Precise mosaicing of mouza plans for the preparation of digital cadastral map using GNSS

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Global Navigation Satellite System (GNSS), an advanced surveying system, is used to determine three-dimensional points accurately. The present study was conducted in Kasta East Coal Block of the West Bengal Power Development Corporation Limited (WBPDCL), India, focusing on data generation, establishing boundary coordinates and mosaicing of mouza plans using real-time kinematic approach. Base station and primary control points were established by the static method. It evaluates the geospatial information using GNSS and quantification of the accuracy of the geo-referenced cadastral map of kasta east coal block of WBPDCL. Scanned mouza plans were converted to vector format through AutoCAD, oriented and placed precisely with the help of established ground control points. The features of the cadastral map were tuned by superimposing the vector cadastral map of the study area. Assessment of the vector cadastral map showed better accuracy and less distortion in large-area parcels/khasras. More variations were observed in small-area khasras. Similarly, smaller mouzas showed more variation compared to larger ones. Distortions were due to manual error in digitization and technical error in scanning. The methodology of mosaicing presented here will be useful for updating the cadastral maps with improved precision in digital cadastral plan preparation.

Keywords: Cadastral maps, digitization, georeferencing, mosaicing, satellite system.

A positioning system is a mechanism for determining the location of an object in space[1]. Application of Global Navigation Satellite System (GNSS) is gradually gaining popularity in the field of geodesy, missile guidance, aviation, land and cadastral surveying. GNSS receiver using Global Positioning System (GPS – US military system) and GLONASS (Russian military system) is being operated globally for civilian purposes[2]. Galileo – a European civilian system and BeiDou – a navigation satellite system established by China will join globally in the next few years[3,4]. GNSS employs a constellation of orbiting satellites working in conjunction with a network of ground stations. In GPS, the trilateration positioning method is used for point-positioning. Four satellites are necessary to determine a three-dimensional position[5–8].

There are two basic approaches to measurements in GNSS: absolute and relative. Absolute positioning is used to determine a point using code measurement from a single GPS/GNSS receiver, along with the broadcast navigation message, whereas in relative positioning two receivers are used and (code or carrier phase) measurements to the same satellites are simultaneously made at two sites. The measurements at both sites are directly combined. This direct combination further improves positional accuracy. One location coordinate is known and the other location is determined relative to the known location, i.e. the vector is determined between the two locations[9]. In geodesy, for accurate determination of the receiver's site, the relative method is often used because it assures accuracy up to a few centimetres[10]. Relative positioning can avoid, and in several cases eliminate, the effects that limit the accuracy of absolute positioning (ephemeris errors in the satellites, daily atmospheric changes and clock errors in the receiver). In the field, a stationary receiver of the GNSS signal is set to a point whose coordinates are known, i.e. base station. The second receiver is mobile and is set to a point whose coordinates are required to be measured; this is the rover receiver[11].

An assembly of individual photographs is known as a mosaic[12]. It shows the actual ground conditions and many details which cannot be shown in plans. The mosaic serves as a basis for land-use map preparation employing conventional photo-interpretive techniques to supplement the photographic ground truth of the land-use study, both synoptically on the smaller scale and in considerable detail at the larger scale. The mosaic and photographic ground truth are significant in preparing land-use maps from conventional photo-interpretive techniques[13].

The problems associated with mosaicing are image composting, georeferencing, error adjustment, image wrapping and geometric correction[14,15].

Mosaicing approach employing GNSS/differential global positioning system (DGPS) has been used in many studies across the world, including India[16–25].

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The present study was conducted for precise mosaicing of a large-area mauza plan using GNSS prepare a digital cadastral plan.

Digital cadastral plan

Purpose

Cadastral data are important because the land parcel is the physical unit for decision-making in land-use change[26]. The use of cadastral is the identification of plots of land, the valuation and taxation of land and property, the registration of land rights, the present and potential future uses of land as well[27,28]. The main aim of the cadastral system is to provide a method for taking inventory of natural resources and land. The use of the cadastral system is to value and describe natural resources originated in Moscow for tax purposes[26,29]. Mapping the land parcels is a continuous process, 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[30,31]. A digital cadastral plan shows the spatial location of the boundary of land/property in relation to the adjoining property and other properties or parcels of land closeby[32]. In this regard, many developed and developing countries like the USA, UK, European Union, Australia, Brazil and Zimbabwe have made an effort to create digital cadastral databases (DCDBs)[33].

