GIS based Land Information System using Cadastral model: A case study of Tirat and Chalbalpur rural region of Raniganj in Bardhaman district

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Abstract Cadastral is the method of registering land, designed to ensure the rights of individuals and the state of their property. Every activity in general, and developmental project activity in particular, is in some form or the other associated with land. Therefore, for planning purpose all land-associated information should be available in the form of a computer database, which can be easily accessed, manipulated by decision makers while formulating and executing a work. Such a database system is called Land information system. Cadastral applications will include cadastral index maps and land registration data in a digital format. Automation linkages will be created and developed between textual data (legal land registration data) and parcel maps. The final goal is to generate digital maps which will facilitate land management and planning and in particular land registration and the issuance of land titles in order to promote security of land tenure and reduce land disputes. Therefore land administration systems are not ‘just handling only geographic information’ as they represent a lawfully meaningful relationship amongst people, between people and land. As the land administration activity on the one hand deals with huge amounts of data, which moreover are of a very dynamic in nature, and on the other hand requires a continuous maintenance process, the role of information technology is of strategic importance. So the present study develops a case study of land information system using cadastral techniques of Tirat and Chalbalpur rural region of

Raniganj in Bardhaman district which contains cadastral information.

Keywords Mining · Cadastral · LIS · GIS · Land management

Introduction

A cadastral map is a map which provides detailed information about real property within a specific area. Real property is property in the form of land, what lies beneath the land, and objects fixed to the land. People have used a wide variety of approaches in not only the development of accurate cadastral maps (Jennifer and Kennedy 2011; Demir et al. 2003; Roco and Leslie 2004; Craig 2003) but also the uses of the developed cadastral maps for scientific investigation of various industrial problems (Chatterjee et al. 2008; Borowitzka et al. 1983). Development of cadastral maps using manual methods (Lillesand et al. 2003; Texas report 1983; Cook 1976) using oblique aerial images (Habbecke and Kobbelt 2009; Frueh et al. 2004) and with better registration techniques (Habbecke and Kobbelt 2009; Ding et al. 2008; Kopf et al. 2008; Fischler and Bolles 1981; Stilla et al. 2009) have been extensively used by the researchers globally. The principal responsibility of the assessor is to locate, inventory, and appraise all property within the jurisdiction. A complete set of maps is necessary to perform this function. Maps help determine the location of property, indicate the size and shape of each parcel and reveal geographic relationships that affect property value. Maps and map data are important not only for assessors, but also for other governmental agencies, the public at large, and the land information community (such as realtors, title companies, and surveyors). In addition, the assessor must track current ownership of all parcels,

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so that the proper party can receive assessment notices and tax bills.

Cadastral can also be labeled as a 'parcel-based GIS which according to statute/law records units of immobile property, their identifiers and attributes' (Stubkjaers 2006). GIS as a subset of information systems enables capturing, storing, checking, integrating, analysing and displaying data about the earth that is spatially referenced (Dale and McLaughlin 1988). It describes geo-spatially referenced objects including terrain objects (e.g. a stream) and man-made objects (e.g. a house). In case of cadastral system or a parcel-based GIS, objects include real property units. Cadastral provide the total assessment of land degradation recorded due to mining activity and its mitigation measures (Govind et al. 2013).

Objectives

- Paper maps are very difficult to store for a long time than digital maps, so digitization of Land Record (LR) sheets is the main objective.
- LR sheets do not have any coordinate system, so georeferencing is also another important objective.
- Incorporation of attribute data.
- Creation of Digital Land Record.

Study area

Raniganj Coalfield covering an area of about 1652 km² and bounded by Latitude 23°30' and 23°40'N, Longitude 87°00' and 87°10'E is located in the eastern part of India. It is covered under Survey of India toposheet no. 73M/2 on RF 1:50,000. This coalfield holds a premier position in India for having the largest share of reserve of superior grade non-coking coal and considered as the birthplace of coal mining in the country.

The area is included in the Tropical Monsoon climate zone. According to rainfall data from the meteorological department of the government of India and is characterized by

- Hot dry summer from March till the middle of June.
- Rainy season from middle of June to middle October.
- Cool dry winter from middle of October to February.

Figure 1 shows the location of the study area for this present work.

Materials and methods

Data

LISS-IV 2008 pertaining to the study area were used and it was verified by ground truthing and cadastral data from

survey building, Kolkata. Toposheet collected from survey of India.

