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# Constructing a seamless digital cadastral database using colonial cadastral maps and VHR imagery – an Indian perspective

A. Sengupta<sup>\*1,2</sup>, C. Lemmen<sup>1,3</sup>, W. Devos<sup>2</sup>, D. Bandyopadhyay<sup>1</sup> and A. van der Veen<sup>1</sup>

A Land Administration System (LAS) with its cadastral component is the infrastructure that facilitates the implementation of land policies to attain sustainable development. Therefore, the availability of a digital, up-to-date and easily accessible cadastral database has become a primary requirement for undertaking efficient land administration and/or spatial planning decisions for any country. In this paper, the authors demonstrate a method for constructing a seamless digital cadastral database (DCDB) based on colonial cadastral maps using Geographic Information System (GIS) and image interpretation techniques for an area of about 326 km<sup>2</sup>. Geo-Eye1 (pan-sharpened) data were used for this purpose in combination with limited on-site survey. The proposed approach could be considered as an alternative to a complete cadastral resurvey. It is important to mention here that the quality of these colonial maps is quite high and can be proven as a basis for spatial planning. A cadastral resurvey may be required in the future where there is an urgent need for higher accuracy, but the approach would be time consuming and potentially bring unrest in villages and urban neighbourhoods. Hence, an alternative is, therefore, to respect the contents of the existing maps and records combined with a quality upgrade: make the existing records and maps up-to-date as a basis for a spatial planning.

**Keywords:** Land Administration System, Cadastral maps, Digital cadastral database, GIS, India

## Introduction

A cadastre is one of the basic building blocks for any Land Administration System (LAS). Williamson *et al.* (2010) describe 'land administration as the process run by the government using public or private sector agencies related to land tenure, land value, land use and land development'. In their view, LAS is an infrastructure for the implementation of land policies and land management strategies in support of sustainable development. The infrastructure includes institutional arrangements, legal framework, processes, standards, land information, management and dissemination of systems, and technologies required to support allocation, land markets, valuation, control of use and developments of interests in land. Williamson *et al.* (2010) further explain the range of systems and processes related to land tenure, land value, land use and development. It should be noted that LADM (ISO 19152) defined land admin-

istration (clause 4.1.10) as the process of determining, recording and disseminating information about the relationship between people and land.

The concept of cadastre is difficult to identify, as it is designed in many different ways, depending on the origin, history and the cultural development of the country. Conventionally, cadastre (i.e. cadastral map) together with registers (i.e. land records) containing the details of the parcels, like ownership, type of land use, its value and size, etc. are used either for taxation (as was the original reason for establishing many European cadastres) or to ensure security of the property to its owner (as was the case in Australia). Today most cadastral registers around the world are linked with both land valuation/taxation and the recording of legal rights in land. As a result, the paradigm has shifted to the concept of a 'cadastral system' rather than a 'cadastre'. Such a system includes the interaction between the identification of land parcels, the registration of land rights, the valuation and taxation of land and property, and the present and future uses of land as well (Enemark 2006). However, because of the rapid growth of the world's population and economic globalisation, the value of land is changing fast, thereby the security of land property rights can no longer be guaranteed by the traditional, paper-based, cadastral systems.

<sup>1</sup>University of Twente, Faculty of Geo-information Science and Earth Observation (ITC), PO Box 217, 7500 AE Enschede, The Netherlands

<sup>2</sup>Joint Research Centre, European Commission, Via E. Fermi, Ispra 21027 (VA), Italy

<sup>3</sup>Kadaster International, PO Box 9046, 7300 GH Apeldoorn, The Netherlands

\*Corresponding author, email a.sengupta@utwente.nl

Cadastral maps and related land records must reflect the changes in the framework arising from development and its effect on land use. This means that the land administration is of a dynamic nature as it depicts the people–land relationship. In such a way, mapping of the land parcels is a continuous job as it must be constantly updated to keep pace with the subdivision, consolidation or mutation of land boundaries. Hence, updating is considered as one of the essential activities in the LAS (Jing *et al.* 2013). In this regard, many developed and developing countries put effort to create so-called Digital Cadastral Databases (DCDBs). During mid-70s, such effort was first made in USA closely followed by UK and other western European countries. Later, Australia, New Zealand, Malaysia, and Singapore have also made effort to create such DCDBs (Habibullah and Ahuja 2005). The European Union Member States have developed DCDBs in accordance to the spatial data infrastructure (SDI) of the country. At the moment, about 50 countries have such LAS (Van der Molen 2003). In this regard, a number of examples representing different countries can be found in the literature showing where the existing maps were used to upgrade or to build initial DCDBs (Lemmen *et al.* 2009; Christodoulou 2003; Kansu and Sezgin 2006; Ondulo and Kalande 2006; Palm 2006; Paudyal and Subedi 2005; Tuladhar 2005).