In Tanzania, the tool for efficient implementation of the Mines Act is the creation of a mining cadastral, including the location of the rights on the surface with an attached sketch map and a report on the topographic map, identification of the holder of the right and description of the right, including the right of construction, protection of the property and overlapping of lease boundary[32,34]. The cadastral map also provides the total assessment of land degradation recorded due to mining activity and its mitigation measures[35]. A cadastral is one of the basic building blocks for any land administration system (LAS). India is lacking in such developments and has not yet reached a position of competence[36].

Updating maps on paper and related registers are anticipated to be a complex task for several reasons. First, in the conventional set-up of the Indian system, cadastral maps and land records are maintained separately in different organizations[22]. In this case, updating plot boundaries changed by mutation and modification of other title information takes a long time. Second, the cadastral maps were earlier plotted on low-quality paper or cloth, thus subjected to various kinds of degradation. Hence, in most cases, maps are in poor physical condition and torn because of a lack of timely substitution. Land-record sheets do not have any coordinate system, so geo-referencing is another important objective. The maintenance of infrastructure to continue with this earlier practice also involves an extremely high cost. All these factors together reinforce the case for a digital cadastral plan and database with up-to-date information for India. In recent times, the Department of Land Records (DoLR), Ministry of Rural Development, Government of India, has initiated the 'National Land Records Modernization Programme (NLRMP)' which was approved in 2008 as a centrally sponsored scheme, and revamped as the 'India Digital Land Records Modernization Programme (DILRMP)' to update the system of land records across the country[37], which already include DGPS/GNSS survey for ground positioning of lease area and cadastral plan depicts lease boundary[38].

Different approaches for cadastral surveying

Two basic approaches are adopted for cadastral surveying and mapping. First is the ground survey technique and hybrid approach. In the ground-based approach, the total station instrument is used for cadastral work. The ground-based approach uses a combination of Total Station and DGPS/GNSS to generate ground control points through which all available areas may be surveyed and cadastral maps of those areas prepared. The other approach is the hybrid methodology. Here a combination of aerial photogrammetric/high-resolution satellite images/remote sensing observations is taken, with ground counter checks/truthing of the observed points using ground-survey techniques like total station or GNSS.

Methodology

Concept

The frequently used GPS relative point positioning systems are static positioning, fast static positioning and real-time kinematic (RTK) positioning. Solutions from each method result in different accuracy levels[39]. Static positioning provides the most accurate results, though the occupation time is much longer than rest of the approaches. This approach is useful for the preparation of ground control points for geo-reference stations[40]. The accuracy obtained from both RTK and fast static GPS techniques is at the centimetre level[41,42].

In static surveying, the base receiver remains stationary over the known point during the entire observation period. The rover receiver remains stationary over the unknown point for a short period of time only and then moves to another point whose coordinates are to be determined.

GNSS requires simultaneous observations of more than four satellites for more than 8 min and yields baseline components with the precision of fast static and static methods. The time duration for which the receivers log data depends on the number and geometry (position dilution of precision; PDOP) of the satellites being tracked and the quality of the data being logged[6,43,44]. The static method requires post-processing after collecting and downloading the field data from both (base and rover) receivers. The location of the base station should be such that a 360° clear view of the sky is available around the clock[44–49].

Trimble Business Centre (TBC) software was used to determine the points in vector format. GPS and GNSS use World Geodetic System (WGS84) as their reference coordinate system. WGS84 has been developed for the US Department of Defence. It is the reference system for both GPS broadcast and GPS precise ephemeris, and will be of immense use in practical applications[50].

Approach

Base and primary control station of the study area were established by continuous observations of 72 h and 3 h respectively. Boundary of the coal block was located by RTK stakeout mode. Some of the structures shown in mouza plans were identified by local amin and the points were counter-checked by the total station. After confirmation, all such points were geo-referenced using GNSS. All the mouza plans available in hard copies were scanned and digitized in AutoCAD software tool support of railway track outline, passing through several mouzas, was taken for precise mosaicing of plans apart from surveyed ground control points to prepare a complete digital cadastral plan.

Study site

This study was conducted at Kasta East Coal Block of the West Bengal Power Development Corporation Limited (WBPDCL) located between lat. 22°45′42″ and 22°47′50″N, and long. 87°03′50″ and 87°13′40″E in Birbhum district, West Bengal, India for the preparation of digital cadastral map (Figure 1).

Field investigation

The coordinates of the base station were established by the static method located outside the mining lease boundary. Care was taken to set-up the base station free from any surrounding obstacles at the recommended elevation of more than 15° from the horizontal. Figure 2 shows the location of the base.

The coordinates of the base station/principal primary control point were acquired by keeping the antenna for 72 h under continuous observation (Table 1). The datum was taken as WGS 1984 and the zone of the study area was 45Q.

