

Village Information System

Preparation of Digital Base Maps from Cadastral Maps and RS Data Products

**A network initiative of
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Preface

India has been passing through a very rapid development in almost all sectors of science and technology. Many major programmes like (1) Digital India, (2) Make in India, (3) Saansad Adarsh Gram Yojana have imparted a great relevance to the use of spatial technologies. Despite the fact that Survey of India has produced precise toposheets, the scale at which they are made available did not facilitate their use for development and other administration purposes. It is, in this context, the cadastral maps prepared long ago are still being used and serve the basic purposes at village level. Incidentally they continue to form the legal basis for many situations. On the other hand, the space technologies developed in our own country and elsewhere are identically much more suitable for preparing base maps with high resolution and accuracy. In this context, major programme like (1) Digital India, (2) Make in India, (3) Saansad Adarsh Gram Yojana envisaged and initiated by Government of India under the leadership of Shri Narendra Modi Ji has reiterated and impressed the need for the generation of digital maps at village with reasonable accuracy.

The Village Information System evolved as a network programme under the aegis of NRDMS, Department of Science & technology, Government of India has taken up the task to prepare digital base maps at village level utilizing cadastral maps, Survey of India toposheets and various level utilizing cadastral maps, Survey of India toposheets and various high resolution remote sensing products adopting a synergic approach. Though these maps are not intended to provide the basis of legal purpose, an integrated approach has been designed and developed to produce the maps at a very high resolution. For the purpose a synergic approach using remote sensing products viz., Cartosat-I, Cartosat-II, LISS-III, LISS-IV, and wherever possible world view and quick bird are being used. However, in the absence of high resolution data either from Cartosat/quick bird/ world view to keep the programme going the data from the Google maps has been realized as a stop gap arrangement. the procedure has been developed by Karnataka State Council For Science And Technology (KSCST) and Anna University mainly by Mr. H Hemanth Kumar and Prof. Raju respectively .The procedure is being widely circulated to the experts for eliciting their suggestions to improve the procedure and documentation. The final version of this document is expected to ready in next two weeks and hope will find acceptable application in preparation of digital basic maps at village level both for development and management of resource and activities.

Visakhapatnam

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Head, NRDMS Division &

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PREPARATION OF CADASTRAL LEVEL BASE MAP FOR VILLAGE INFORMATION SYSTEM

1. Introduction

Land information refers to physical, legal, economic and environment information about land features in a given area. The creation and maintenance of land information in India, is under control various agencies like Survey and Land Records Department, Revenue Department, Registration Department, Local Administration and Public Works Department. These agencies will generate and maintain data pertaining to their activities like Revenue Department maintains details of land ownership. An efficient village planning requires modern cadastral information system of the village with linkage to other subsystems like Resource data, economic data. Various thematic maps like land use, soil, water resources are to be generated at very large scale (i.e. 1:5,000 to 1:10,000). Unlike small scale mapping where a base map is generated from Survey of Toposheet, Village Information System requires base map showing parcel boundaries at a scale of about 1:5,000. The village maps prepared by Survey and Land Records Department of the state government are very old and available mostly as paper maps or scanned maps. Hence the maps are to be georeferenced and digitized to prepare a base map of the village. The same can be used for thematic mapping of resources and socioeconomic parameters of the population.

Background facts/information (Karnataka)

- Land is the subject matter of State Government. State Government makes all the policies regarding Land management and land records management within the State. The State Governments is also having an authorized administrative department to service updated Cadastral land information to the citizens, under Karnataka Land Revenue Act and Rules 1964, formulated by it.
- The Central Governments assists/supports State governments in the management of Cadastral Land Records in the following areas
 - Provides funding (full or partial) for the projects for improvement of Cadastral Land information management and citizen delivery system. A 10 years scheme/programme (2008 to 2018) NLRMP was formulated in 2008 for all the states. Each state is permitted to avail financial assistance to up to 100 crores in Karnataka, in phased manner.
 - The State governments are free to adapt any method any strategy for implementation of the modern Cadastral Land Records management system based on ICT and GIS technologies in this NLRMP scheme. The Central Government is offering very flexible free assistance in technology (through NIC, Governance, Science and Technology departments, ISRO, NRSC, SoI, etc.), in law (Central law departments.) for any amendments in land laws, any industry assistance (PPP models, Technology aids purchases, private consultancy services, etc.), and other form of assistance in formulation

of strategies and implementation of guidelines. In spite of all these provisions the most of the States are yet to adapt GIS and ICT for implementation of Cadastral LR, for whatever reasons. It is to be noted that technology has never been a reason, but the requirement of policy is.

