

Web-Based Geospatial Technologies to Support Decision-Making



H. Hemanth Kumar

1 Introduction

Conceptual changes in the practice of planning were brought in, around late 70s, by adopting the decentralized or local-level planning to ensure that the development is sustainable and area-specific and takes into account the felt needs of the local people. The Constitutional (73rd and 74th Amendments, 1992 and 1993) amendments empowered the State governments to form the institutions of local self-governance i.e., rural local bodies (RLBs/Panchayats) and municipalities (ULBs) in rural and urban areas, respectively. KSCST, recognizing the need for both spatial and non-spatial data to local-level planning across Karnataka, established Karnataka natural resources data management system (NRDMS) programme in 1992 to develop a comprehensive spatial data management system for easy access of data and information to support RLBs/ULBs. The 73rd and 74th Amendments to the Constitution also emphasized the need for geospatial data for development planning to local-level governments or panchayats.

Karnataka NRDMS programme is a multi-disciplinary and multi-institutional programme aimed at developing methodologies for building and promoting the use of spatial data management and analysis in local area planning. The vision of the NRDMS programme during its inception was to provide S&T inputs for operationalizing the concept of decentralized planning of the country by developing computer compatible spatial databases on natural resources, socio-and agro-economic parameters to further the concept of area-specific decentralized planning.

The council established district NRDMS centres in each district over a period and established all the centres by 2008 with the funding support of both the Central and State governments. The district NRDMS centres now are being solely supported by the State government, and Karnataka government is the first State in India to

H. Hemanth Kumar (✉)
KSCST, IISc, Bangalore 560012, India
e-mail: hemanth@kscst.iisc.ernet.in

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institutionalize spatial data for local-level planning. These centres are tasked with empowering local communities to make informed decisions in local-level planning initiatives using geospatial technologies.

The utilization of geospatial data and services for a wide range of uses has seen steady growth in the requests for both data and services by planners and administrators. The NRDMS programme is continuously updating its datasets in diverse fields with an increasing set of application requirements. Application domains include, for example, public health and education, environmental analysis and mapping, transportation, water quality/quantity, watershed management, elections, support to disaster management, administration and planning. NRDMS centres provide value-added information, spatial decision support systems, training and support to planners and administrators in local governments [3].

1.1 NRDMS Methodology

NRDMS programme aims to analyze the evolution of methodologies and techniques for formulating development strategies. In a scenario of large diversity of data sets, data users and data generating agencies, the programme aims at developing and demonstrating the use of spatial decision support tools for integrated planning and management of resources at the local level. The NRDMS programme uses both maps and textual data collected from various data generating agencies and remote sensing sources. Maps are digitized and stored on a computer as a series of thematic data layers. Depending on the real unit of planning, maps on 1: 250,000, 1: 50,000 and cadastral scales are utilized. Data on natural resources, demography, agro-and socio-economy and infrastructural facilities for a district form the core database. Those pertaining to specific problems of an area constitute the sectoral database. MIS data obtained from secondary sources are normally stored with village as a unit. Data gaps are filled in by limited primary surveys. GIS based decision support systems/modules help process the data and generate alternative scenarios for making optimal planning decisions. Outputs in the form of thematic maps, tables and reports based on spatial analysis are obtained from the database as per the user requirements (see Fig. 1) [3].

1.2 Major Activities/Achievements [3]

- NRDMS centres have been providing custom applications, value-added information, training and support to planners and administrators.
- Developed a standardized seamless spatial data for storing and sharing through Karnataka Geoportal to facilitate data access and discovery on Survey of India framework data.
- Seamless administrative and derived boundaries geospatial information for entire state of Karnataka is available, and data has been updated as of 2017.