Mine management provided boundary coordinates of the coal block comprising 84 points. Initially, a reconnaissance survey was conducted using handheld GPS to get broad information on the approximate location of the coal block. Eventually, all the points were located by GNSS in

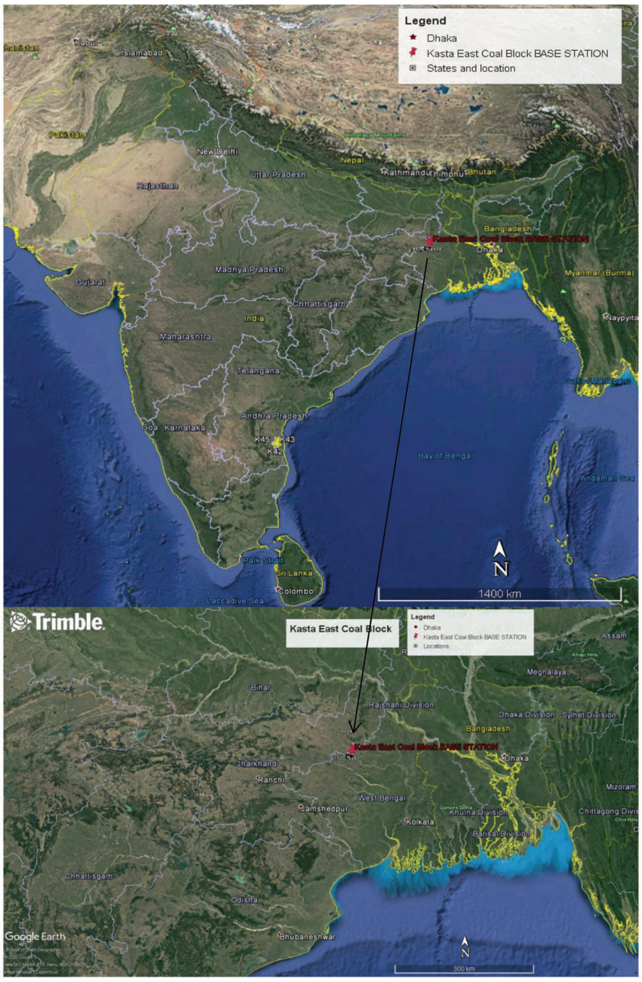

Figure 1. Location map of the study area in Kasta East Coal Block of West Bengal Power Development Corporation Limited, India.

Figure 2. Location of the base station at Kasta East Coal Block.

Table 1. Coordinates of the base station

	Global coordinates		UTM coordinates		
Station	Latitude	Longitude	Northing (m)	Easting (m)	Elevation (m)
Base	23°47′33.4608″	87°11′23.323″	2631280.781	519336.807	106.759

Figure 3. Location map of the base station and mine boundary of Kasta East Coal Block.

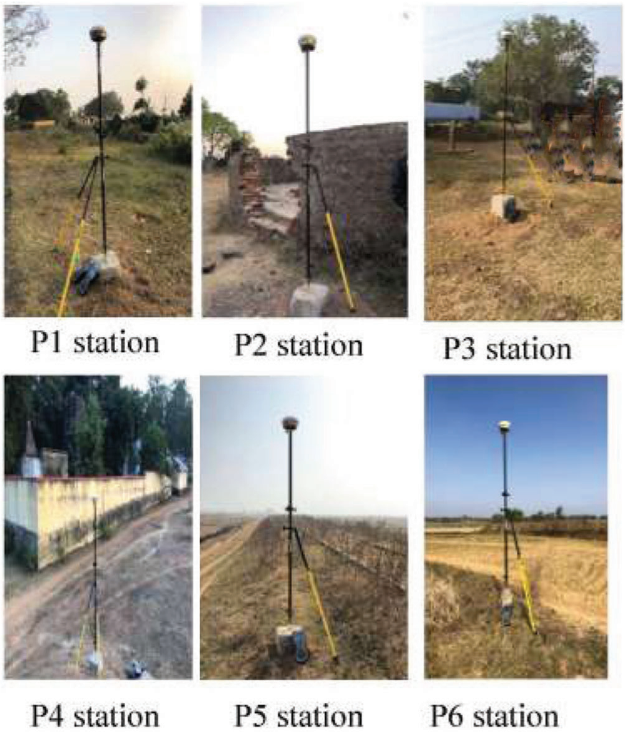

Figure 4. Primary control points at Kasta East Coal Block.

the RTK stakeout mode and pegs were fixed on the predefined coordinate points (Figure 3). The stakeout-mode back-up in navigating the points was fed into the controller for the precise location of the boundary coordinates. Once the rover reaches close to the point, the screen switches to ‘fine mode’ from ‘coarse mode’ displaying a circle with plus mark at the centre and the boundary coordinates can be exactly pin-pointed by superimposing on the plus mark through the rover movement.