2. Cadastral Mapping

Land is the most important assets of any country. The Land also contains all other valuable assets of the country such as forests, rivers, Minerals, oil, agricultural resources such as crops, orchards, industrial resources such as hydroelectric power, factories, markets, etc.

Cadastral surveying is the branch of surveying which is concerned with the survey and demarcation of land for the purpose of defining parcels of land for registration, and creation of land records in a land registry. The record consisting of:

- Record of ownership describing the nature of rights or interest in the respective parcels.
- Map of land parcels linked to other records

The primary objective of cadastral mapping is to maintain Ground to Record-Record to ground-truthfulness at all times. Only then that it can be used for legal, administrative, planning and developmental purpose. There are several ways of presenting cadastral information. The most common and popular one is through maps. Generally in India, cadastral information is stored as written records containing lists of parcels, areas, landholders, assessed values and other items regarding the land.

The Cadastre (Cadastral Information) is classified into Graphic and Numerical Cadastre. The Graphic Cadastre system contains the land parcel data in the form of graphic record, from which area & other dimensional measurements has to be extracted. The Numerical Cadastre contains each individual land holding and is physically measured and parcels are recorded in the FMB. This system is also known as FMB (Field Measurement Book).

In developed countries as well as in India, cadastral survey uses the following three methods namely (i) Ground based survey using Total station and GPS, (ii) Aerial photographs or (iii) High resolution satellite images.

Proposed administrative Strategies for implementation of CLR (Cadastral Land Records) management

1. Land Records are legacy data and they are in service of the citizens on a continuous basis and hence keeping the present records for the day today transactions, every data has to be corrected or modified or replaced on a record by record basis. Therefore strategic approach is very critical in shifting from existing system to ICT/GIS based system
2. CLR by default has to be in GIS platform as the major information content is spatial and everything else is an attribute attached to spatial data (precisely the land parcel)
3. A GIS platform needs to be created for every record/parcel (alphanumeric data).

4. Government can have a policy first and drive the department to implement the project (with private participation or PPP model- the UPOR for Urban areas was done with PPP model by the department)
5. It is to be noted that in Karnataka, the Government ushered in a policy that all Land Records (attribute data) to be in digital by the year 2000, and only digital records printed from the Bhoomi database are legally valid, all paper based records are illegal, from the year 2000; Bhoomi could become a reality.
6. Similar Policy decision has to come from the Government that all the Land parcel maps to be in GIS platform and only then GIS can be realized.

3. Base Map Preparation for Village Information System

The Village Information System requires base map showing parcel boundaries at a scale of about 1:5,000. Conventional base maps prepared from Survey of India Topographic Sheets at 1:25,000 or 1:50,000 scale may not be useful for this case. Hence a methodology was formulated considering the availability of resources and limitations of various partner institutions of the network project. The methodology for base map preparation at 1:5,000 scale for VIS project is detailed below.

3.1 Part I (Cadastral map)

- Procure village maps (Cadastral map) from authorised agencies like Survey and Land Records Department of the State Government preferably at 1:5,000 scale or whichever is available.
- Scan the cadastral map in JPEG or TIFF format at 300 dpi resolution or higher.
- Digitise the cadastral map using any GIS package and extract the features like village parcel/survey polygons, water bodies, road/rail network, water and soil information, drainage, settlements, plantation etc.
- Through field survey identify Ground Control Points (through GPS/DGPS).
- Georeference the cadastral layers using GCP's.
- Set datum and projection for these vector layers i.e., WGS 84 datum and UTM projection.
- Using geospatial adjustment tool available in GIS packages, spatially adjust the digitised cadastral layers to fit with corresponding features seen on High Resolution Satellite Imagery (georeferenced and ortho-rectified) to improve positional accuracy.
- Attach survey numbers to each of these polygons.

3.2 Part II (High Resolution Satellite Imagery)

- Procure High Resolution Satellite imageries (HRSI) (georeferenced & ortho-rectified) either from NRSC or any other HRSI available in public portal.