India has remained away from such developments and is yet to reach a position of competence (Habibullah and Ahuja 2005). The existing LAS of the country is a British legacy considering the village as an administrative unit. Since independence, a few exceptions apart, no significant efforts have been made to revise or to update these colonial cadastral maps and registers. As a result, the colonial cadastral maps and land records available today are mostly outdated and do not always reflect the realities on the ground either in relation to ownership or plot boundaries. Nevertheless, updating of those maps on paper and related registers is anticipated to be very cumbersome for several reasons. First, in the conventional set-up that prevails in India, cadastral maps and land records are maintained separately in different organisations. In this case, updating of plot boundaries changed by mutation and modification of other title information, takes a long time. Second, the cadastral maps used to be plotted on low-quality paper or cloth thus are subject to various kinds of degrading factors. Hence, in most cases, maps are in poor physical condition and torn because of lack of timely substitution. Finally, the maintenance of an infrastructure to continue with this earlier practice also involves an extremely high cost. All these factors together reinforce the case for a digital (seamless) cadastral database with up-to-date information for India.

During the late 1990s, a pilot project was carried out in the states of Andhra Pradesh, Bihar, Kerala, Orissa and West Bengal for the digitisation of paper-based cadastral maps. However, the project experienced several problems because of the varying size and the quality of maps available, the absence of standards on accuracy to be maintained in digitisation, quality of equipment to be used and the amount of cost involved. More recently, the Department of Land Records (DoLR) under the Ministry of Rural Development,

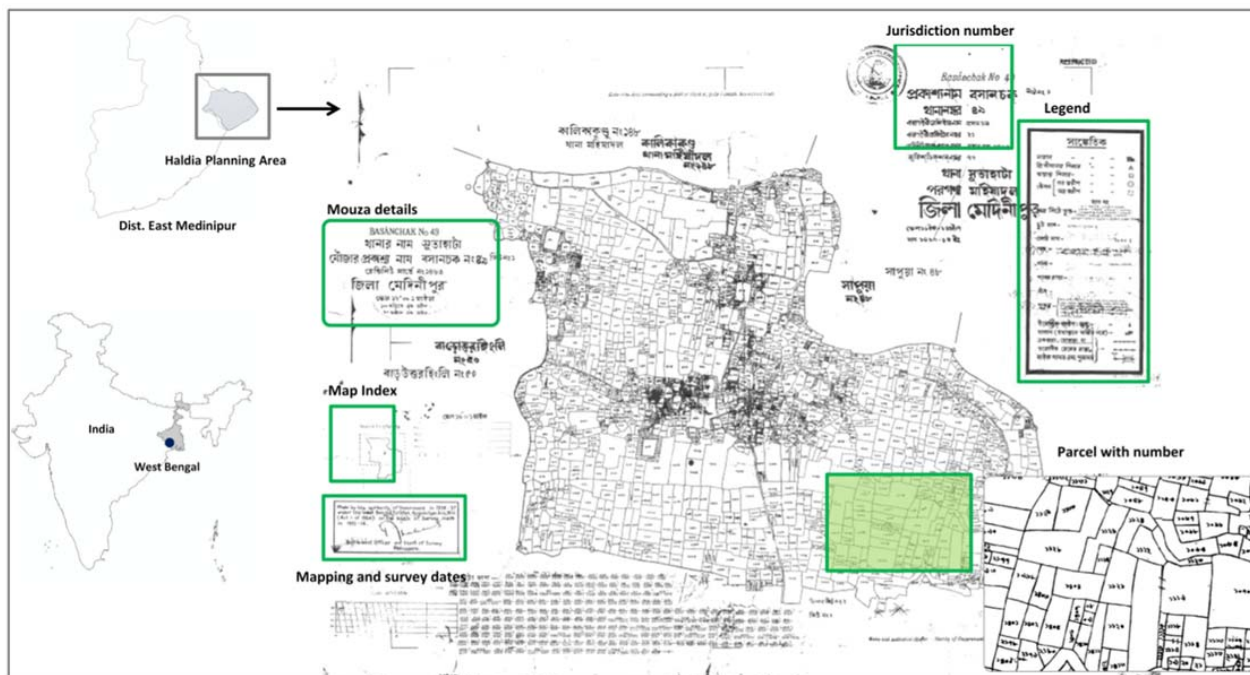
Government of India has taken an initiative called the ‘National Land Records Modernization Programme (NLRMP)’ for the modernisation of land records system across the country (NLRMP Guidelines 2008–2009). Major components of this programme comprise the computerisation of all land records including mutations, digitisation of maps and integration of textual and spatial data, survey/resurvey and updating the records, generation of original cadastral records wherever necessary, computerisation of registration and its integration with the land records maintenance system, with the aim to develop a comprehensive and transparent GIS (Geographic Information System) based land-title system. However, so far, application of this guideline using VHR imagery has not been carried out over a large area. In addition, certain discrepancies pertaining to the digitisation of scanned maps were also observed.

Different methods can be used to update the quality of attributes and spatial data. Public inspections or field checks with the participation of the community may be used to find the existing owners after inheritance, marriage, transactions, prescription, expropriations, recognised claims by courts or other ways of acquiring lands. The accuracy of the maps can be improved by renovation methods, see Salzmänn (1996), Salzmänn *et al.* (1997), Song (2008) and Kumar (2006). Lemmen and Zevenbergen (2010) provide reference experiences and references on the use of satellite images for first cadastral data acquisition. Resurvey is another method, but this is expensive and time consuming. In this paper, the authors present ‘an improved concept of map representation’, or ‘an innovative concept of map improvement’ based on satellite images.