The coordinates of primary control points/stations were determined at six locations (P1–P6) under 3 h of observation using the static method (Table 2). These geo-reference stations were used in the preparation of the cadastral plan and will further be useful for a futuristic survey of reference points during mining. Figure 4 shows the location of primary control points.

The variation of PDOP with respect to the number of satellites was from 1.605 to 1.833, and the number of satellites was found to vary from 15 to 17 (Table 3).

According to Langley[51], PDOP values should be less than 6 for a fixed solution and correct results. Figure 5 shows the location of all the points. RTK data were processed using TBC software for real-time checking.

Preparation of digital cadastral plan

Initial work of mouza

Each plan at a scale of 1 : 3960 graphically, according to the IBM Circular[38] depicts the individual parcels with respect to plot number. A plan showing the location, area and land characteristics is known as mouza[22,52]. In India, the parcel

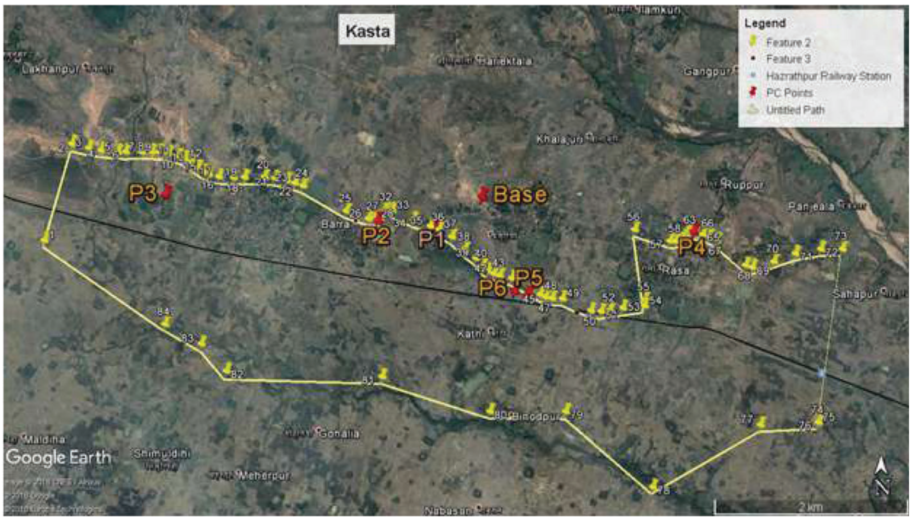

Figure 5. Location map of primary control stations.