- Further ortho-rectification can be taken up using local ground control points to get a fairly good horizontal accuracy in distances.
- Ground control points identified and collected earlier can be used for ortho-rectification of HRSI.
- Extract the features like village parcel/survey polygons, water bodies, road/rail network and other physical features from Satellite Imagery by keeping scale at 1:500 in GIS software while digitising.
- The cadastral maps are to be used as reference while extracting information from HRSI.
- To assist digitization using HRSI, we may physically shift the cadastral vector layer suitably over the imagery to clearly identify/demarcate the parcels and sub-parcels/Hissa is also extracted through HRSI.

3.3 Part III (Field verification)

- Field Verification and Validation of parcel boundaries to identify and update the left over (parcels which could not be identified from satellite imagery) and unidentified parcels.
- Identification of the land parcels on the ground also fixes its location on the ground, its boundary polygon and its place in the village with reference to a spatial standard reference point already established and accepted by the Government.
- Edit/mark the survey boundary with existing/ new PIN and clear adjacency.
- Field measurement of 5% of the parcels using Electronic Total Station for quality assessment of parcel mapping and to check the area w.r.t. records available with revenue department.
- Linking of the attribute information available with the departments to digital vector layers i.e., for both survey and hissa polygons.
- Preparation of Thematic Maps like Land use/ Land cover, Soil, Geology using base map

3.4 Part IV (Unique identification)

- Unique identification code for parcel/hissa – Census revenue village code +c+ parcel id (three digit)+ hissa id (alphanumeric - 5digit)
 - ✓ The unidentified parcels will be identified by number starting from 500.
 - ✓ Parcel id – 3 digit: e.g., if parcel id is ‘1’ record it as 001.
 - ✓ Hissa id – 5 digit: e.g., if hissa id is ‘1/a’ record it as 001/a.
- Unique identification code for habitation - Census revenue village code +h+ plot id (three digit)
- Unique identification code for assets - Census revenue village code +a+ asset id (alpha numeric – 5 digit)

The following information is mostly available with all state SSLR departments and can be linked to features.

- Parcels (revenue, non-revenue, water bodies, forest)
- Survey Number and Hissa Number of Land.
- Total Land under the Pahani.
- Land Revenue details.
- Land Owner's name with Extents and Khatha Number.
- Classification of the Soil.
- Number of Trees.
- Source of irrigation (rain fed/bore well/canal etc.)
- Area irrigated.
- Utilisation of land under various categories.
- Details of Crops grown season-wise.
- Details of Mixed Crops.