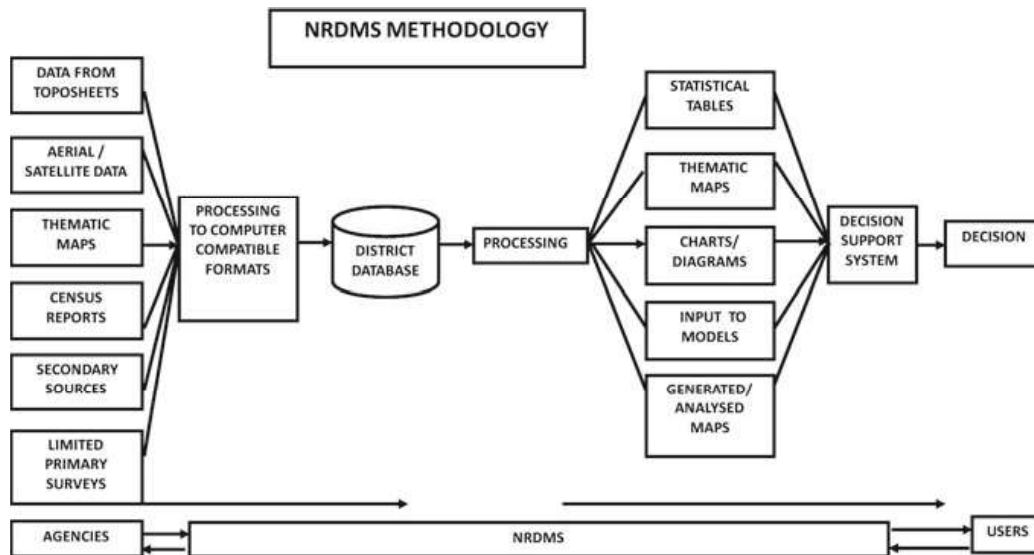


Fig. 1 NRDMS methodology

- Development of Web-based geospatial applications/decision support system to support informed decision-making.
- Initiated mapping of urban local bodies as well as resource mapping for Panchayati Raj institutions using latest geospatial technologies.
- NRDMS centres have been continuously updating information (spatial and non-spatial) for the benefit of user departments.
- Conducted district level workshops in all the districts to create awareness among end-users.

1.3 Typical Applications Developed Under NRDMS Programme [3]

- Election information and management system.
- Rural Health Facilities-Allocation/Location and its jurisdiction.
- Impact of stone crushers on environment.
- Crime mapping.
- Education Management Information system.
- Rural water supply and water quality for PRIs.
- Resource, Infrastructure and Habitation mapping for Gram Panchayats.
- Prioritization of MI tanks (see Appendix Fig. 6).
- Watershed and related applications [6].
- Digital Tourism ATLAS.
- Gram Panchayat ATLAS—2016 (see Appendix Fig. 7) [1].
- Planning ATLAS of Karnataka.

2 Development of Karnataka Geoportal

With increasing dependence on spatial datasets and extensive use of Web-based technologies in other domains, a need has been felt to allow the discovery of and access to up-to-date spatial datasets. The council with the support of State and Central government developed a geoportal and data clearing house to discover/access spatial datasets useful in the local-level planning process through Karnataka State Spatial Data Infrastructure (KSSDI) Project [7]. KSSDI also called as Karnataka Geoportal is a centralized single window access mechanism for all the spatial data acquired by various agencies in the Government of Karnataka using State's resources primarily to support planning activities of the Panchayati Raj institutions, district/state line departments, urban local bodies and civil society organizations in the State.

Table 1 Predefine applications under Karnataka Geoportal

Department	Application requirement	Application query	Data required
Department of Education (Akshaya Yojana Programme)	Opening of new primary school	Distance of a school from a village doesn't exceed 1.5 km	Scale 1:50 K: village point, school point data Scale <1:25 K: village polygon, school polygon/point data
(District Primary Education Programme)	Opening of new primary school	1. Population exceed 300 2. Village with Adult Education Centre	Village level population/census data with: Village Name, Village Panchayat Population, Existing school, Existing Adult Education centre
(Akshaya Yojana Programme)	Construction of new school rooms	Select schools for which additional rooms were constructed Population is in excess of 600 number of students in excess	Village name Village population School name Number of students Number of dropouts Current year Number of School Rooms Number of rooms added last 3 year
(Akshaya Yojana Programme)	Repair to school rooms	Select schools for which rooms were repaired	Village census/settlement data Rooms repaired attribute information Date of repair information

Spatial datasets generated, maintained and provided by various concerned line departments of the State government, academia, private or civil society organizations of Karnataka have been made accessible through the portal. The available data are catalogued and the search for availability of any dataset is made available through metadata. The complete Karnataka Geoportal is developed using an OGC compliant proprietary software with facilities to share the vector and raster datasets through WMS, WFS and WCS Web services along with the solutions and products from OEM for server hardware, storage, backup and retrieval systems, networking components and for RDBMS requirements. The portal was developed with the support of a turn-key solution provider through open tendering process [4].

2.1 Need Assessment of Karnataka Geoportal

The objectives of the need assessment were to determine how Karnataka Geoportal can leverage geospatial technologies, and what resources are required to support access/discovery of data and applications in terms of hardware, software, data and personnel. The need assessment of Web geoportal includes logical overview, data description, scope, potential applications, functional/non-functional requirements and map services. The need assessment provides the basis on which the conceptual system design is structured. The design is based on the information compiled in the needs assessment phase of this project and addresses mainly the functionalities of the portal [4].

KSCST organized several workshops at district/division level to assess the geospatial requirements of the user, and with the support and knowledge of district NRDMS centres, more than 500 GIS applications (typical query and analysis) were prepared. The applications are categorized based on the department scheme/programme or a search keyword. A sample list of predefined applications and application requirements is shown in Tables 1, 2, Figs. 2 and 3 and are available as part of geoportal modules.