Methodology

1. Collection of analogue cadastral village maps with sheet wise.
2. Scanning of those cadastral map.
3. Create various data layer such as road, pond, parcel etc.
4. Generate a database with Dag number and Bata number.
5. Then every digitize sheet are convert into sheet.
6. Checking for GIS conversion, attributes, null and duplicate errors.
7. Conversion of the digitized data into topologically correct GIS data format.

Here the cadastral map has given every parcel of land with Dag number and Bata number. This map fully digitize from cadastral sheet. In this process I also added attribute table. The process of digitization can be summarized in following steps:

Selecting the rectification method in the study

Aerial photographs must be geometrically corrected before they can be used in an on-screen vectorisation. The process of correcting and removing these displacements can be divided in two steps to correct the systematic distortion. Those produced by lens distortion, earth curvature, refraction and scanning; and rectification, to remove the effects of tilt and establish scale. Since the photographs were taken with a photogrammetric camera at a relatively low altitude and the scanning size was 42 µm without noticeable geometric distortions, we have considered the previously mentioned systematic distortions negligible. As part of the digital rectification process, the mathematical relationships between the map coordinate system and the scanned aerial photograph must be determined. These relationships can be modelled using one of several algorithms, each of them having advantages and disadvantages. What follows is a short description of some of them, including an analysis to select the one that can be achievable and that can fulfil our needs of accuracy and costs.

Polynomial-based algorithms

The most commonly used method that is based on the determination of polynomial coefficients for two transformation equations using a least squares adjustment over row and column. The polynomial transformation can be written below as

Fig. 1 Location map of the study area

$$r = \sum_{i=0}^n \sum_{j=0}^i a_k x^{i-j} y^j \quad (1)$$

$$c = \sum_{i=0}^n \sum_{j=0}^i b_k x^{i-j} y^j \quad (2)$$

$$k = \frac{i(i+1)}{2} + j \quad (3)$$

where, (x, y) = control point coordinates in the ground reference system (r, c) = control point coordinates in the

image reference system $a_k b_k$ = equation coefficients n = the order of the polynomial.

The above equation or method is most commonly implemented, although it is easy to realize even with a few control points, it does not take into account the geometry of aerial photograph and when the value of n is more than one it is not a planar transformation anymore.

The following (Fig. 2) shows the flow of activities for the present study.

Result and discussion

Cadastral application in ground level and verified with high regulation imagery

It is clear from Fig. 3 that the digital cadastre provides a platform for the detailed investigation of the related issues in connection with the area of study/interest. The associated attribute data also proves to be very much helpful in the analyses and implementation of different sustainable developmental plans to cadastral level (see Fig. 4). Table 1 provides the distribution of the different area-wise covers of eight LU/LC observed in the Tirat and Chalbalpur rural region of Raniganj. Figure 5 is the pictorial representation of the same area-wise distribution of the eight different LU/LC in the same location. These statistical information proves to be very much useful for any decision makers while planning the natural resource utilization in and around the area. The attribute data of this plot would serve as a check to understand the compliances with various environmental

and other norms set by the state/central government agencies.

Figures 6, 7, 8, 9 present one of the cases of the present study where starting from overlaying on the high resolution satellite imagery for spatial adjustment, building the attribute details over the high resolution satellite imagery for the whole of the cadastral area, generation of the final output cadastral map based on the satellite imagery comparisons and finally field/ground truthing of specific locations (here the pond). Once such activities are completed the generated cadastral map is ready to be utilized for any developmental decision making process.

Kinds of parcel identifiers

There are three basic forms of parcel identifiers in common use, as:

- Location.
- Name-related work.
- Alphanumeric work.

Fig. 2 Final framework of the study

Fig. 3 Scan copy (subset) cadastral sheet of the Tirat and Chalbalpur rural region of which contains cadastral information

For mapping systems, the primary identifier for assessment purposes should be a location identifier. Name-related and alphanumeric identifiers are frequently used as secondary identifiers and should be cross-indexed to the location identifier.