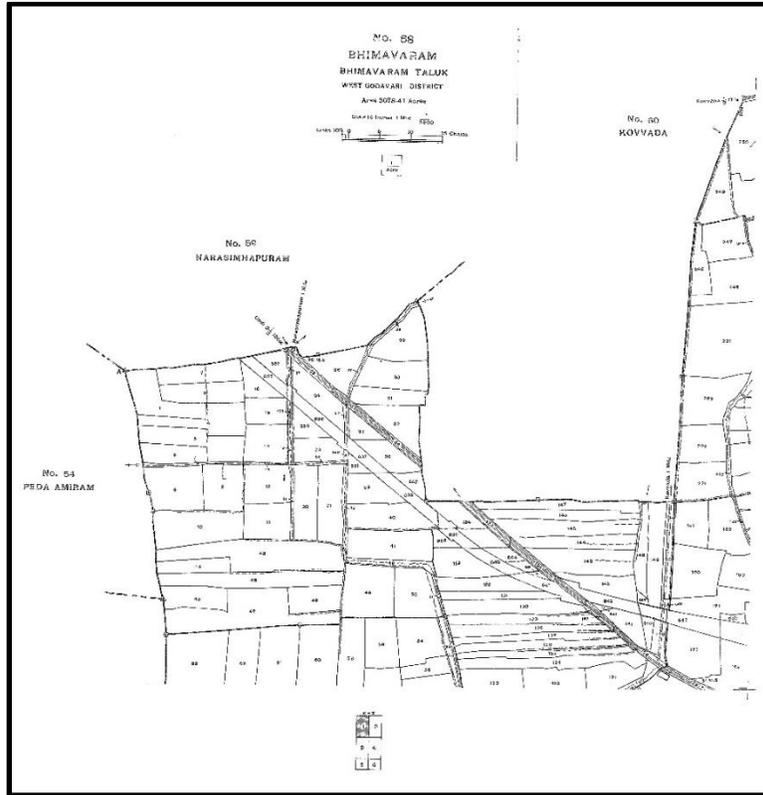
4. Village Maps

A village map consists of land parcels which are numbers sequentially. A land parcel is an extent of land and shown in the Government record associated with a set of ownership rights officially recognized as property. The physical boundary of the parcel is contiguous and is defined uniquely in the official record. The said boundary is depicted in the form of two-dimensional map known as village map prepared by methods of plane tabling and chain and tape measurement. The village map shows individual parcels of all free hold, public and government land, encroachment and adverse possessions. The scale of the village maps varies in different states but the most common being 1: 4000. The land parcel boundary is quite old which calls for fresh mapping / updating. Also for developmental purposes it is important to associate present natural resources information with the land parcels. The availability of high-resolution data from satellite based platform has opened up new possibilities for land parcel mapping and updating with unique opportunity of natural resources appraisal and its change analysis. The cadastral maps for villages are prepared and maintained by Land Records Department. Most of the village maps have either no projection or the Cassini projection. As these maps are not geo-referenced, hence, they cannot directly be overlaid on any other resources map prepared using remote sensing data or other method.

4.1 Tracing and scanning

The village maps procured from Survey and Land Records Department for each village are to be traced wherever required before scanning in case it is torn, mutilated or not legible. In Many states, the village maps are scanned by Survey and Land Records Office and hence available in TIFF format, which can be opened directly in any standard GIS software like ArcGIS. Some of the states like Karnataka; Andhra Pradesh has made the village maps available to public through Internet. In case of paper maps, the source maps can be scanned using a good scanner with resolution better than 300 dpi. Maps collected in sheets were scanned after quality checking of

each sheet with regard to its physical condition, readability, content and clarity. The map should be cleaned properly before scanning to avoid dust particles, lines due to folding of maps occurring in the scanned output. The resolution and output format can be chosen as 300 dpi or better and TIFF format to avoid loss of information.



Most of the villages are covered in more than one cadastral sheet. For example, the village indicated above is divided in to 6 sheets. Hence mocking of all the cadastral sheets of one village through matching of edges like parcel boundaries, roads is to be carried out.

4.2 Verification of Scanned Data

The scanned maps are to be verified for the feature legibility before proceeding to digitization of features. The map can be displayed in the GIS software and zoomed to 1X to check the scanning quality. The features, labels should be legible at this zoom. The scanned map normally contain speckles (noise) arising due dust particles, mutilations of original village maps hence to be cleaned using image processing methods like filtering. In case of manual digitization of village maps, these errors can be taking sufficient care while digitization of features from village maps. Some of the low quality scanner distort the maps during the process of scanning. Hence it is advised to verify the geometry of scanned data by measuring length and width of bounding box with map manuscript measurements. The deviation must be uniform in both x and y directions and within $\pm 0.1\%$.

4.3 Geo-referencing of Scanned Map

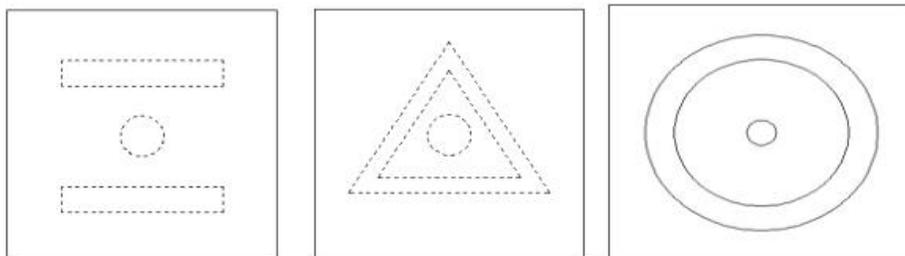
Geo-referencing can be defined as the process of transforming the spatial data from image (row and column) coordinates into ground coordinate system using an nth order polynomial. For geo-referencing of the cadastral map, sufficient number of Ground Control Points (GCP) with ground coordinates is required. The primary source for acquiring GCP is through ground control survey, topographical maps. The secondary sources consist of aerial images or high-resolution satellite images. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or orthorectifying the data.

The scanned map may contain the errors due to differential scanning, wear and tear, differential shrinkage / expansion resulting in non-uniform scale at different locations of the map, deflection in north orientation etc. The process of georeferencing with suitable number of GCP will help to make the map planimetrically accurate.