2.2 Design of Real-World Object Catalogue

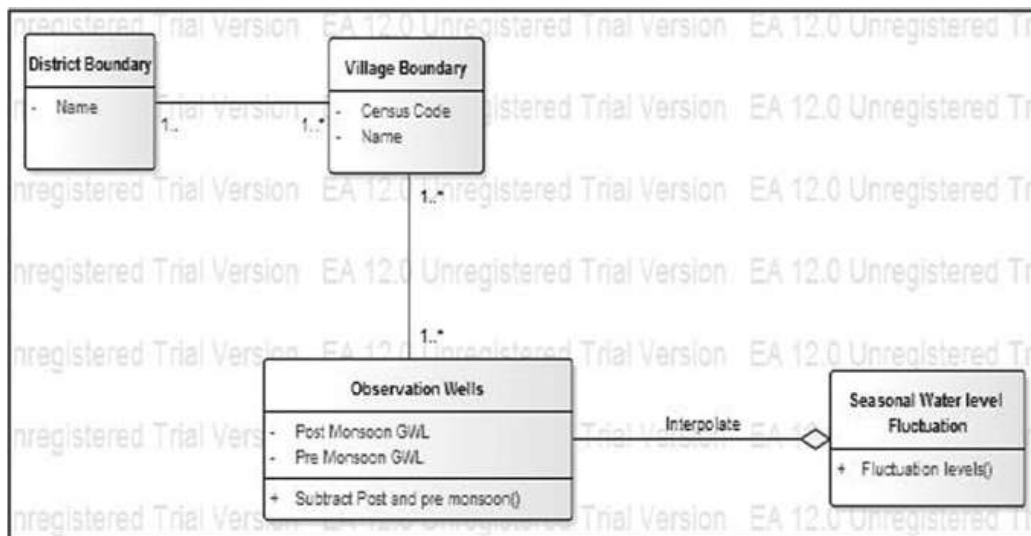
A layer or a table dataset is defined and expressed as a real-world object bringing out the feature properties of each and the attributes. Defining the layer/dataset in terms of a real-world object is defined as following (Table 3) [3].

- Real-world object—properties or feature properties
- Physical data model

The objective behind designing the real-world object catalogue is to:

Table 2 Sample need assessment (UML shown in Fig. 2.)

Name of the application	Seasonal depth to water level fluctuation
Name of the department	Mines and Geology department
Brief about the application	The water level fluctuation is mapped for assessment of drought and ground water recharging using interpolation method.
Application query	To estimate seasonal fluctuation of water
Data required	Administrative boundaries, observation wells (depth to water level of pre-and post-monsoon)
Description	Administrative boundaries: district boundary, village boundary DTW: fluctuation level range $-0.5-5$ mbgl GPS: observation well points
Conceptual design of the application	<ol style="list-style-type: none"> 1. Display district and village boundary. 2. Calculate seasonal water level fluctuation from post-and pre-monsoon depth to water level by finding the difference. 3. Interpolation of seasonal fluctuation level values using inverse distance weighting method. 4. Final map shows distribution of interpolated seasonal level fluctuation with ranges of variation

