CADASTRAL RESURVEY USING HIGH RESOLUTION SATELLITE ORTHO IMAGE - CHALLENGES: A CASE STUDY IN ODISHA, INDIA.

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ABSTRACT:

Advancements in satellite sensor technology enabling capturing of geometrically accurate images of earth's surface coupled with DGPS/ETS and GIS technology holds the capability of large scale mapping of land resources at cadastral level. High Resolution Satellite Images depict field bunds distinctly. Thus plot parcels are to be delineated from cloud free ortho-images and obscured/difficult areas are to be surveyed using DGPS and ETS. The vector datasets thus derived through RS/DGPS/ETS survey are to be integrated in GIS environment to generate the base cadastral vector datasets for further settlement/title confirmation activities. The objective of this paper is to illustrate the efficacy of a hybrid methodology employed in Pitambarpur Sasana village under Digapahandi Tahasil of Ganjam district, as a pilot project, particularly in Odisha scenario where the land parcel size is very small. One of the significant observations of the study is matching of Cadastral map area i.e. 315.454 Acres, the image map area i.e. 314.887 Acres and RoR area i.e. 313.815 Acre. It was revealed that 79% of plots derived by high-tech survey method show acceptable level of accuracy despite the fact that the mode of area measurement by ground and automated method has significant variability. The variations are more in case of Government lands, Temple/Trust lands, Common Property Resources and plots near to river/nalas etc. The study indicates that the adopted technology can be extended to other districts and cadastral resurvey and updating work can be done for larger areas of the country using this methodology.

1.0 Introduction

Generation of Cadastral maps is possible through High-tech survey methods using Ortho-images, DGPS and ETS. Cadastral boundary vectors obtained from ortho-images are used as base maps and obscured/difficult areas (not delineated/mapped from ortho-images) are surveyed using DGPS and ETS. The vector datasets thus derived through RS/DGPS/TS survey are integrated in GIS environment to generate the base cadastral vector datasets for further settlement/title confirmation activities. This exercise is undertaken to demonstrate the efficacy of the hybrid technology for cadastral map preparation. The project was conducted in Pitambarpur Sasana village under Digapahandi Tahasil of Ganjam district, Odisha.

2.0 The objective of the project

- To generate cadastral maps by using high-tech survey methods using ortho-images, DGPS and ETS.
- To store the cadastral maps in digital format (storing & updating cadastral maps using state-of-art technology) and to use this as base for all type of revenue administration and development planning.
- Deriving lat-longs of cadastral maps, its mosaiking and Geo-referencing to generate Land Information System (LIS) for Tahasils.
- To use GIS applications for plot level RoR, land use and infrastructure information generation using digital cadastral database.

3.0 Study Area

The Pilot Study was under taken in Pitambarpur Sasana village of Digapahandi Tehasil, Ganjam District. The total area of Pitambarpur Sasana is 317 acres. The area is falling within the Survey of India Toposheet No. 74 A/11. Approximate coordinates of polygon bounding of the village are:-

Lower left corner- 19^0 20' 30" N, 84^0 35' 00" E
Upper right corner- 19^0 23' 00" N, 84^0 39' 00" E

4.0 Methodology

The broad methodology adopted under this Pilot project is as follows: -

- Acquisition of digital stereo satellite data of World View-II.
- Establishment of GCP control network by DGPS.
- Generation of photogrammetric block.
- Ortho image generation
- Collection of existing cadastral maps & Coding/Scanning/Digitization of maps
- Delineation & confirmation of village boundary

- Plot level vectorisation & map generation from ortho image
- Integration of image derived vectors and cadastral vectors (DoLR map) / ROR linking
- Survey and mapping of difficult areas/ ground truth collection
- Integration of vectors and preparation of base maps
- Map/RoR printing (output generation)
- GIS Database Creation

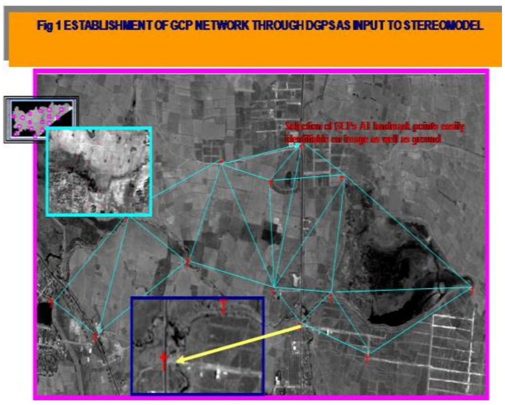
4.1 Acquisition of Digital Stereo Data

Digital Stereo Data of World View-II, PAN was acquired through National Remote Sensing Centre, Hyderabad, Department of Space, and Govt. of India having spatial resolution of .5 m for this study.