Subsequently, the objective of this research is to demonstrate a methodology to construct a DCDB for an extended area using GIS tools and limited GPS survey. The work presented here represents a part of the broad research framework where the usability of these colonial cadastral maps as an acceptable basis for spatial planning is investigated (Sengupta *et al.* 2012, 2013). In particular, the present research focuses only on the ‘spatial’ aspects of the conversion of colonial cadastral maps to create a seamless DCDB based on the satellite imagery. In the following sections, the case study area is introduced in Study area section; description of the data and method used mentioned in Methodology section; results and level of accuracy achieved revealed in Results and accuracy assessment section; and finally, the conclusion and recommendations in Conclusion and recommendation section.

## Study area

The present research work was carried out in the state of West Bengal, located in the eastern part of India (Fig. 1). The state has a fairly long history of cadastral mapping, which was initiated in 1888 and then steered through different phases. In West Bengal, the unit of survey for cadastral mapping and land records is a mouza (i.e. revenue village). Following the survey principle of ‘from whole to part’, the boundary of the mouza under survey was first subjected to theodolite traverse, and then, ground details were surveyed and plotted by using plane table or chain survey. To achieve homogeneous accuracy in cadastral mapping, a uniform



1 Location of Haldia, West Bengal, with example of colonial cadastral map available

method of survey and scale of mapping was followed for the entire state.

Owing to the high population density (1028 persons/km<sup>2</sup> as per 2011 Census), the average land holdings size of the state is among the lowest in the world, about 1 acre\* per person. Moreover, the state has witnessed several land reforms in the postindependence era, hence rapid fragmentation of the land parcels. Keeping all this in mind, the authors tested the proposed approach in one of the medium-sized towns of West Bengal.

Haldia, located at the southern tip of the state, with a population density of 620 persons/km<sup>2</sup> as per 2011 Census, was selected as the study area for this research. During the last few decades, the town has emerged as one of the major petrochemical industrial hubs of India, and as a consequence experiencing radical change in land use pattern. Moreover, being located in the lower deltaic region, the area is also subject to river dynamics, changes in the courses of natural canals, etc. and which eventually result in changing the plot boundary (locally known as ‘aal’).

The planning area as demarcated by the Development Authority† including 258 mouzas (i.e. rural area) and 26 municipal wards (i.e. urban area) covering an area of 327 km<sup>2</sup> is represented in a total of 310 analogue cadastral maps or sheets. It is important to mention here that many of these maps were prepared in mid-1950s and were later updated in different time periods. A

\* 1 acre = 4046.86 m<sup>2</sup> = 0.404686 hectare.

† Development Authority is a statutory authority constituted under the West Bengal Town and Country (Planning and Development) Act, 1979.

detailed history of the survey conducted for the area and mapping accordingly is presented in Table 1. Each of such maps at a scale of 1:3960 graphically depicts the individual plots (locally known as ‘dag’) with respective plot number. An example of the cadastral map available for the area is shown in Fig. 1.

### Methodology

The proposed methodology to construct a seamless digital cadastral map (database) DCDB using VHR‡ imagery was formulated by adapting the technical manual of the NLRMP mission in accordance with the geodetic framework of India. Therefore, the dataset could easily be integrated with the other spatial datasets. For this purpose, Geo-Eye1 (pan-sharpened) imagery with 0.45 m pixel size, and 310 colonial paper-based cadastral sheets were used with limited on-site survey carried out in early 2012. In addition, other maps including topographic maps (sheet nos. 79B/4 and 78N/16) and a planning area map provided by the Development Authority were used for ground verification. The methodology is summarised in the following sections.

### Image processing

For the entire area, the Geo-Eye1 image was received in 18 scenes with different spectral and spatial bands. Using image processing software, resolutions of the Panchromatic (PAN) and Multi-spectral (MS) bands for each scene were merged to combine spectral and spatial

‡ Very high resolution.

Table 1 History of cadastral maps of Haldia planning area

	Surveyed in			Mapped in	Revised in		
	1913–14	1915–16	1933–34	1954–57	1979–91	1980–95	1996–2000
No. of sheets	70	18	158	258	2	4	2





2 Selection of ground control points (GCPs) from image features (L) and by edge matching (R)

quality into a pan-sharpened image. Later, these 18 different pan-sharpened scenes were mosaicked using an UTM Projection with WGS-84 ellipsoid as per the NUIS (i.e. National Urban Information System) standards provided by the Town and Country Planning Organization (TCPO), Government of India<sup>5</sup>.

### Collection and preprocessing of paper-based cadastral maps

Paper-based cadastral maps (also known as mouza maps) of the area were collected from the local District Land and Land Reforms (DLRS) office. In order to make use of these maps to create a DCDB, it was the first requirement to convert those analogue maps into a digital format (i.e. raster format). Accordingly, paper-based mouza maps were scanned at 300 dpi resolution and saved in TIFF format, which were then converted to vector format. However, a few mouza maps were readily obtained in scanned format from the DLRS office.

### Georeferencing and vectorisation of scanned cadastral maps

Georeferencing or geocoding is the process of assigning geographical coordinates (e.g. latitude and longitude) of known locations to the corresponding positions on the raster map. In the process of georeferencing, the raster datasets convert from one coordinate system to another using a transformation function. In this research, the scanned cadastral maps were georeferenced with respect to the Geo-Eye1 pan-sharpened imagery. An affine or polynomial first-order transformation parameter was used for this purpose as the area is mostly flat land with little undulation. For each map, 10–15 points identified both on satellite imagery and scanned cadastral maps were used as ‘ground control points (GCPs)’ to define the coordinate location. In addition, few GCPs were also taken along the map boundary by matching the edge of the individual mouza, thus to set the adjacent mouza accurately (Fig. 2).