**Fig. 2** UML class diagram model showing interpolation of seasonal water level fluctuation

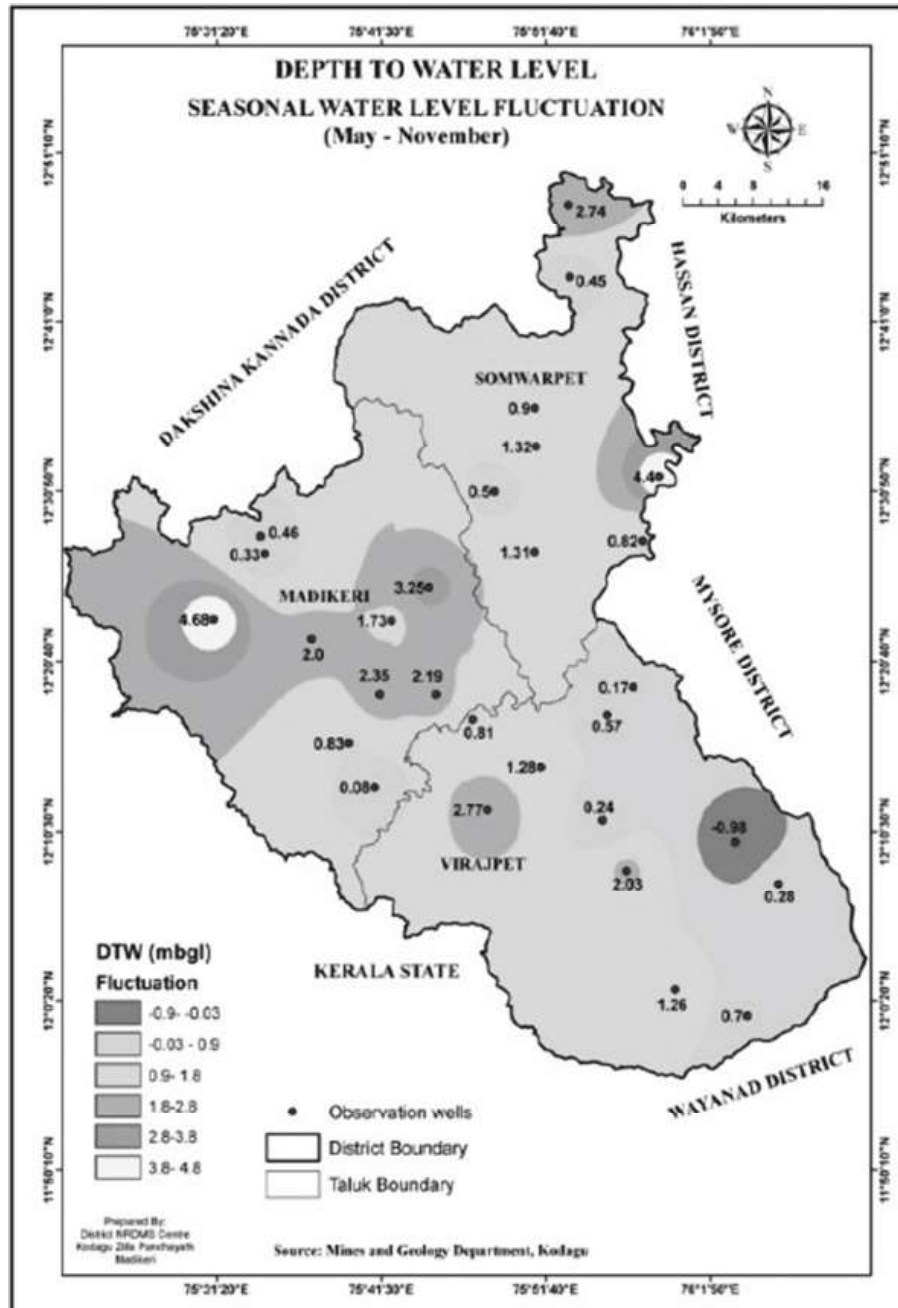


Fig. 3 Seasonal water level fluctuation map of Coorg District, Karnataka as represented by UML diagram in Fig. 2

- Listing of available real-world objects.
- Defining real-world objects and identifying their sources.
- Listing of features and attributes of each real-world object.
- Describing of each of the features or attributes identified.
- Comprehensive data dictionary of the real-world objects.

Table 3 Real-world object catalogues

Variables	Description
Layer code	A unique code given to a layer for its identification
Catalogue ID	Identification code given to the layer to link to the data dependencies at a user use case level
Layer title	Title of the layer
Layer Alias	Alias of the layer, is the most common name of identification which will label the layer while display
Category	Category identifier for the layer classification
Layer type	Geometry feature type of the layer, whether Polygon, Line or a Point
Source	Name of the data generating agency
Scale	Scale of the layer reflecting the feature details that are captured
Layer definition	A definition to the layer describing the layer
Definition source	Source of the layer

- Real-world objects classification by feature type.

2.2.1 Real-World Object Properties: The Real-World Objects Are Defined by the Following Properties

The procedure adopted for developing Karnataka Geoportal: is given below.

- Requirement analysis
- Real-world object catalogue
- Conceptual data model
- Procurement of hardware/software
- Centralized database
- Publishing metadata
- Creation of geoportal
- Customization of available software
- Testing of the geoportal/database/services
- User acceptance testing
- Final deployment of the complete system

2.3 Karnataka Geoportal System Architecture

The diagram (see Fig. 4) shows a schematic representation of the infrastructure and network requirements to host the geoportal and the clearing house. The diagram also shows required number of servers, and server types, and how these servers will communicate with existing infrastructure and partner systems.

The Karnataka geoportal has been developed using OGC compliant proprietary software to share the vector and raster datasets through WMS, WFS and WCS Web services along with the solutions. Products from OEM's have been procured for server hardware, storage, backup and retrieval systems, networking components and for RDBMS requirements.

The KSSDI portal passed preliminary stage of development and was released to users during October 2009 for portal functionality testing. The release allowed the testing of the portal to undergo usability testing with selected users who provided feedback to the project team. Identified malfunctions were rectified. The council officially launched Karnataka Geoportal during December 2009 at the ninth annual event of National spatial data infrastructure [2, 4].