4.2 Establishment of GCP control network by DGPS survey

ORSAC has established a Ground Control Network named Primary and secondary at a spatial grid of 16km x 16 km and 4km x 4 km respectively with the placement of cemented pillars having its pillar numbers. Tertiary control points were also created within a visible distance from both types of control points to facilitate ETS survey in the study area. DGPS observation of 4 hours at the primary control point and 1 hour at the secondary point were recorded. The recorded DGPS observations were post processed and network adjustment was performed using fixed solution with triangulation closing limit of 5cm in case of primary control network and 10 cm for the secondary network. The network adjusted values were provided in both geographic co-ordinate system as well as real world co-ordinate system i.e. Universal Trans Mercator (UTM) projection with WGS 84 Spheroid and WGS 84 datum. The triangulated GCP network is shown in fig-1 below.

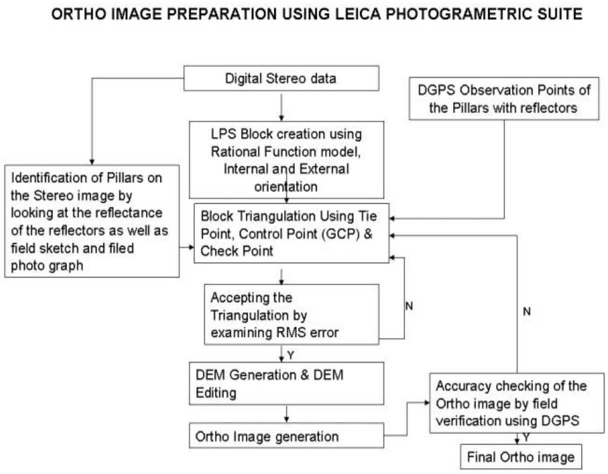
Fig 1



4.3 Ortho image generation

Leica Photogrammetry suite was used for generation of DEM as well as ortho-image for this study. This software uses block triangulation procedure taking the internal and external orientation using both sensor recorded DGPS observations from the header files of digital stereo pairs as well as GCPs taken from the study area. The RMS for the triangulation was .3 pixels. DEM of spatial resolution of 2 m. was created which was then edited properly to create a good surface image. The orthoimage was created using the raster DEM as well as digital stereo pair images of spatial resolution of .5 meter. The process flow diagram is given below in fig-2.

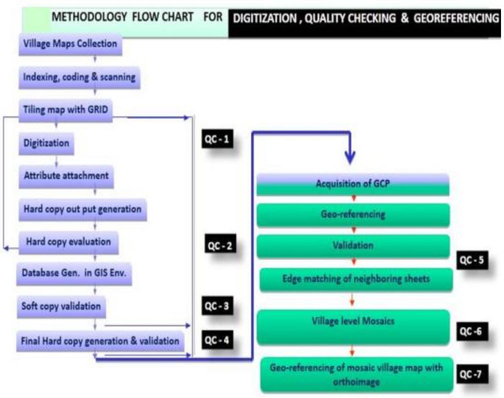
Fig 2



4.4 Collection of cadastral maps & Coding/Scanning/Digitization of maps

Cadastral maps of the study area (Pitambarpur Sasana mouza) (maps in 1:2000 scale) were collected from the Directorate of Land Records and Survey, Cuttack. Maps collected in sheets were scanned after quality checking of each sheet with regard to its physical condition, readability, content and clarity. Maps were tiled on 100mx100m dimension of grid cells. All the four cadastral map sheets were digitized as per the guidelines of Department of Space. Hardcopy printouts are taken for 1 to 1 matching and quality assurance. After necessary quality check the existing cadastral maps are converted to GIS format for further geo-rectification with orthoimages. The detail methodology is described in Fig. 3.