However, these geocoded raster maps do not have any spatial component in them, and hence are incapable of supporting further spatial analysis. It was therefore required to convert these raster maps into vector format. The process of transforming the raster map into vector map is called vectorisation. Here, georectified scanned cadastral maps were vectorised or digitised on-screen in a GIS platform. In doing so, first the boundary of each mouza map was digitised in a polygon layer with respect to its neighbouring mouza map. Taking the adjusted boundary layer as the base, individual parcels or plots within each mouza map were then digitised as separate polygon layer. Subsequently, all the individual parcel layers were merged to make a seamless parcel layer covering the entire area. Then, topology was built for the layer to check for any gaps in between the parcels or overlaps between parcels.

### Results and accuracy assessment

Following the methodology mentioned in the previous section, a seamless DCDB was prepared for the entire Haldia planning area. Figure 3 shows the different steps involved in the preparation of the DCDB.

For any spatial dataset, accuracy defined as ‘fit for purpose’, is one of the prime requirements from a user-perspective (Enemark 2012). Accordingly, the accuracy of the DCDB prepared was evaluated from certain aspects as described in the following section.

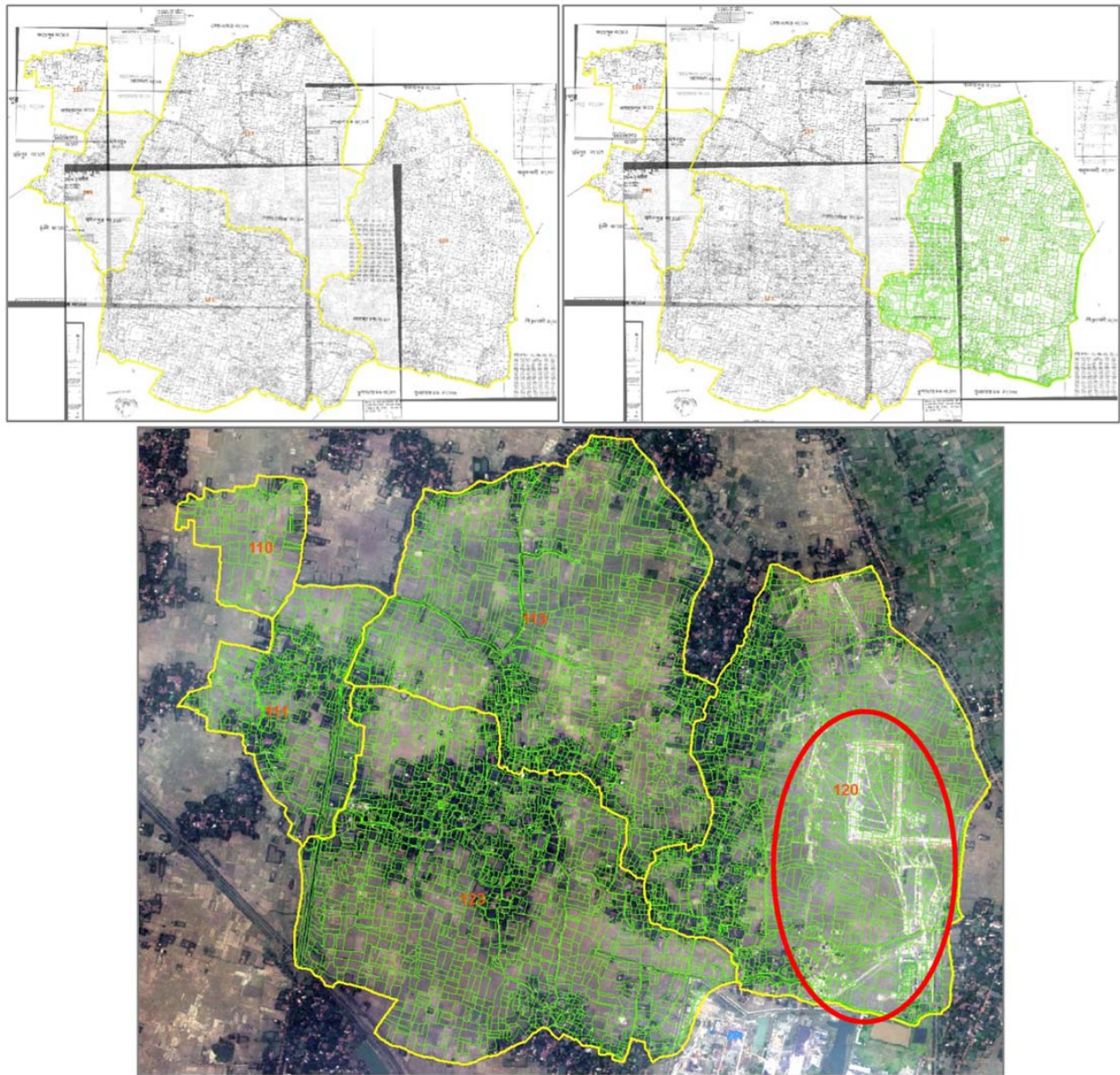
#### Positional accuracy assessment

Positional accuracy is one of the important parameters to determine the geometric quality of a digital dataset (Positional Accuracy Handbook 1999). It is the coordinate difference between true and represented position of a particular point with respect to a particular reference system (Shi 1994; Caspray and Scheuring 1993). Thus, the accuracy in the position of a set of features can be expressed in terms of RMSE (i.e. root mean square error).