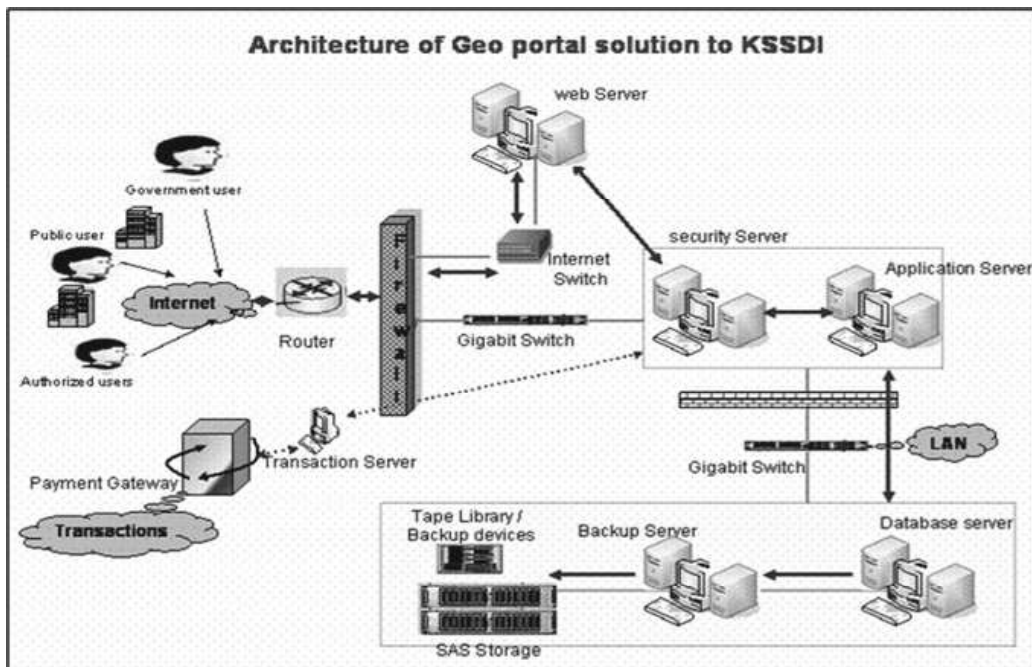


Fig. 4 Karnataka geoportal architecture

2.4 *Services Under Karnataka Geoportal*

Karnataka Geoportal envisaged as a centralized single window access mechanism for all spatial data held and acquired by various agencies/line departments of the state. The modules in the Karnataka Geoportal are categorized into [5]:

- Map viewer—Web map service (WMS)
- Product catalogue/metadata—catalogue service on Web (CS-W)
- Services specific service/feature data sets—Web feature service (WFS)
- Simple applications (query-based decision support)
- Coverage services/images—Web coverage service (WCS)
- Biogas portlet
- Help/support

On Karnataka Geoportal, few portlets were developed to support Ministry of New and Renewal energy, and Ministry of Human Resource Development supported Government of India to monitor the implementation of Biogas programme and to check the availability of schools in rural areas, respectively.

User acceptance testing (UAT): UAT is the last phase of the portal/software testing process. During UAT, actual portal was tested to make sure it can handle required tasks in real-world scenarios, according to specifications with the support of state and district NRDMS centre staff, experts from IIT—Bombay and IISc.

Following are the steps involved in in-house UAT:

- Planning—the UAT strategy was adopted by the advice of experts from IIT—Bombay.
- Designing test cases—test cases are designed to cover all the functional scenarios of the software in real-world usage. The access and discovery of data was an important bench marking for testing the portal. They were designed in a simple language and manner to make the test process easier for the testers.
- Selection of testing team—the testing team comprised of real-world end-users.
- Executing test cases and documenting—majority of the test cases were documented and tested randomly for bugs.
- Bug fixing—responding to the bugs found by the in-house testing team, the vendor made few adjustments to the code to make the portal relatively bug-free.

The geoportal has a centralized geospatial database on variety of spatial layers available to users for query and analysis. A real-world object catalogue was developed to indicate all the datasets with its data dictionary. However, the primary objective of providing geospatial services through Web geoportal remained elusive. Based on the learnings, the requirements for showcasing the utilization of geospatial technologies by user were defined and formed the basis for initiating the second phase of portal development.