Fig 3



4.5 Plot level vectorisation, map generation from orthoimage & ROR linking

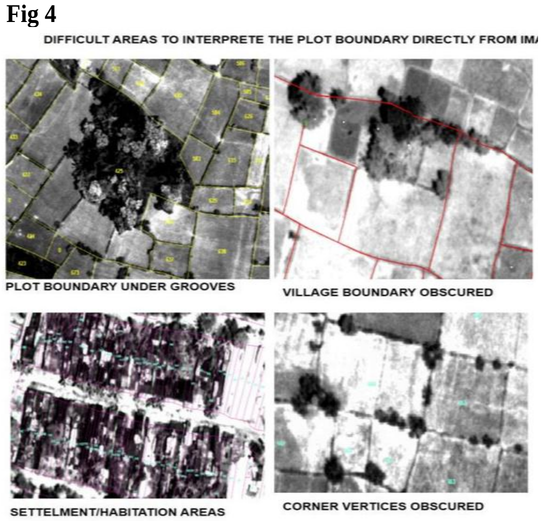
The outer village boundary along with the location of bijunction and triunction points are extracted from digital cadastral map and transferred to the orthoimage by georeferncing the cadastral map with orthoimage. The field observations were taken using DGPS to confirm the outer boundary of the village and its co-existence with the neighboring mouza. The plot boundaries / vectors are interpreted by onscreen digitization method from enhanced Worldview orthoimage with precision following segmented approach i.e. the mouza divided into zones taking natural boundary into consideration and the sum of the area of the zones matching with ROR area. The vectors are drawn for the plots, which are clearly visible on the image in the first instance. The plots whose boundaries are obscured because of tree canopy and other reasons are not closed and left as it is. These difficult area polygons are finalized by field survey technique using DGPS and ETS. The habitation polygons, which are very small, are incorporated to the map from the existing cadastral map. A pre-field map was generated in 1:2000 scales for ground validation and DGPS based data collection. The pre-field map was used for ETS survey for the obscure areas where existing ground control co-ordinates were used for the measurement of co-ordinates in the obscure areas. The co-ordinates then transferred to the plot vector geo-database for the finalization of complete plot vector extraction of the mouza. The plot numbers were transferred from the geo-referenced cadastral map as well as from data collected from the tehesils for the mutated plots. ROR data for the mouza then linked with plot vector for finalization of the geodatabase.

4.6 Survey and mapping of difficult areas/ ground truth collection

DGPS observation was conducted in the field for establishment of a primary control point in the study area by a 12-hour observation. Simultaneous Observation for one hour was undertaken using a Rover for Secondary / Tertiary Control point. Further Ground control points were also retrieved by DGPS-900 with real time processing capabilities at Pitambarpur Sasan village. Field verification was also conducted for the following locations.

- Field boundaries obscured by tree cover (Vertices closed by field measurements) Example of difficult areas is shown in Fig.4.
- Plot boundaries not clear on the image
- Govt. land under holding (cadastral plot showing subplots on image) by individuals
- Acquisition of plots (road and other infrastructure like Tank/ Canal/ Water Harvesting Structures (WHS) showing no plot boundary on image but multiple plots on cadastral map & Record of Rights (ROR)
- Alteration of plot boundaries (locally) by owners
- Verification of same plot in ROR
- Encroachment of land (Temple/ Trust board land, canal and road side, Government land) for which cadastral plot boundary and image boundary not matching
- Water channel (disused) encroached by nearby plot owners.
- Cadastral map showing two plots but on the image it is one plot
- Cadastral map showing one plot but on the image it is two plot
- Boundary plot (village boundary) truncated due to acquisition of adjacent plot of another village by same owner and subsequent removal of common boundary
- Village boundary (boundary plot) vector changed after construction of Water Harvesting Structures (WHS)
- Linear measurements in two villages to check the map accuracy
- Sample DGPS observation on plot corner (vertices) and post plotting for accuracy checking
- Ground truth on zero fill parcels, part/divide /Joint parcels were undertaken and Geo-coordinates were taken up using DGPS (RTK) at few checkpoints for accuracy checking.

Fig 4



5.0 Accuracy Checking

Accuracy of data sets was checked in 3 steps. First step involves comparison of geo-coordinates (of randomly selected points) generated by computer with that of actually observed through DGPS. 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. The results of these three steps of accuracy checking are discussed below.

5.1 Comparison of Geo-coordinates

The geo-coordinates measured at random on the ortho image and the respective location on the ground by DGPS to check the accuracy as well as consistency based on the RMS of the photogrammetric block.
The table below depicts geo-coordinate comparison.

Table -1: A comparative study (Post-field Interpretation) of Geo-cordinates of observed (DGPS) and Satellite Image Point