In principle, an RMSE of a digital dataset close to 0 is considered as a perfect transformation. Nevertheless,

<sup>5</sup> Refer to: [http://top.cg.gov.in/nuis/Design\\_Standards.pdf](http://top.cg.gov.in/nuis/Design_Standards.pdf)





3 Digitisation of individual parcel from georectified cadastral map (above); overlaying digitised parcel layer on VHR satellite image to update same (below) Note: A significant change in parcel boundary as well as land use pattern can be observed in the area under the red circle as highlighted in the figure

sometimes that is not the case, as the positional accuracy of any digital datasets depends on the quality of the original image (in this case analogue cadastral maps used), in combination with any errors accumulated from the survey, the mapping and also through the scanning process (Caspray and Scheuring 1993). Ghosh and Dubey (2009) has reported that the acceptable limit of RMSE for a digital dataset at a scale of 1 : 10 000 should be 4.38 m as a combination of the square root of plotting accuracy (0.25 mm), the accuracy while georeferencing (0.25 mm) and the digitising accuracy (0.3 mm).

In this research, the RMSEs of georectified mouza maps were calculated using a polynomial first-order transformation parameter. In more than 80% cases, the level of RMSE achieved was within the acceptable limit (Table 2). Nonetheless, to justify the level of RMSEs achieved for individual maps through this exercise, the authors also applied the second-order transformation function to those sheets with a higher level of RMSE

obtained from the use of a first-order transformation. A comparison of the level of RMSEs achieved in both orders is presented in Table 3.

### Ground control point selection for georeferencing

Scanned analogue mouza maps were georeferenced with respect to the Geo-Eye1 imagery using 10–15 GCPs. Nevertheless, poor choice of GCPs may also contribute

Table 2 Number of sheets with level of root mean square error (RMSE) achieved

Range of RMSE/m	No. of sheets
Less than 2.00	7
2.01–3.00	64
3.01–4.00	185
4.01–5.00	47
More than 5.01	7



4 Gaps and overlaps in adjoining mouza boundaries (mapping or plotting error)

error to the georeferencing process. Sometimes it turned out to be difficult to ascertain the location of the identical points from the paper-based cadastral maps and that from the image, for example, if there is a horizontal shift in the plot boundaries. These disturbances could have been created either by natural events like flood, cloud cover\*\*, ground vegetation or man-made reasons.

#### Validation of georeferencing

In order to validate the georeferencing process, it requires further investigation. For this purpose, the coordinates of the identical points on the georectified cadastral maps must be compared with the original coordinates of those points. However, because of the security and confidentiality issues associated with the sharing of the original coordinates of those GCPs, it was not possible to perform the validation exercise, and therefore to access the quality of the original cadastral maps.

#### Area calculation and error analysis

Error analysis of a spatial dataset is one of the key issues in GIS research. In land administration, the cadastral parcel is the basic object. According to the feature classifications in GIS, a cadastral parcel belongs to one kind of closed polygon objects. However, in cadastral parcel digitisation for capturing data, it is unavoidable to have some errors (including surveying, mapping and digitising error), and as a result, with the propagation of errors, the digitised parcel area is not equal to the authorised area (i.e. true area). Therefore, it is one of the major problems to minimise the effects of such errors to

\*\* In principle, cloud coverage should be avoided by making a composition of images from different dates. However, for this research, it was not possible.

Table 3 Comparison of root mean square error (RMSE) using first- and second-order transformations

Sample No.	Level of RMSE/m	
	First order	Second order
1	3.668	3.177
2	3.171	2.510
3	3.962	1.339
4	4.089	3.096
5	5.010	2.889

ensure the precision of the area attribute in the GIS database.

#### Problems related to mouza boundary demarcation

The paper-based cadastral maps used in this research, are mostly from pre-1920s surveys and 1950s mapping (Table 1). Customarily, these maps were prepared manually as individual maps following a systematic mapping system. In many cases, it has been found that the boundaries of adjacent mouzas do not fit each other precisely, either they overlap each other or leave a gap in between them (Fig. 4). In addition, depending on the size and shape, one single mouza is sometimes subdivided in a number of separate sheets. In such cases, the division among these individual sheets is often not clear (Fig. 5).

Apart from this, often a canal is used to delineate the adjacent mouza boundaries. In such cases, this canal, is usually represented on both mouza sheets (Fig. 6), increasing the possibility for adding the same area twice for individual mouza area calculations. Another important issue to mention, in a few cases, a discontinuation of this bordering canal has also been observed.