4.4 Geo-referencing using GCP from GPS

The best approach to geo-reference the scanned village map is to use GPS observed Ground Control Points (GCP). The boundaries of a village will be marked on the map with village boundary stones, condom boundary stones and parcel boundary stones. Village boundary stones will be shared by adjacent villages and will have demarcations showing if the boundary is a Bi-Junction or a Tri-Junction. If the village boundary is shared by two villages then the boundary is indicated by a Bi-Junction stones, while a boundary or point shared by three villages is shown by a Tri-Junction stone. Using Dual frequency GPS, the coordinates of these stones can be measured in WGS84 datum.

Bi-junction, Tri-junction and condom boundary stones.



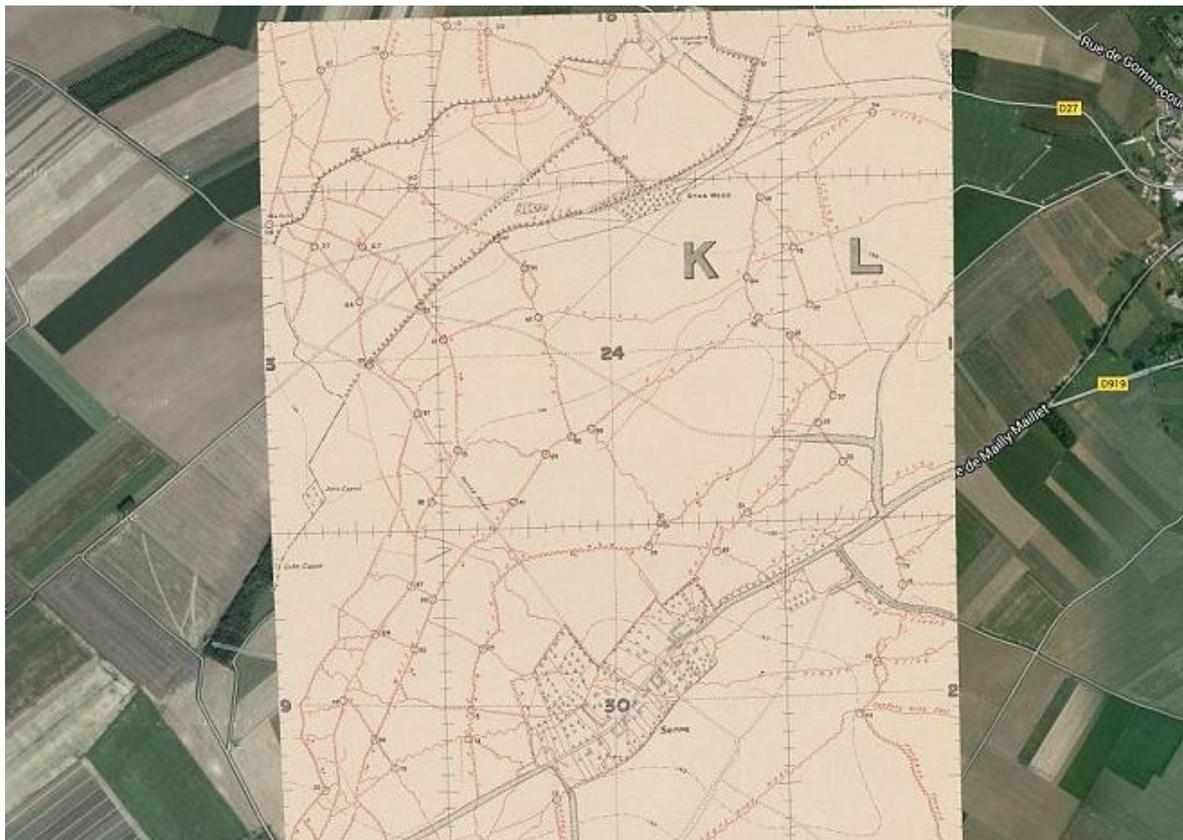
Field photos of Bi-junction, Tri-junction and condom boundary stones.



The Village Maps can be georeferenced using well distributed GCPs surveyed using GPS. The root mean square of the georeferencing process shall be less than 1m. The alternate method in case of villages where the boundary stones could not be located, is to identify features like road junctions, railway intersections, cross drainage works in the village map and use them as GCP. Dual frequency GPS receivers are required for acquiring GCPs in this method of georeferencing.