3 State Geoportal for Watershed Management

Karnataka Watershed Development Department (KWDD)—an agency under Government of Karnataka is in-charge of running various watershed schemes/projects, formulating policies, planning, organizing, coordinating the activities and implementing the watershed programmes. KWDD uses datasets for planning, implementation, monitoring and evaluation of watershed programmes. Pradhan Mantri Krishi Sinchai Yojana (PMKSY) programme (earlier known as Integrated Watershed Management Programme—IWMP) is a flagship programme of KWDD with a financial outlay of above Rs. 400 Crores per annum. KWDD has multi-disciplinary technical experts drawn from agriculture, horticulture and forest departments who are pooling their experience, expertise and technology in the watershed programmes being financed under External, Central, State and District Sector schemes. The department currently has an in-house online management information system (MIS) for monitoring watershed programmes by its Head Office. It makes use of existing cadastral and thematic maps available with other departments, from planning to implementation stages, and tries to document all the activities with geo-tagged time-stamped photographs before, during and after the implementation of various programme-based activities. However, they do not have an easy and timely access to geospatial data of right resolution and currency for use in planning, implementation, monitoring and evaluation processes. KSCST felt the need for integrating KWDD's MIS with the Web-based SDI approach of NRDMS-NSDI/DST to provide standards-based online geospatial information services to end-users in KWDD by utilizing the Karnataka State geoportal already operational in the State. Towards achieving the above goal, the project “Development of Geospatial Web Applications on Karnataka Geoportal for G-governance” was launched by KSCST under the collaborative support of DST, Govt. of India and Govt. of Karnataka during April 2013 to March 2016 [2, 6].

3.1 Features of the Portal

On the launch of the above project, a user requirement analysis was taken up to understand and study the geospatial information needs of the KWDD to be accessed over the Web. KSCST showcased the utilization of geospatial technologies by developing geospatial applications on the Karnataka State geoportal to evaluate watersheds in Belagavi Division of Karnataka under the Phase I and Phase II projects of PMKSY. Development and deployment of the “State Geoportal for Watershed Management” technology enables the users to query on various geospatial and non-spatial (attributes) parameters at cadastral/beneficiary level for activities taken up under agriculture/horticulture/forestry sectors. The geoportal enlists a host of open geospatial consortium (OGC)/international standardization organization (ISO) Standards-based Web services for accessing datasets to support watershed management.

Crowd sourcing of data for data updating, mobile (smart phone) compatibility and online editing of datasets are some of the technology's major highlights [2].

3.2 Additional Features of Watershed Portal Information Services for Watershed Management Include the Following [2]

- Web processing service (WPS)
- Transactional Web feature service (WFS-T)
- Mobile mapping
- Multi-spatial and multi-attribute query and analysis (see Fig. 5)
- Multi-lingual support
- Online help/support to end user

Accessible on the State geoportal, above Web-based services could be used by the end-users in the field (watersheds) to capture relevant datasets from the watersheds and update the geospatial database at a central server over the Web. In this instance, the database is located at KSCST for access by all end-users across the Belagavi Division of Karnataka contains the cadastral map layers secured from the Survey Settlement and Land Records (SSLR) Department of the State's Revenue Department. Non-spatial information from the MIS of the Karnataka Watershed

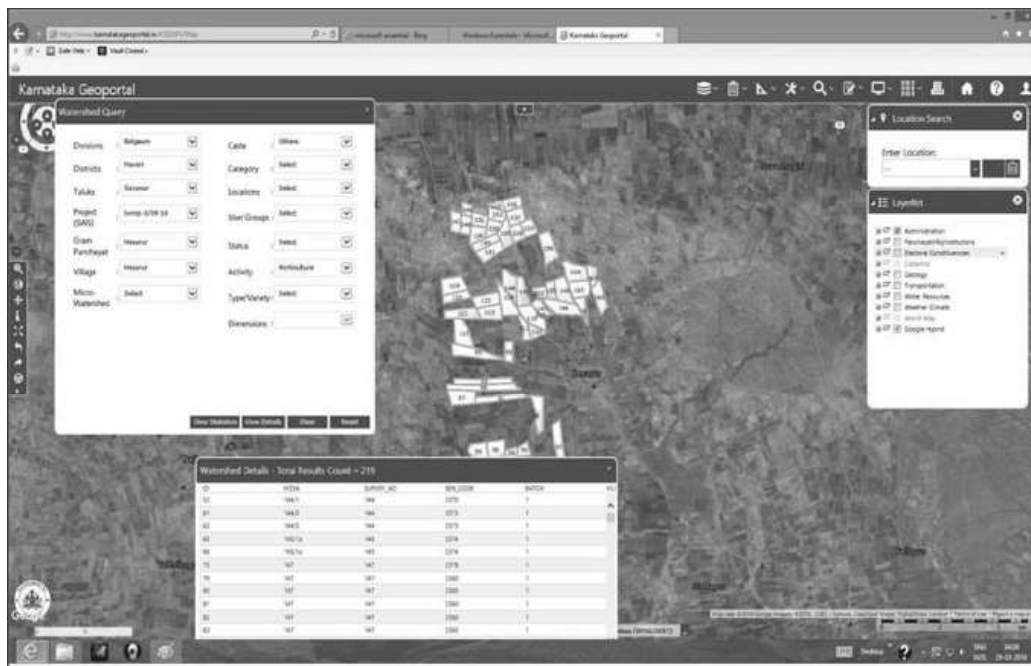


Fig. 5 Locating cadastral plots showing horticulture scheme implementation under IWMP

Development Department (KWDD) has been integrated with the cadastral (spatial) data layers to facilitate querying and analysis over the hitherto unavailable on integrated database and the Geoweb. Use of the services has been demonstrated to the potential end-users in various training workshops in Karnataka and several other States for adoption in State SDI projects of NRDMS-NSDI. The Karnataka District NRDMS Centres in the State have been trained on the use of the State Geoportal in watershed Management.