Such errors in the geometry of the analogue maps leads to a subsequent lack of accuracy while using these as the base for the preparation of a seamless digital cadastral map; hence, it was required to resolve these errors before area calculations. For example, gaps and overlaps between the original paper-maps were eliminated by matching the edge of the two, or in exceptional cases three or four, neighbour maps. It is important to mention here that special care was taken for small parcels along the boundary while doing the edge matching. On the other hand, in the case of a common canal, the boundary was digitised by following the middle of the canal. However, these cartographic adjustments in the boundary resulted in altering the area of the individual mouza. In order to assess how much of the area of an individual mouza was distorted because of this adjustment, areas compiled from official records (DLRS) were compared with the digitised area. A few examples are shown in Table 4.

Table 4 shows that the differences (positive or negative) between the legal area and digitised area were negligible. As mentioned earlier, these differences mostly occurred either because of canal as a common boundary, or of the overlaps and/or gaps existing between the adjacent map boundaries. Exceptionally, in a few





5 Unclear division between two adjoining sheets

instances, where original areas either slipped into the river or a new area was added to the original mouza area because of rapid change in river dynamics (Fig. 7), a significant difference has been observed.

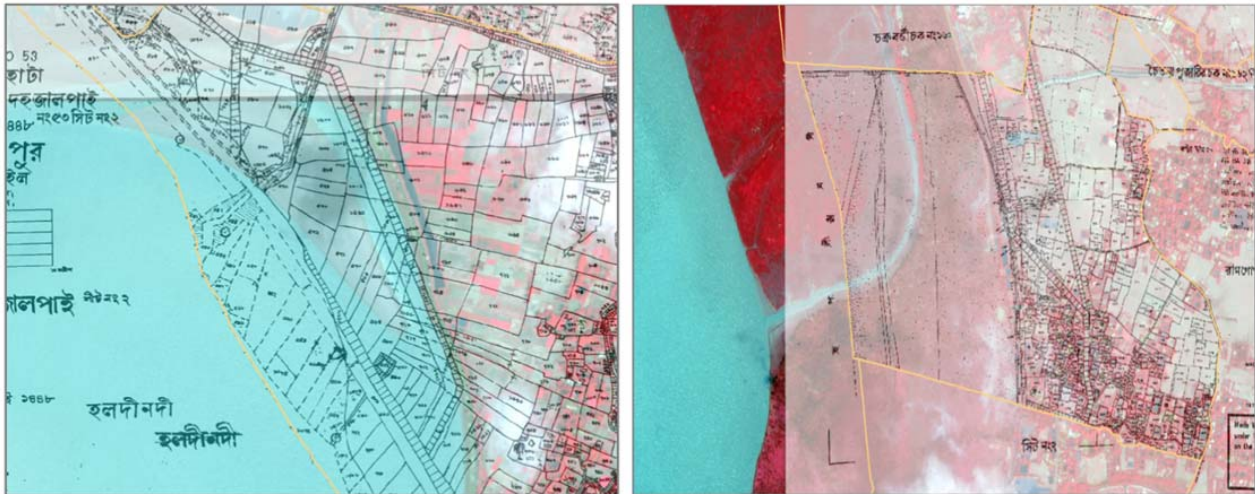
The above mentioned cartographic adjustment or harmonisation at mouza boundaries also changed the area of the parcels within the mouza. Accordingly, the area of each individual parcel was compared with the official record (as shown in Table 5). It is important

to mention that these traditional analogue maps do not represent the area of individual parcel as measured with a planimetric survey. Conventionally, the area of these individual parcels used to be calculated from the map itself, hence depending on the accuracy achieved in the process of surveying and plotting or mapping (Habibullah and Ahuja 2005). On the contrary, in case of a digital cadastral map, the area precision of an individual parcel depends on the positional accuracy of the map. In order to



6 Actual mouza boundary including canal (L): part of canal common for both mouzas (R)





7 Area of original mouza slipped into river (L): new area added to the original area (R)

clarify the issue about how the area of a particular mouza and thereby its parcel may change with respect to the first- and second-order transformation functions used were also compared with official records. A few examples from one mouza (i.e. sample no. 5 in Table 3) are shown in Table 6. Fig. 8 is graphically showing the distribution of number of plots with corresponding area difference.

Another important issue for parcel area calculation is the inconsistency with the land records or registry and the paper-based maps.

#### Errors transferred from input (mouza maps) used

In addition, other types of errors also result from the paper-based cadastral map itself. These cadastral maps used to be plotted on a low-quality paper or cloth, which are subject to various degrading factors like paper shrinkage, wrinkling or folding and tear, etc. over time. The scanning of such maps therefore can also contribute to error. Examples of scanning and archiving errors are shown in Fig. 9. Furthermore, the 'map lines' in the

analogue cadastre are themselves crude and the scanned version of the line is often more than 4–5 pixels wide

Table 5 Example of parcel area calculation (in acre)

J.L. no.	Parcel no.	DLRS record	Calculated area	Difference
165	43	5.42	5.50	-0.08
165	44	0.16	0.18	-0.02
165	45	0.27	0.28	-0.01
165	46	0.07	0.07	0.00
165	47	0.04	0.04	0.00
165	49	0.12	0.11	0.01
165	51	0.1	0.10	0.00
165	52	0.01	0.02	-0.01
165	53	0.02	0.03	-0.01
165	54	0.02	0.03	-0.01
165	55	0.07	0.06	0.01
165	56	0.12	0.12	0.00

District Land and Land Reforms.

