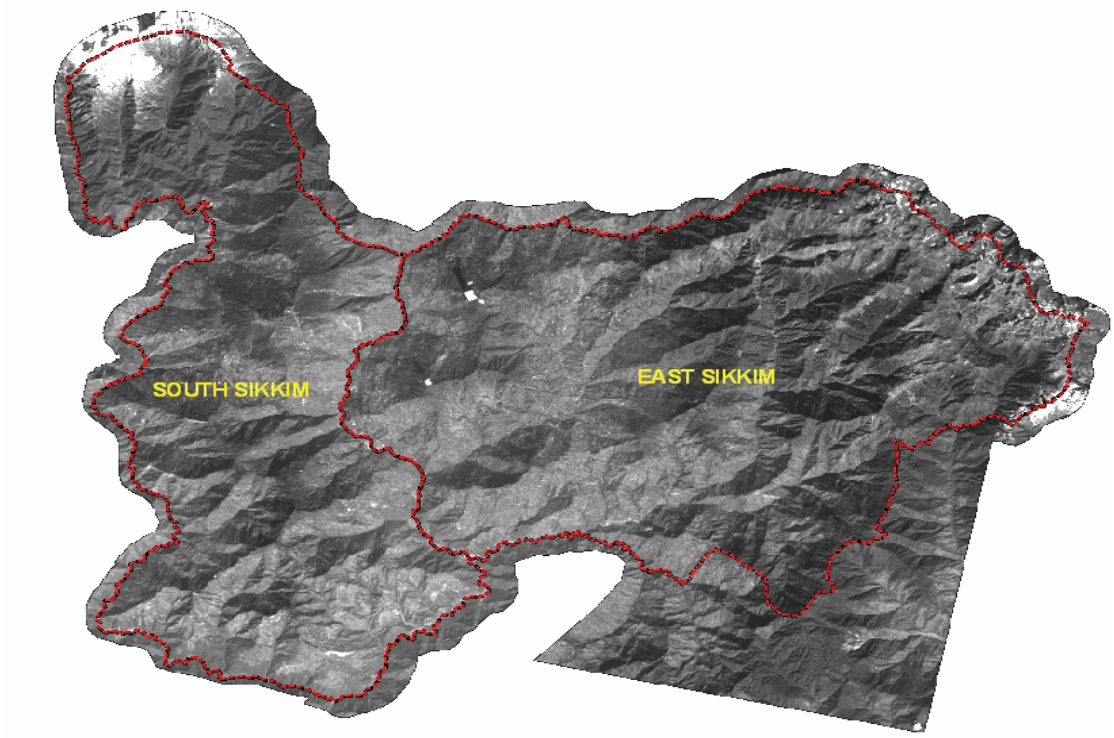

Figure 2: Ortho-rectified Cartosat-1 image of South and East districts of Sikkim

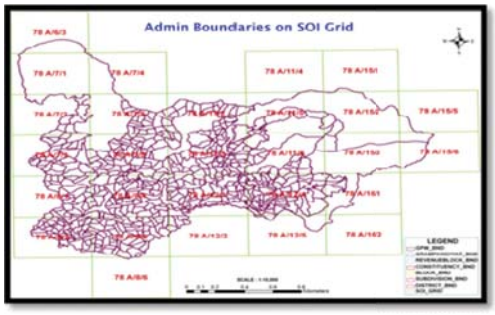

Fig. 3a

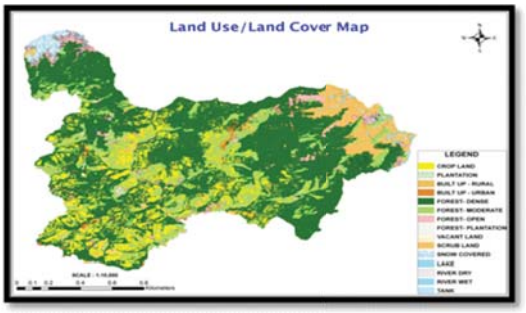

Fig. 3d

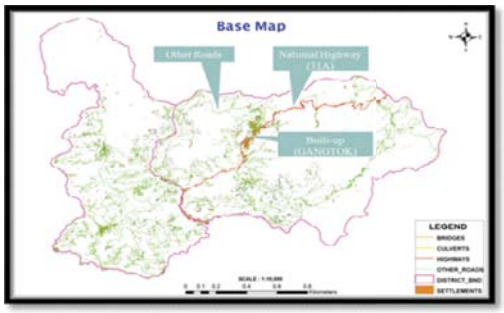

Fig. 3b

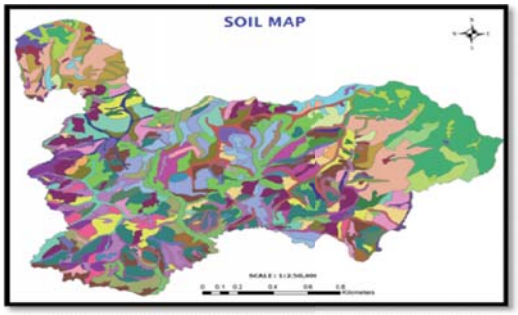

Fig. 3e

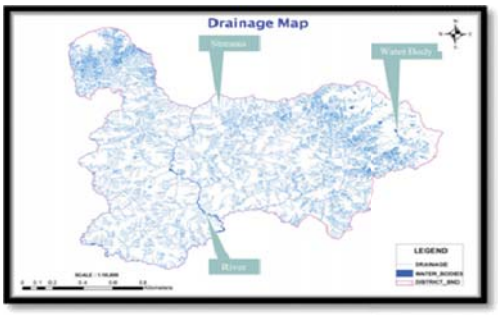

Fig. 3c

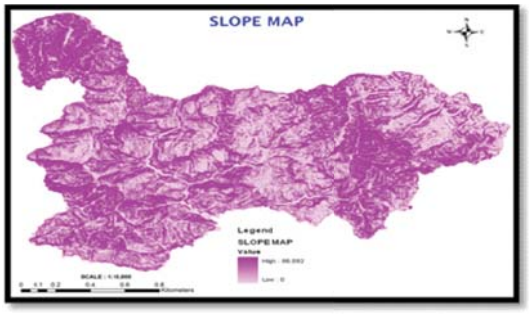

Fig. 3f

Figure 3: Thematic database of East and South districts of Sikkim

6. Web application development

The concept of a state wide information system for land related data has been actively under development for several years by working groups that include various levels of government, and private sector (GIS-related) representatives. The Land Management system developed for Government of Sikkim is a distributed web-based system with heterogeneous data residing on state servers. The system will include access to multiple forms of data including spatial data (e.g., zoning maps), data tables (e.g., cadastral information), text-based documents (e.g., local information related to spatial content) and images (e.g., relating to point of interest) maintained by Govt. at various levels. It is designed to meet information needs of a broad range of audience, ranging from land use planning professionals to interested citizens. One of the most important functions for ILMAP is to integrate land use data across jurisdictions to enable decision-making for comprehensive land use planning. The query tools developed as part of the system helps addressing the requirement of finding the right mix of resources required by the user.

Web based GIS has the capability to give the citizens to communicate with the local Government via the internet. This is one of the most obvious benefits of e-Government to the citizen. The emergence of web-GIS technologies is providing the catalyst for easier collaboration, integration and cooperation among organizations with a stake in good governance and sustainable development. Web enabled GIS facilitates decision making at the strategic, tactical, and operational levels, support administrative operations and serves as a gateway for decision makers and general users to access the system conveniently and effectively. It allows building positive relations between the authority and individual citizens, businesses, investors and tourists via sharing essential

information in an intuitive and understandable way. Web based GIS, can be integrated with different technologies such as multimedia, virtual reality and visualization to disseminate information for better public participation. Such an environment can make complex information more easily understandable to people who are not sophisticated in technology. As a result the emergence of web-GIS technologies is providing the catalyst for easier collaboration, integration and cooperation among organizations with a stake in good governance and sustainable development.