Location identifiers

A location identifier is one in which the parcel number provides the location of the parcel, examples include map-based identifier systems, geographic coordinate identifier systems etc. Assessors' Map Based Systems is a map-based system that is relatively simple and easy to use. Under this system, the assessment map itself is incorporated into the parcel identifiers. The parcel identifier consists of a map, block (or group), and parcel number such as 920, 310 etc., where Dag/Bata no represents the map on which the parcel is to be found. In the study area the boundary of rural and urban area of Raniganj, Bardhaman district have been shown that

indicates the block on the map and the name identifies the parcel in that block. Rural maps usually do not use the block designation. In some jurisdictions maps are bound in books. In such instances parcel identifiers may consist of map book, page, and parcel numbers. Maps based identifiers do, to some extent, refer to a geographic area and are convenient in the field. Problems may arise in this system where extensive development is occurring, requiring re-mapping and the assignment of new parcel identifiers. However, in stable areas, this system may be satisfactory.

The geographic location of the parcel can be determined from the parcel number alone. This system tends to be complex, and an understanding of coordinate systems is needed to fully utilize it. Once understood, the system is relatively simple to use and maintain. It also meets the criteria of uniqueness and permanence. This system lends itself to automated systems since computers can be programmed to prepare maps and assign parcel identifiers based on coordinates.

Fig. 4 Map showing parcel wise land used/land cover map and plot no in the study area. The details of the area marked by yellow box are provided below

Rectangular survey system of parcel numbering is based on the U.S. Public Land Survey System. The parcel identifiers based on the rectangular survey system are developed using the township, range, section, quarter-section and quarter-quarter-section numbers, along with individual

parcel identifiers that are assigned to each tract. This kind of identifier readily provides the geographic location of each parcel which is relatively easy to understand and maintain, and meets the criteria of uniqueness and permanence.

Table 1 Eight different land used/land cover classes with the respective areas observed in the Tirat and Chalbalpur rural region of Raniganj

Land used/land cover classes	Area (km ²)
Agricultural land-crop land	3.08
Built-up mining/industrial area	0.31
settlement	0.39
Tree clad area	0.56
Transportation	0.16
Waste land-scrub land open	0.02
Water bodies-lakes/ponds	0.15
Water bodies-river/stream	0.14

Name-related identifiers

In this research area, there are numbers given in the place of parcel owner names along with the dag no and bata no which can be used to identify the particular feature of the parcel. People can do some planning using the cadastral map techniques.

Reference to geographic location

A parcel identification system that is based on geographic location makes it possible to describe and locate a parcel using only the parcel identifier. Such a system simplifies the handling of property records.

The Fig. 4, used a replica of Tirat and Chalbalpur rural region of Raniganj in Bardhaman district which contains cadastral information. There are eight classifications in the figure, namely agricultural land-crop land, built-up mining/industrial area, settlement, tree clad area, transportation, wasteland-scrub land open, water bodies-lakes/ponds, and water bodies-river/stream.

wasteland-scrub land open, water bodies-lakes/ponds, and water bodies-river/stream. It can be seen from the figure that in this region agricultural land-crop land holds maximum 3.08 %, built-up mining/industrial area 0.31 %, settlement 0.39 %, tree clad area 0.56 %, transportation 0.16 %, wasteland-scrub and land open 0.02 % water bodies 0.15 % and river/stream minimum area covered is 0.14 % and finally a bar graph is used to represent the classification in a diagram.

Incorporation of attribute data

GIS data sets include not lonely spatial data (such as point, line, polygons) but also attribute data in tabular form. List of attributes that could be included in the table for a polygon data set of attribute data is defined as data that relates to a specific, precisely defined location. The data are often statistical but may be text, images or multi-media. These characteristics can be quantitative and qualitative in nature. Attribute data is often referred to as tabular data. Some examples of attribute data include, attitudes, opinions, occupation, gender, environmental parameters, soil parameters, groundwater details, mining parameters etc. In the present study both spatial data and attribute data have been incorporated for further use and have been explained below.

Spatial data

Special data contain the coordinates and identifying information for various map features. These types of features can be represented in the map, viz., point, line and areas/polygons etc. The various physical aspects of the map, viz., political boundaries, roads, waterways, and so

Fig. 5 Bar graph showing area-wise distribution of eight different land use/land cover classes

Fig. 6 Map after spatial adjustment in one of the selected research area (yellow box) over the satellite imagery

Fig. 7 Map with spatial adjustment having Dag/Bata No in the selected (yellow box) research area, overlaid on the satellite imagery

Fig. 8 Composite cadastral map in the selected (gray box) research area, Raniganj showing the adjusted spatial features after proper extraction from the satellite imagery

Fig. 9 Real field location of the selected study area shown in boxes depicting the presence of pond in the same place, Raniganj

forth are organized into different layers according to their common features.