Table 4 A few examples of individual mouza area calculation (in hectares<sup>1</sup>)

J.L. No. <sup>2</sup>	DLRS record	Adjusted boundary	Accurate boundary <sup>3</sup>	Difference <sup>4</sup>	%	Difference <sup>5</sup>	%
9	92.31	93.71	93.99	-1.68	-1.82	-1.40	-1.52
10	55.36	55.43	56.12	-0.76	-1.37	-0.07	-0.12
13	189.70	191.54	191.58	-1.88	-0.99	-1.84	-0.97
14	161.67	160.39	161.13	0.54	0.33	1.28	0.79
15	13.96	13.98	14.03	-0.07	-0.50	-0.02	-0.18
16	49.55	49.97	50.37	-0.82	-1.66	-0.42	-0.85
17	25.68	25.09	25.49	0.19	0.73	0.59	2.28
18	131.11	132.58	133.13	-2.02	-1.54	-1.47	-1.12
19	43.53	43.67	43.76	-0.23	-0.52	-0.14	-0.32
20	48.09	49.16	49.16	-1.07	-2.23	-1.07	-2.23
21	32.06	32.36	32.42	-0.36	-1.11	-0.30	-0.94
22	93.54	94.70	95.31	-1.77	-1.89	-1.16	-1.24
23	28.93	29.17	29.32	-0.39	-1.36	-0.24	-0.82
24	86.97	87.64	87.47	-0.50	-0.57	-0.67	-0.77

<sup>1</sup>1 Hectare = 2.47105 Acre = 10 000 m<sup>2</sup>.

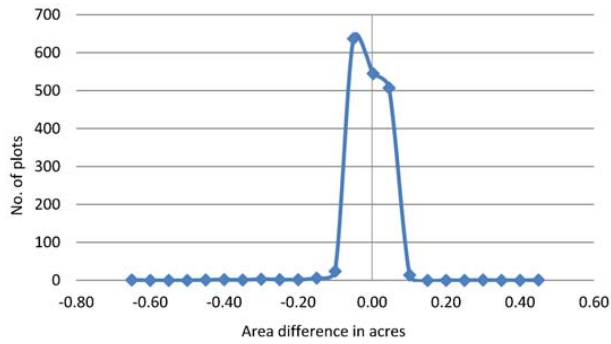
<sup>2</sup>Village identification number as per DLRS record.

<sup>3</sup>Digitised as shown on the scanned maps without doing any cartographic adjustment.

<sup>4</sup>Difference between official record and digitised accurate mouza boundary.

<sup>5</sup>Difference between digitised adjusted mouza boundary and official record.

DLRS: District Land and Land Reforms.



8 Distribution of number of parcels in range of area difference

(Fig. 10) because of which uncertainties are bound to arise in the process of digitising those lines on-screen.

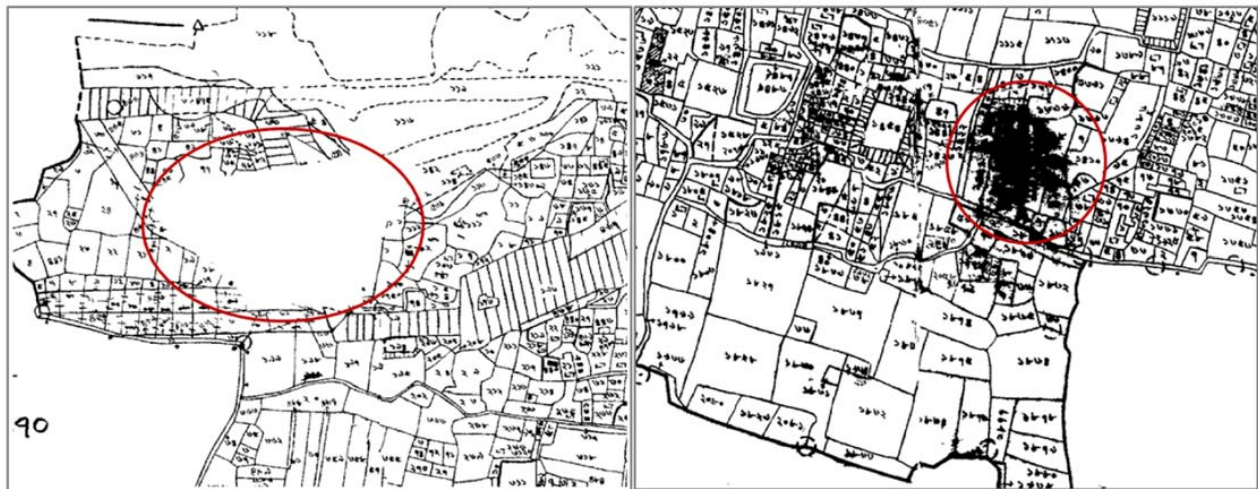
**Errors because of changes in coordinate reference system**

Many of the cadastral maps available today in India do not conform to any conventional known map projection. Conventionally, the casini-soldner projection with the Everest-1830 ellipsoid was used for cadastral mapping in the eastern states of India, including the state of West Bengal. However, this projection neither represents correct shapes nor the correct areas because of scale distortion (Nagarajan 2001). Following the Indian National Mapping Policy (2005) in this research

work, UTM projection with the WGS-1984 ellipsoid was used. Therefore, it is anticipated that such a change in the projection system would also contribute errors in area calculations.