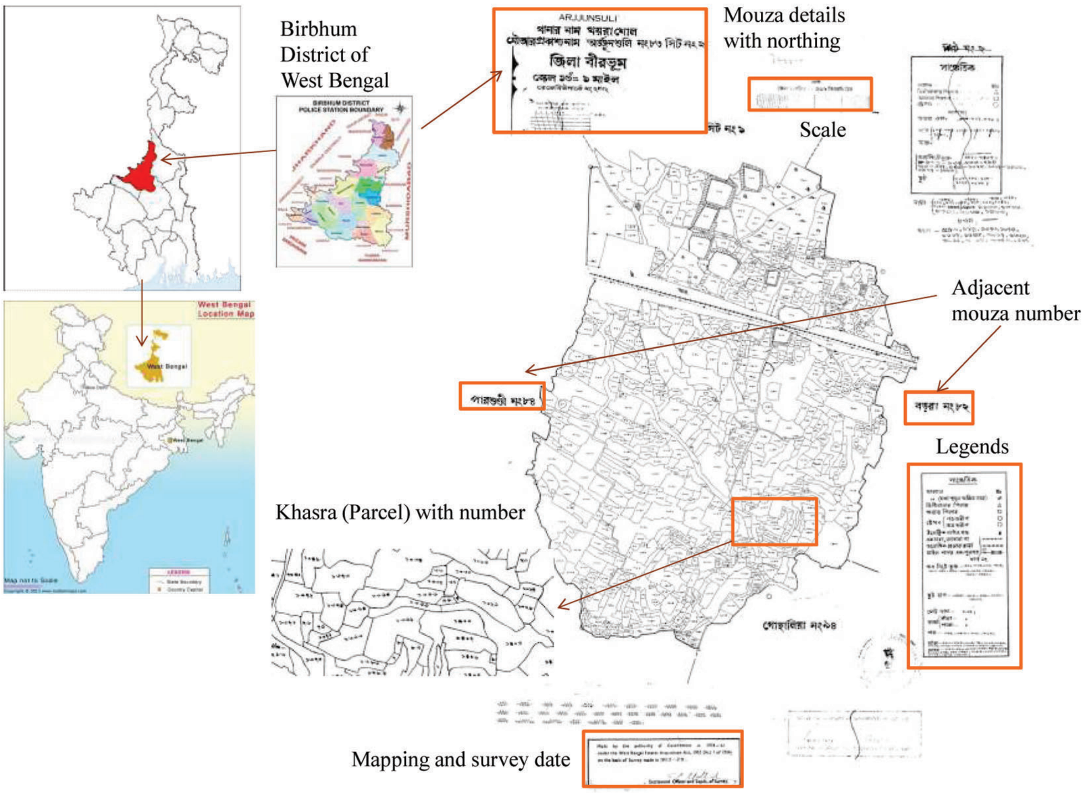

Figure 6. Mouza with village and parcel (khasra) details.

Table 2. Coordinates of primary control points

Station	Easting (m)	Northing (m)	Elevation (m)
P1	518841.664	2630996.656	98.618
P2	518257.23	2631033.919	99.652
P3	516063.362	2631302.961	102.544
P4	521523.419	2630925.505	98.903
P5	519807.969	2630274.628	93.184
P6	519672.269	2630318.215	91.363

Table 3. Position dilution of precision (PDOP) and the number of satellite observed for primary control points

Station	No. of satellite	PDOP
P1	15	1.607
P2	15	1.627
P3	15	1.833
P4	15	1.605
P5	16	1.803
P6	17	1.688

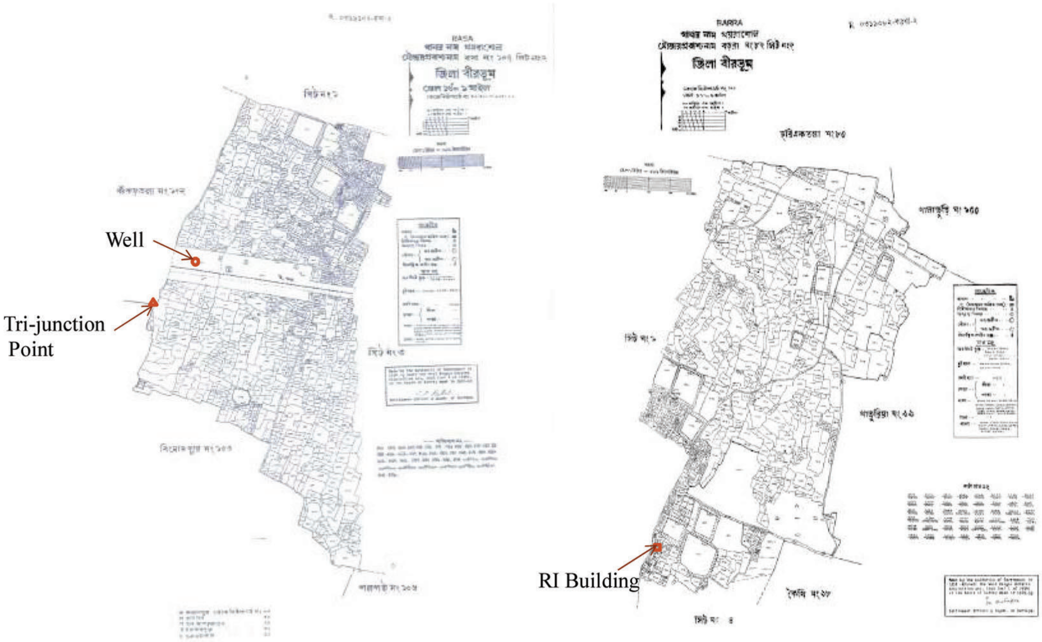

Figure 7. Location of permanent structures in the mouza plans.