In the present work, with the help of GIS database created, a web application was developed and hosted on server. Some of the salient modules included in the web are as follows.

The user admin. module is used to manage creation of the users and restrict the users from entering into the system without proper authentication by the administrator. The profile management module is used to manage the creation / editing of the roles of the application. In GIS Module Development, GIS page is the core of the application and allows to navigate through the maps and the related attribute information that has been captured during the process of database development phase of the project. Navigation Control Module allows the user to navigate in the map. The table of contents view section of the application allows the users of the application to view the different themes available for the application. It also allows for toggling the layers on / off from its current state.

Thematic map generation module allows the users to create thematic maps on the fly using the existing associated attribute information. The Information module tool allows the user to view the information associated with the feature. The view Associated photograph module allows the users to view the associated photographs collected during the database building phase of the project. The google map Integration Module allows the users to view the google map as the backdrop basemap for the area of interest being viewed. The search module allows the users to search for information.

This is a reliable multi-purpose information base for both generation of developmental programs and also monitoring the progress. It acts as a basic building block in the process of e-governance and forms the basic framework for the development of new areas. This web application helps in channelization of the existing manpower and infrastructure right from the village level with improved data sharing among line departments. It also helps in better policy making and facility management.

Aligning of existing point of interest like location of schools, offices, hospitals, colleges, transformers, substations, telephone towers, water-tanks, bridges etc., captured during the survey and geo-database development and superimposing them with state of art tools for analysis powered via custom application developed, depict commendable as-is state information database.

The web based application has the access rights for the users based on login password to access the application which are clearly defined. Additionally, the application has a log that is maintained for all the users what they have accessed. The Govt. of Sikkim registered a new domain, http://www.sikkimgis.gov.in and the web based application is hosted on to it. This is the first application hosted by the Sikkim state Data Centre. Presently, there are six departments namely Urban Development & Housing, Roads and Bridges, Forest, Mines and Geology, Rural Management and Development and Police that are using the GIS maps from the project.

Based on defined search for a specific requirement using the system for planning purpose or retrieving the information for visualization can be made to provide the necessary information. This can be set with editing of information based on the user credential and respective roles to play for correcting the information on the need basis. The photographs included in the website showing the point of interest (POI), can be queried to understand the current state during the operation of study using the query info tool to display the features.

The Government of Sikkim is aware of the transformational changes in Information Technology (IT) and trying to harness its capabilities for the welfare of the state by having up to date citizen services, ensuring greater accountability through e-governance and also to promote IT investments in the state. The IT policy has been formulated to put IT on a firm footing in the state. As a result, procedures in the government are being re-engineered to make them amenable to computerization and e-governance. The IT department is actively assisting other government departments in computerization and development and maintenance of websites. As part of resource mapping, the rich biodiversity of Sikkim is under inventory through bioinformatics. All natural (forest, rivers), manmade resources (roads, monasteries) and disaster prone areas (landslide, glacial outburst) are being mapped and monitored using satellite data and GIS. Several departments like Information Technology, Forest, Tourism, Roads and Bridges, Transport, Rural Management and Development, Elections etc. have developed web based GIS applications for the development of Sikkim.

7. Conclusions

This customized GIS application is useful for e-governance which can be accessed by authorized user departments through State Wide Area Network (SWAN). Spatial and non spatial data is available on a single platform and easily retrievable and updatable format. The database is in a comprehensive manner to meet the requirements of the user departments. This

web based application with geo-database caters the needs of planners, decision makers and field level officers not only in land management and administrative planning but also in all developmental programmes of the state. It is the first step towards adoption of modern GIS tools for analysis and planning. It acts as the essential building block in the entire process, forming the basic framework for development of new areas.Its implementation has improved data sharing among the line departments and data visibility during policy making discussions.

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