**Conclusion and recommendation**

To the best of our knowledge, this approach to construct a digital (seamless) cadastral database (DCDB) with an acceptable level of accuracy for a sufficiently large area is first of its kind in India. As a result of this research, the authors are optimistic about the reuse of existing cadastral maps. They are also of the opinion that those existing maps can be completed in alignment to land registry data and will be of sufficient quality for many purposes including tenure capacity, valuation and taxation, access to credit, support to land markets, management of land disputes and resource management. This ‘fit for purpose’ approach even allows that the first steps in spatial planning combined with land re-adjustment and/or development of infrastructure can be supported. A cadastral resurvey may be required in the future, but this will be time consuming. The authors think it is better to build on the existing (legal) data. For this purpose, the data should be available and ready to use, then upgrading of the accuracy is always possible and different approaches are known from practices in many countries. Another important aspect needed to be



9 Distorted and missing parcel (archiving error)

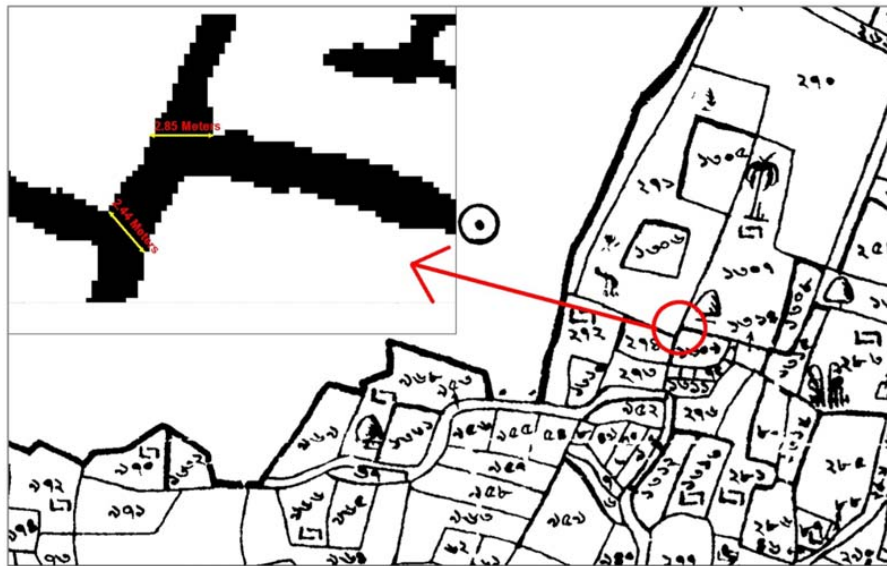
Table 6 Comparison of parcel area (acre) after first- and second-order transformations

Parcel no.	DLRS record	Calculated area		Difference	
		First order	Second order	First order	Second order
2	0.16	0.30	0.15	-0.14	0.01
3	0.18	0.10	0.17	0.08	0.01
4	0.39	0.11	0.39	0.28	0.00
6	0.19	0.09	0.19	0.1	0.00
9	0.18	0.41	0.19	-0.23	-0.01
10	1.16	1.23	1.13	-0.07	0.03
12	0.09	0.48	0.39	-0.39	-0.30
14	0.14	0.65	0.11	-0.51	0.03
16	1.90	1.39	2.00	0.51	-0.10
17	0.44	0.17	0.41	0.27	0.03
19	1.55	1.48	1.64	0.07	-0.09
20	1.53	1.05	1.56	0.48	-0.03

DLRS: District Land and Land Reforms.

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10 Example of crude map line of analogue cadastral maps

mentioned here is that the present method would be much more cost and time effective than resurvey; however, no investigation was done in this regard. Therefore, the authors strongly recommend that further assessment needs to be carried out to estimate the time and cost involved in this proposed method, and thereby its comparison with the method of resurvey.

With the advent of GIS techniques, the map can be overlaid on high-resolution satellite imagery to update the details of the parcel within a short time. Thus, it would also be helpful in monitoring the changes in land use across parcels, fragmentation or consolidation of parcels, areas, which have gone either into the river or have been added, thereby highlighting the changes that need to be carried out in the DLRS records. Then, the proposed methodology could be adopted to prepare a seamless and updated digital cadastral database for a large area with limited field survey where require.

The proposed methodology is formulated in accordance with national mapping standards, so it can be used with any other spatial datasets at any scale. However, so far, no standardised framework for projection, scale, contents, accuracy in surveying and mapping is available in India, which has led to a serious barrier to the creation of national geospatial data infrastructure (Kumar 2006). Therefore, the authors strongly recommend that following this method, a standard can be formulated about the level of accuracy and other parameters to be achieved for digital cadastral map. Moreover, a digital cadastral map with updated land-related information is one of the prime requisites for any Land Information System (LIS), a component of a LAS. Consequently, this can be used as a basis for a cadastre-based LIS preparation.

It is recommended to continue this research with developing a methodology for:

- updating the colonial cadastral maps;
- updating the land registers;
- linking the maps and registers;
- the inclusion of a mechanism for historical data retrieval; and

- the assessment if the total approach is 'fit for purpose' where the basis for spatial planning is concerned (with participatory approaches, fair compensation in case of expropriation, speed and costs of availability compared to resurvey as criteria for assessment).

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