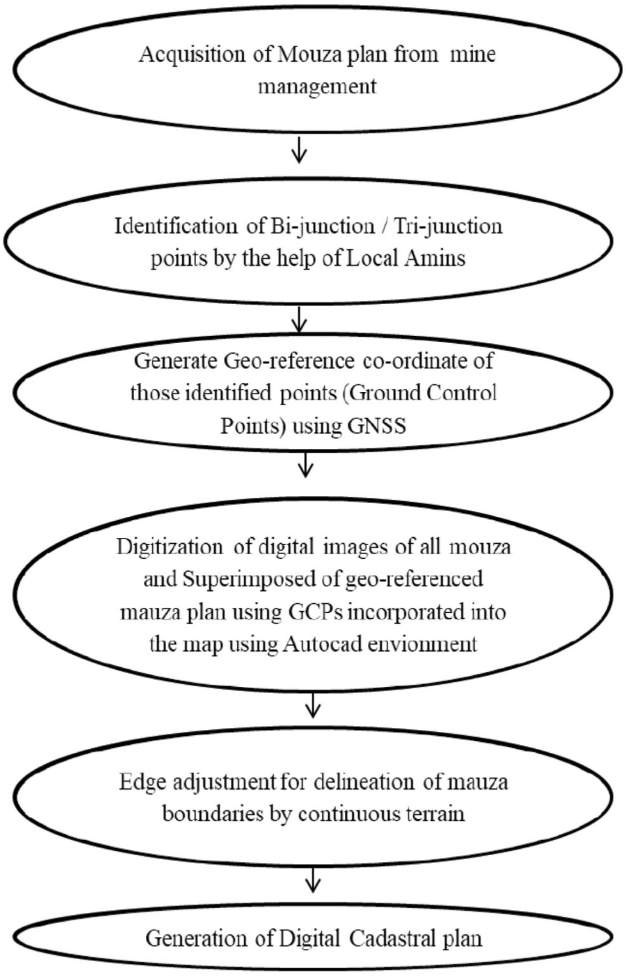

Figure 8. Methodology of the present study.

number assigned to a land parcel in a particular mouza or village is known as a khasra. Each khasra uniquely identifies a piece of land. It is a unique number assigned to each plot that helps in providing information such as its area, ownership details, registration time and owners of plots adjoining that particular piece of land. Figure 6 shows one such plan within the study area.

Collection and pre-processing of mouza plans

Hard copies of mouza plans of the study area were collected from the mine management. In order to make use of them for digital cadastral plans, the mouza plans were initially scanned at 300 dpi resolution and saved in TIFF format. The scanned copy of each plan was further processed for conversion into digital format.

Plan assortment and digitization

The raster format of the mouza plans was converted into vector format by digitization in the AutoCAD platform. Care was taken to scale each plan, as demarcated, during digitization. A few large mouzas like Barra, Rassa, Arjunsuli, Kaithi and Binodpur were divided into sub-mouzas.

Geo-referencing and vectorization

Eleven structures, including old buildings or quarters, temples, abandoned wells, tri-junction and bi-junction points with reference to mouza plans were identified with the support of local amin (Figure 7). The global coordinates of

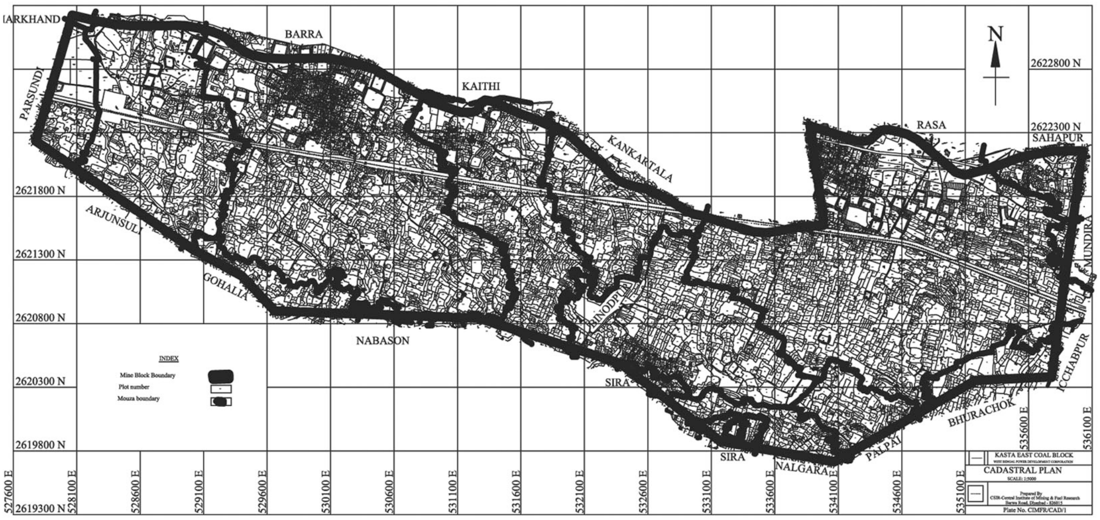

Figure 9. Cadastral plan with mouza and parcel number.