4.5 Geo-referencing using Satellite Imagery

The alternate method of georeferencing is to use georeferenced high resolution satellite imagery of the village. The high resolution satellite data, which depicts distinctly the field bunds, roads, tracks, streams, tanks etc., is being used as ground control points database for the cadastral maps geo-referencing. Common points are identified on the satellite image and scanned village map which will be used as GCPs for georeferencing. The village map is geo-referenced to the image



using sufficient number of GCPs. The coverage is transformed into the new co-ordinate system, and the projection parameters added to the transformed coverage so as to make it compatible with other spatial database. The following image depicts the georeferencing of scanned map using high resolution satellite imagery.

4.6 Vectorisation / Digitisation of Village Map

Spatial data of any feature tells where it is and non-spatial data tells what it is. The next step is to create spatial and non-spatial database related to the village. Spatial database include digitization or vectorization of cadastral maps and non-spatial database indicate attribute information about every parcel of land or Khasra, the information include owner name, area, crop, land use and other relevant information.

The raster data may be converted to vector data using raster to vector conversion option available in GIS/CAD software. Three distinct methods are available for vectorization or digitisation namely Full Automatic Method, Semi-Automatic Method and Manual Method Considering the size of study area for VIS project, Manual method of digitization can be preferred to avoid errors in vector data. In this method, scanned village maps in image format are digitized using heads-up digitisation using GIS/AutoCAD. Various features in village map like parcel boundaries, roads, canals/drains, railways lines, boundary stones, intersections are categorized into either polygon, line or point features.

Before starting of the digitization, a standard template is to be created. In the template the outer boundary of the village is to be standardized. This process maintains uniformity in all the maps, which are to be created for the village. All the features will be captured as different layers use standard template of village boundary. Some of the rules to be followed during digitization include

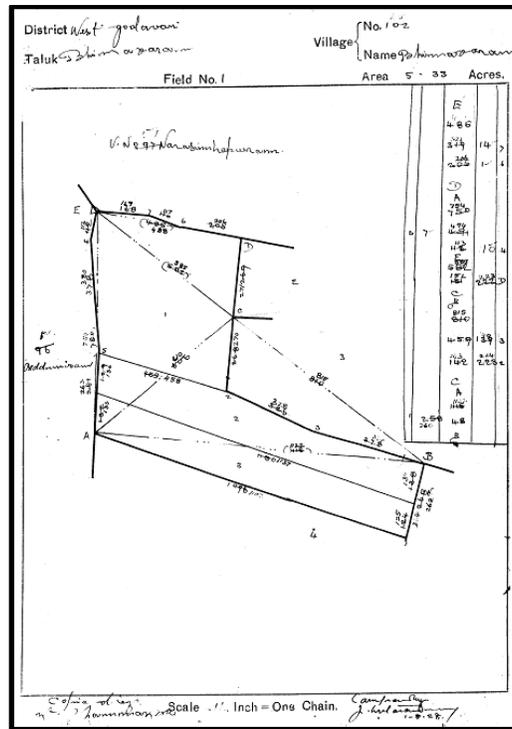
- Polygons, points, and lines are to be captured in different layers.
- The features such as wells, temples, trees, village tri-junctions etc. are to be digitized as point features. The features such as rivers and roads are to be digitized as line features
- The features such as parcel/khasra boundary, settlement boundary are to be digitized as polygon features
- Logical connectivity of the features is to be maintained i.e. a river would not join a road.
- Centre lines need not be digitized for the double line features / polygons.
- Each parcel polygon would have a unique Khasra/ survey number as provided in the village map
- Care is to be taken to maintain continuity of polygon and linear features

4.7 Updating subdivisions of parcel with FMB

The cadastre boundary in the village maps is quite old with many of the parcel boundaries are divided or merged which are not reflected in the village map. The subdivision of each parcel is recorded and updated in Field Measurement Book (FMB) by the revenue department and these are not updated in the cadaster. FMB describes the area of each parcel with the corresponding schematic diagram. The subdivision of each parcel is recorded and updated in FMB by the revenue department and these are not updated in the cadastre.

The dimensions of the subdivisions in the parcel available on the FMB can be used to update the village map so that they will better correspondence to actual land holdings on ground. It will be

improve the quality of spatial data as the attribute data is collected at individual holding level during field data collection under VIS project. However, this process requires collection of FMBs from Revenue Department and updating of digital village information with the measurement available.