This portlet enables users to query and analyse on various geospatial and non-spatial (attributes) parameters at cadastral/beneficiary level for activities taken up under agriculture/horticulture/forestry sectors by integrating with the MIS developed by the Karnataka Watershed Development Department. This facility hitherto was unavailable on integrated database and the Geoweb. The geospatial services like multi-spatial-attribute queries, mobile compatibility, crowd sourcing, online editing of data and integration of MIS are the highlights of the programme [2].

4 Conclusions and Future Perspectives

The geoportal provides tools to the end-users to monitor the progress/implementation of projects/programmes of the government and allows adopting possible mid-course corrections through better and improved management practices through geospatial technologies. This, in turn, will contribute to the economy by saving governmental staff-time, improving quality of decision-making, ensuring better transparency and accountability, and bringing in better delivery of outputs of government schemes and programmes. We have envisaged and proposed following activities to enable Karnataka geoportal to fully support the informed decision-making.

- Creation of spatial data 1:10 k or below by adopting technical standards i.e., category, content, metadata, accuracy, services, etc.
- Mapping of all public/private assets (POI)
- Integration of MIS to GIS content near real time
- Identification of core application for each department
- Building of SDSS/applications
- Very good data connectivity including hardware and software
- Capacity building and spatial data policy for usage
- Smart city Applications (2D/3D)