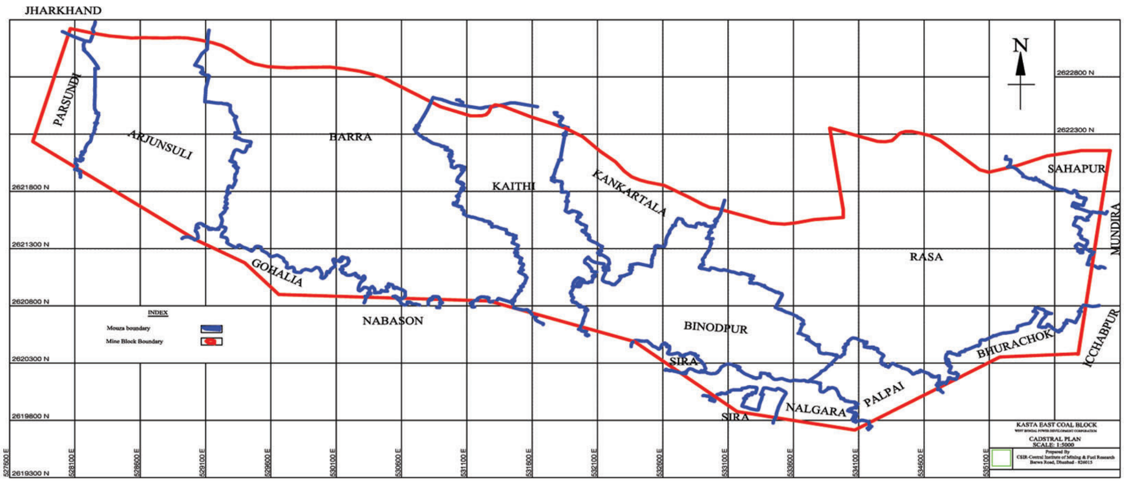

Figure 10. Digital cadastral plan of Kasta East Coal Block.

these points were determined and the distance was counter-checked by total station (TS) with permanent structures to confirm the precise location of the points. Ground control points/geo-reference points helped in placing 16 mouza plans in global coordinates. Three points were determined within a single mouza plan in a few cases. Superimposing of structures of mouza plans with respect to three global coordinates not only helps in precise scale of the plan, but also in orienting the plans. Mosaicing and stitching of each plan were done with the help of such ground control points (GCP).

The boundary of such fixed mouza plans becomes the reference profile for precise mosaicing of adjacent mouza plans, although the maps were brought to true scale according to the digitized scale mapped in the plan. Figure 8 outlines the methodology of the present study. Two to three geo-reference points were used to scale the mouza plans and match the railway track of each mouza.

The remaining mouza plans were placed at the respective locations by mosaicing boundary edge profile of each mouza. Railway tracks crossing several mouzas were key in mosaicing the plans with minimal error. Points located by local amin were measured by GNSS to prepare GCP. Mosaicing all digitized mouza plans taking into consideration the GCP helped in the finalization of a digital cadastral plan.

Discussion

The methodology adopted here for the preparation of a digital cadastral plan with reference to global coordinates requires a combination of GNSS and total station. Cadastral plan was finalized after mosaicing all the 16 mouza plans falling under the coal block boundary (Figure 9). Some of the mouza plans partially coming under the coal block are Sahapur, Gohalia, Nabason, Sira, Palpai, Ichhapur and

Table 4. Percentage deviation in mouza area with respect to digitized area measurement

Mouza	Total no. of patches/khasras	Area according to mouza plan (acre)	Area after digitization (acre)	Percentage deviation in area (±)
Arjunsulli	827	378.080	379.485	0.37
Sahapur	274	54.860	54.250	1.11
Gohalia	243	67.860	65.901	2.89
Sira	150	34.533	32.831	4.92
Burachuk	133	60.630	62.616	3.27
Parsundi	114	85.717	85.840	0.14
Mundira	26	10.170	10.810	6.29
Nabason	22	7.520	7.742	2.95
Icchapur	2	0.220	0.221	0.45