FMB of sample Parcel/Khasra in a village

4.8 Updating Parcel boundaries using Satellite Imagery

Cadastral maps are indispensable tool for the administration in dealing with day to day revenue and development activities in the district. In most cases, these maps have lost their relevance since the maps are not updated over a long time. Updating the cadastral information is very essential so that transformation/changes of ownership, size etc., can be record in an orderly manner for documentation and further use. In many cases, the subdivisions of parcels are not properly reflected in revenue maps even in FMBs. High Resolution Satellite imagery will enable updating of parcel boundaries by tracing features like field boundaries. The satellite imagery and digitized village map is to be co-registered to update the property boundaries from satellite imagery.

It will be optimal, if the same GCPs used for georeferencing of village map can be applied for co-registering satellite imagery. Otherwise the features like roads, canals, railways, water body can be used for co-registering satellite imagery with village map.



Merged Product of Cartosat-2 and LISS IV (source: YVN Krishnamoorthy, S Srinivasa Rao, NRSC Hyderabad)

The digital village map created through vectorization will be overlaid on georeferenced satellite imagery in GIS environment to identify and digitize missing features like new field boundaries, roads.



Satellite Imagery Overlaid with Cadastral Information for updation (source: YVN Krishnamoorthy, S Srinivasa Rao, NRSC Hyderabad)

4.9 Edge Matching and Mosaicing

Mosaic of continuous villages is to be prepared to develop a single database for the group of villages. As village information system is generated from georeferenced village maps, they appear to be continuous in GIS software. However, the continuity of features like roads, rivers may be missing hence the process of edge matching is normally adopted to prepare mosaic of villages. The mosaicking of individual village layers can be carried out through following process.

1. The satellite image is displayed in the backdrop during the edge matching process.
2. The boundary feature that best fits the image is taken as reference.
3. The boundary feature that is under lapping or overlapping on the fitting feature is adjusted using the background image as the reference.
4. After edge matching, the duplicate boundary is eliminated to keep only one single boundary.

After the edge matching process the village maps are mosaiced into one single data layer. Another coverage containing only the village outer boundaries along with a label of the village code is created separately by extracting the outer boundaries of villages from the mosaiced cover to form the village map of the taluk/districts.

4.10 Digitisation of the Physical Features

Value addition to the base map prepared can be carried out to improve utility by adding various physical features like roads, canals on to the base maps. Some of the village maps already contain these features may require updation. The satellite imagery co-referenced with the village map will be used to digitize various physical features like roads, road, railway, drainage, pond/tanks, government buildings, religious structures like temples, church, mosque. These features will enable better verification of contents during field verification process.

4.11 Field Verification and Validation

A thorough field verification of the parcels boundaries is required to avoid missing or unidentified parcels in the base map. 100% verification of parcel boundaries in the field assisted with GPS receiver need to be carried out to identify and update the left over (parcels which could not be identified from satellite imagery) and unidentified parcels. This process will facilitates complete identification all the sub-divisions of the land which were not reflected in the village maps, land records. These parcels need to be numbered from 1001. For example, if a village has 20 sub-divisions in the field which are available in land records then they can be assigned identification numbers 1001 to 1020. After the field verification process, the base map will contain all the property polygons appearing on ground will be mapped and assigned an identification number.

4.12 Quality Assurance of Base Map

Field measurement of 5% of the parcels using Electronic Total Station/ GPS need to be carried out for quality assessment of parcel mapping. The agriculture field boundaries can be selected in random throughout village and have to be measured using Total Station/ GPS to calculate the length, perimeter and area of the fields/parcels. The same can be compared with their corresponding area in the updated base map to assess the quality of representation of geometric parameters of the land records. The GIS database will contain both the area information from land revenue records as well as GIS map.