Thematic layer can use different graphical attributes to classify the features in the layer. For example a thematic area layer representing sales regions could use

different colors to show the quarterly mining output or re-vegetation parameters of each region. A thematic line layer representing highways could use different line widths to show the classes of roads available in the cadastre.

Attribute data

The second type of data used in a GIS is attribute data associated with any particular land area. Data views can be associated with the map through links to the spatial data. For instance the spatial data might represent a county and contain information for city boundaries, census tract boundaries, streets, and so forth. An attribute data set with population information for each census tract can be linked to a map by the corresponding tract value in the spatial data using variables from the attribute data as themes for layers. For example an attribute data set containing population data could provide a theme for a map of census tracts creating actions that display or manipulate the attribute data when features are selected in the map. The action can range from simple, such as displaying observations using a attribute data set that relate to features in the map, to complex such as submitting tasks for GIS software to perform statistical analyses of the patterns/trends.

Accuracy checking techniques

In the present study area, several visits were made to many interior areas of Raniganj and finally accuracy of data sets was checked in three steps given below:

- First step involves comparison of geo-coordinates (of randomly selected points) generated by computer with those of actually observed ones obtained using GPS.
- Second step involves comparison of length measurement (of tie lines) generated by computer with that of actual field measurement.
- Third step involves comparison of boundary measurements (of randomly selected parcels) generated from image data set with that of actual field measurements.

Tie line measurement

The district is covered by alluvium so it is very difficult to measure the tie lines. For the present study seven tie lines were selected. The lengths of the tie lines were measured from the images and its corresponding field measurement was recorded using GPS observations (Table 2).

Parcel boundary measurement

In this study area randomly selected in this study of the parcel boundary measurement. Four sides of these plots were measured on the ground using meter-tape. The corresponding measurements were extracted from the images also.

This map generated using remote sensing was overlaid in GIS with the parcel boundaries map, show that parcel-

wise data are matching in the satellite images. This information may prove useful to a planner who can assess various statistical models for planning purposes using above the geo spatial techniques (Mondal et al. 2015).

Geospatial aspects of cadastral sheets and their use in scientific investigation

Cadastral is the method of registering land, designed to ensure the rights of individuals and the state of their property. Cadastre is important as it provides hidden, submitted and followed variations continuously with lots of basic data which follow the provisions of law, economy, social life, statistics and science. Submitted as information systems with basic spatial and non-spatial information that cadastre and land organization produces them.

To make maximum use of data on land parcels, in a manual or digital mapping environment, it is necessary for jurisdictions to develop a multipurpose cadastre. A multipurpose cadastre furnishes a framework to record, store, and provide comprehensive land information at the parcel level, and makes it possible to share parcel data among all users of the data.

Conclusion

In case of any natural disaster, either due to human activities or industrial activities, the problems of accessibility also needs to be resolved for avoiding risky situations. In the absence of formal cadastral layout design for the area, there has not been commitment to proper sustainable development and control on the part of government agencies. The new layout design in this study cuts across many buildings; hence significant demolitions in the affected plots would be required to upgrade the area. It could be generated in the area for the full benefit of land revenue from taxation using the LIS.

The new layout design in this study cut across many buildings; hence significant demolitions in the affected plots would be required to upgrade the area. It could be generated in the area with the full benefit of land revenue from taxation using the Land Information Systems. It is clear that different villages of Raniganj in Bardhaman district are moderate to highly vulnerable in respect of their socio-economic conditions as disclosed on the basis of an weighted average matrix developed after analyzing the variables critical for socio-economic studies such as income, education, health, water resource, transport. The study aimed at GIS techniques for Cadastral application include cadastral index maps and land registration data in a digital format. Automation linkages should be create and developed between textual data (legal land registration

Table 2 Tie-line measurements using image-based approach and GPS observations

Sl. no	Line no.	Length measured from image (m)	Length measured from field using GPS (m)
1	1	820.40104	820.40110
2	2	232.8120	232.8122
3	3	427.5132	427.5140
4	4	256.33255	256.33260
5	5	934.35220	934.35224
6	6	527.26533	527.26536
7	7	783.47449	783.47451

data) and parcel maps. The final goal is to generate digital maps which will facilitate land planning, management and also parcel information system.

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