Table 5. Percentage error with respect to area measured

Mouza	Parcel/ khasra no.	Coordinates of corner points according to mouza (acre)	Coordinates of corner points after digitization (acre)	Percentage error (±)	Remark
Rasa	921	0.270	0.264	2.22	
	897	0.060	0.053	11.67	
	2170	1.100	1.090	0.91	
	4901/5217	0.890	0.856	3.82	Pond
	2733	1.300	1.260	3.08	Pond
	2789	1.210	1.274	5.29	Pond
	2776	4.890	4.850	0.82	Pond
	3125	3.090	3.123	1.07	
	3358	2.470	2.474	0.16	
	884/1050	0.04	0.05	25.00	School
Ichhapur	48	0.010	0.012	20.00	
	49	0.210	0.212	0.95	
Sira	46	0.060	0.047	21.67	
	9	0.080	0.72	10.00	
Parsundi	456	9.470	9.473	0.030	
	430	0.020	0.026	30.00	School
	3161	0.310	0.272	12.26	
Binodpur	282	0.070	0.054	22.86	Temple
	423	0.020	0.024	20.00	Temple
	431	0.020	0.020	0.00	School
	240	2.980	2.981	0.03	
	317	1.170	1.161	0.77	
	302	0.080	0.090	12.50	
	750	0.180	0.211	17.22	
	640	0.150	0.142	5.33	
	615	0.080	0.065	18.75	
	835	0.060	0.061	1.67	
	566	0.020	0.023	15.00	
Nabasan	209	0.299	0.290	3.01	
Kaithi	3	0.760	0.794	4.47	Idgah
	488	1.24	1.26	1.59	Pond
	86	0.090	0.073	18.89	Masjid
	327	4.170	4.030	3.36	
	328	0.060	0.062	3.33	
	329	0.050	0.049	2.00	
	315	0.080	0.090	12.50	
Arjunsulli	835	0.020	0.022	10.00	
	1052	3.260	3.188	2.21	
	1040	1.930	1.821	5.65	
	651	1.000	0.917	8.30	
	683	1.030	1.010	1.94	
	825	0.690	0.660	4.35	Pond
	671	0.420	0.414	1.43	Pond

Table 6. Percentage variation error with respect to total mining lease area measured

Mining lease area according to CMPDI (acre)	Digital cadastral plan area (acre)	± Percentage error
3483.592	3476.748	0.196

CMPDI, Central Mine Planning and Design Institute Limited.

Mundira. Large mouza plans like Barra, Rassa, Arjunsuli, Kaithi and Binodpur were divided into sub-mouzas.

Figure 10 shows the outline of each mouza within the coal block.

Digitized khasra area was verified and the variations in area were observed more in small mauza areas than larger ones (Table 4). Higher percentage error was noticed for small khasra boundaries due to the influence of small patch size and vice versa for patches of larger area (Table 5).

The larger khasra areas and the corresponding digitized khasra areas were measured and found to show less percentage error (Table 5).

Total computed area of the coal block was 3476.748 acre. However, the mining lease of the block was 3483.592 acre. An area of 3.06 acre of the coal block falls in Jharkhand (northwest corner). Table 6 shows the variation in the area of the actual mining lease block and the computed area of the cadastral plan.

Cadastral accuracy standards should be in the order of ± 0.03 m maximum error in urban areas, ± 0.09 m in suburban areas, and ± 0.3 to ± 0.6 m in rural areas[53]. Further research is necessary for this domain. According to Williamson[54], DCDBs will have an accuracy of coordinates of parcel corners of approximately 0.03 m in urban areas, 0.2–0.3 m in rural areas and 0.5–2 m in large properties or mountainous terrain. Standard overall accuracy for land-cover and land-use maps should be at least 85% (ref. 55) and 90% (ref. 56) respectively. The area of each mouza was calculated and the sum within 5% of the area determined from the boundary survey was acceptable[57]. The area of each khasra was compared with the record of rights (ROR) and the accuracy range of (±) 2% from the ROR area was accepted[58]. Another study conducted in Bir Hisar, Haryana, between cadastral image and ROR showed an area within 1%, which was considered acceptable[59].

The error in the entire coal block area was 0.19%. Keeping in view the accuracy standards of the cadastral plan as expressed by various researchers, an error of 0.19% for an area of 3476.748 acre (1406.99 ha) is negligible and can be accepted for mining applications.

Conclusion

Mosaicing of 16 mouza plans falling under Kasta East Coal Block, WBPDCL, was done for an area of 3483.592 acre (1409.76 ha), according to the approved coal block. Pinpointing the location of each mouza plan in global coordinates was done by the GNSS system. Precise scaling and orientation of the mouza plans were done with the support of primary control points determined at bi-junction, tri-junction points, old building points and other significant structures identified by local amins. The deviation in the computed area for preparation of the cadastral plan from the approved coal block was 0.19%; this was found to be negligible based on the accuracy standards detailed by various researchers.

With total stations, GNSS provides better support for large-scale mapping and digital cadastral survey. Field investigation and mosaicing provided good accuracy of the cadastral plan and hence may be adopted in other studies elsewhere. Thus, a combination of GNSS and total station is useful in the preparation of large cadastral plans.

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