4.13 Integration of Attribute Data

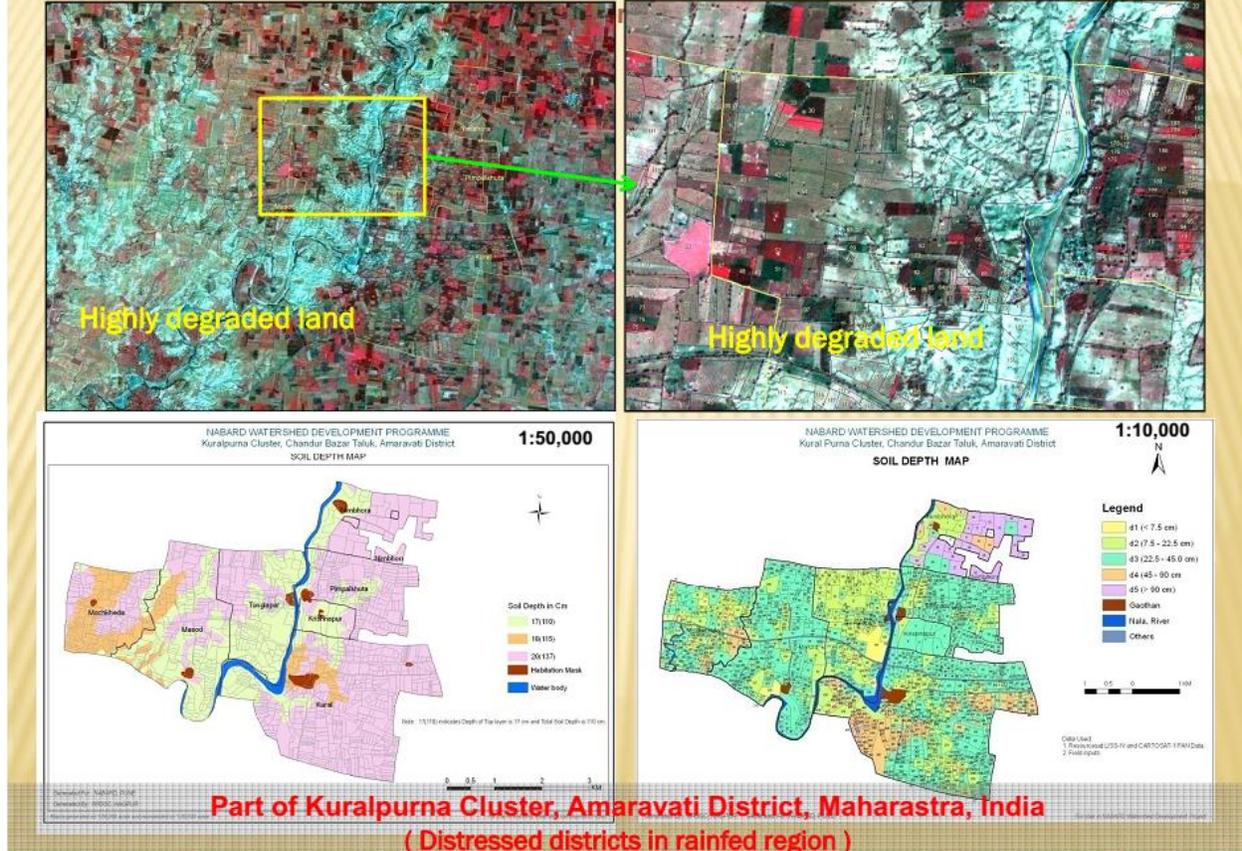
Any spatial database is an integration of spatial and attributes databases: Spatial data consists of thematic maps prepared from ground survey, remotely sensed (satellite / aerial) data, other collateral & legacy map data. The Attribute data consists of attribute data collected from field / site, natural resources, census, socio-economic characteristics.

Each feature in GIS database will be identified by a unique Identification which can be numeric or alphanumeric. Normally, Survey Number with subdivision numbers like 23/A may be used as unique id or any sequential number. All the attribute data related to the feature will be linked to spatial data through this unique id. The attribute data about the features will be as per standard documentation provided in the VIS project meeting.

4.14 Preparation of Thematic Maps from Satellite Imagery and Ground Survey

The base map (updated cadastral map of the village) prepared using above process can be used as a base layer for generating thematic maps like land use, drainage network, road network, soil characteristics, ground water resource. The resource maps available at small scale from other agencies like NRSC, SOI, GSI, and State Remote Sensing Applications Centre can be used as reference along with required ground data collection as specified in the VIS project meeting may be used to generate large scale cadastral level database of physical, economic and environmental resources of each village. The attributes for each resource can be added to GIS database for efficient use in local level planning.

Map of Soil Depth Updated using high resolution satellite data (CartoSat + IRS LISS IV) with georeferenced cadastral boundary overlay on 1: 10000



Source: Using Satellite Data to Secure Rights and Guide Land Use Planning in India Dr Y V N Krishna Murthy Dr. S. Srinivasa Rao, NRSC, Hyderabad, India

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