Appendix

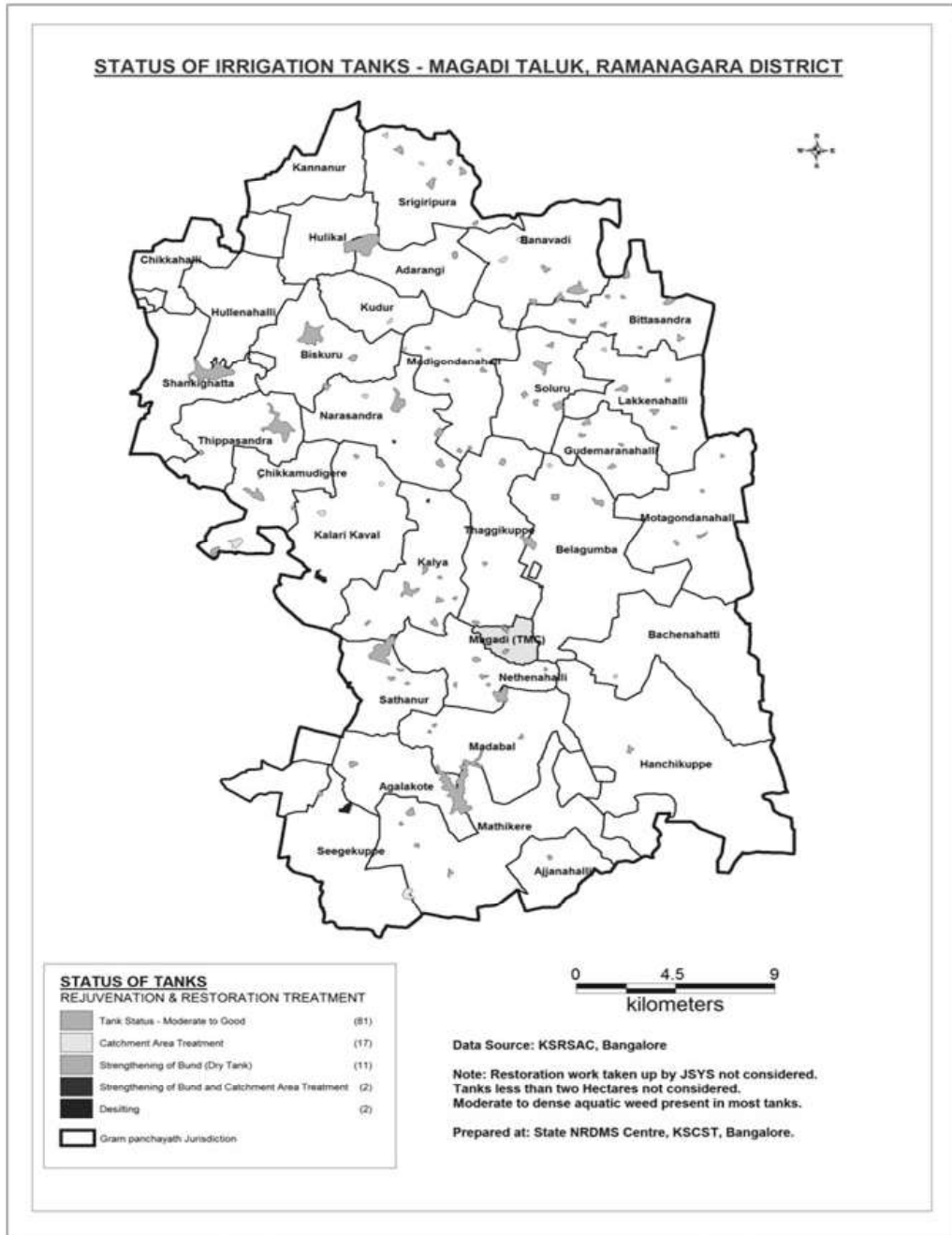


Fig. 6 Status of minor irrigation tanks of Magadi Taluk, Ramanagara District

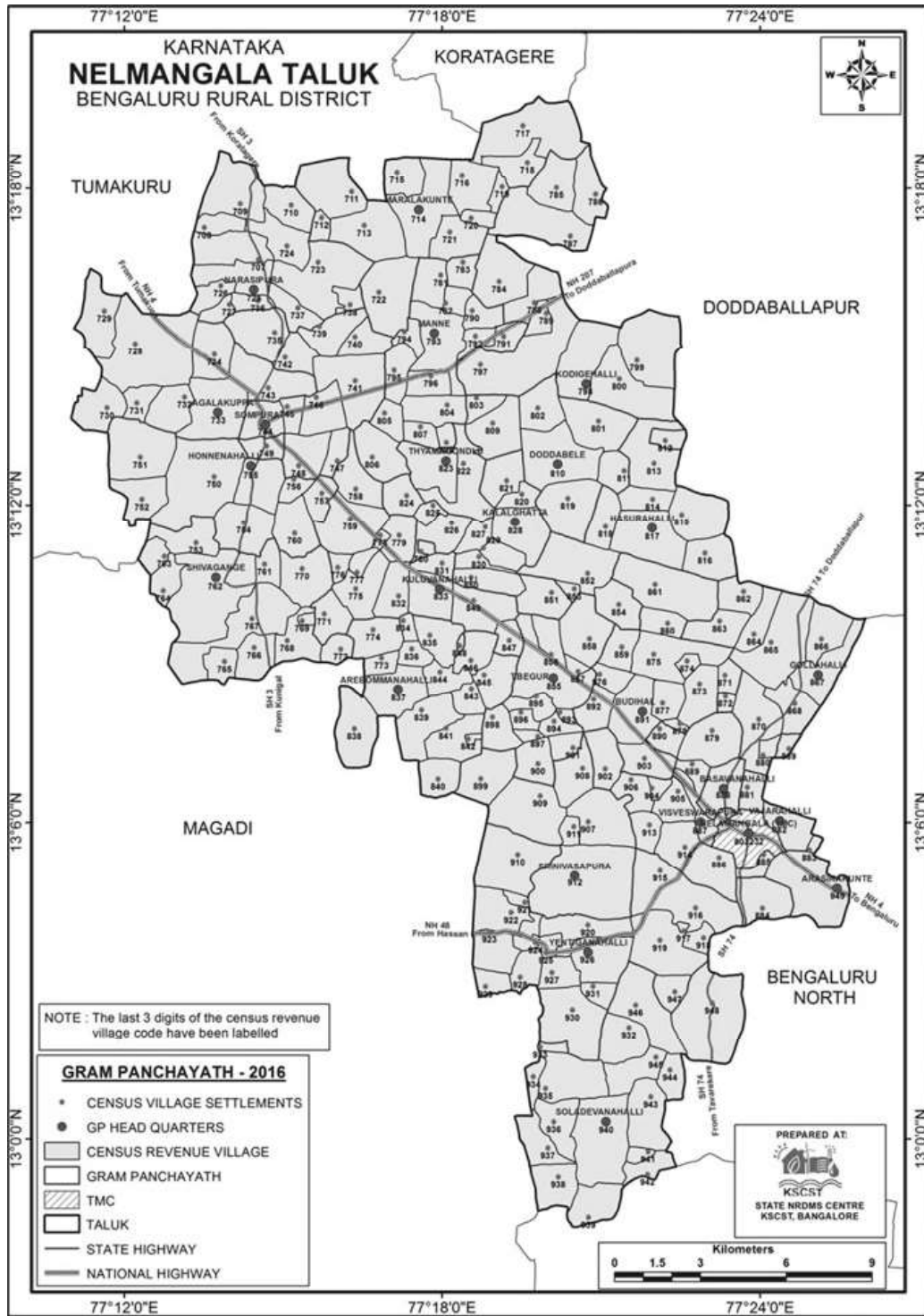


Fig. 7 Gram Panchayat map of Nelamangala taluk, Bengaluru rural district [1]

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