		Longitude						Latitude					
		Image			Dgps			Image			Dgps		
Sl. No.	Image Pt. Id. No.	Degree	Minute	Second	Degree	Minute	Second	Degree	Minute	Second	Degree	Minute	Second
1	1	84	35	56.724	84	35	56.73	19	21	49.608	19	21	49.617
2	2	84	35	56.364	84	35	56.36	19	21	49.716	19	21	49.713
3	3	84	35	55.932	84	35	55.94	19	21	49.752	19	21	49.736
4	4	84	35	55.5	84	35	55.52	19	21	49.86	19	21	49.845
5	5	84	35	54.924	84	35	54.90	19	21	50.04	19	21	50.046
6	6	84	35	56.544	84	35	56.55	19	21	50.652	19	21	50.638
7	7	84	38	11.436	84	38	11.42	19	22	34.824	19	22	34.844
8	8	84	38	7.404	84	38	7.40	19	22	32.484	19	22	32.476
9	9	84	38	19.644	84	38	19.65	19	22	24.888	19	22	24.889
10	10	84	38	21.768	84	38	21.78	19	22	24.204	19	22	24.194
11	11	84	37	55.236	84	37	55.24	19	22	11.028	19	22	11.032
12	12	84	37	51.636	84	37	51.66	19	22	28.092	19	22	28.102
13	13	84	37	46.596	84	37	46.60	19	22	32.7	19	22	32.693
15	15	84	35	37.644	84	35	37.65	19	21	46.044	19	21	46.030
16	16	84	35	37.932	84	35	37.93	19	21	46.8	19	21	46.780
17	17	84	35	16.008	84	35	15.99	19	21	36.756	19	21	36.770
18	18	84	35	11.904	84	35	11.90	19	21	38.052	19	21	38.061
20	20	84	35	38.616	84	35	38.61	19	21	45.612	19	21	45.600
21	21	84	35	38.832	84	35	38.80	19	21	45.504	19	21	45.493
22	22	84	35	39.192	84	35	39.17	19	21	45.36	19	21	45.345
23	23	84	35	39.552	84	35	39.56	19	21	45.216	19	21	45.232
24	24	84	35	40.416	84	35	40.41	19	21	44.856	19	21	44.838
25	25	84	35	40.848	84	35	40.84	19	21	44.676	19	21	44.676
26	26	84	35	41.352	84	35	41.34	19	21	44.46	19	21	44.465
27	27	84	35	42.576	84	35	42.57	19	21	50.472	19	21	50.463
28	28	84	35	44.916	84	35	44.91	19	21	46.944	19	21	46.963
29	29	84	35	44.196	84	35	44.20	19	21	47.124	19	21	47.132

As may be observed, the measurements match up to second places after second decimal point.

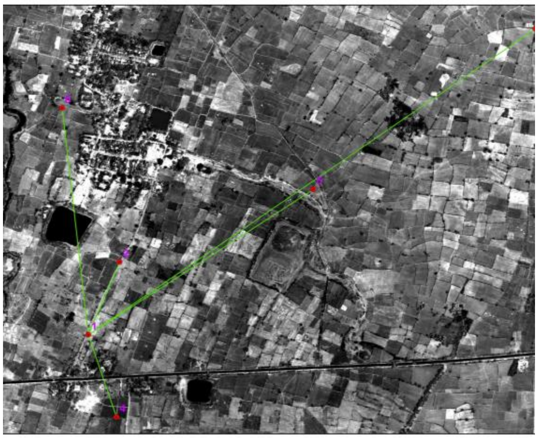
5.2 Tie line measurement

For tie line measurement five tie lines were selected. The length of the tie line was measured from the image in GIS environment and its corresponding field measurement was done through DGPS. The results are tabulated in table-2 & Fig-5 for comparison. The measurements were found to be matching upto third places after decimal point.

Table-2 Tie-line Measurements

Sl No	Line No	Length measured from Image (meter)	Length measured from Field using DGPS (meter)
1	1	226.52274	226.52280
2	2	1470.9126	1470.9130
3	3	248.44296	248.44299
4	4	725.50104	725.50110
5	5	658.35443	658.35450

Fig-5



5.3 Parcel Boundary Measurement

Five plots in study area were randomly selected. Four sides of each of these plots were measured on the ground using meter-tape. The corresponding measurements were extracted from the image. The measurements were tabulated in the table.3 for comparison. The difference in measurements in each case is below 1%.

Table-3

FIELD MEASUREMENT ON SAMPLE PLOTS (RANDOM SELECTION) – GROUND DISTANCE VS. IMAGE MEASUREMENT PITAMBAPUR SASANA, MOUZA, DIGAPAHANDI TEHASIL, GANJAM DISTRICT

SL NO	PLOT NO	FIELD MEASUREMENT (FEET)				IMAGE MEASUREMENT (FEET)				DIFFERNCES (FEET)				DIFFERENCES IN %			
		1	2	3	4	1	2	3	4	1-1	2-2	3-3	4-4	1	2	3	4
1	1256	155.60	80.00	154.00	75.83	155.05	80.21	154.30	76.40	0.55	-0.21	-0.30	-0.57	0.35	-0.26	-0.19	-0.75
2	438	228.00	175.00	205.00	172.00	228.30	175.10	205.10	172.30	-0.30	-0.10	-0.10	-0.30	-0.13	-0.06	-0.05	-0.17
3	782	140.00	183.00	150.00	185.00	140.10	182.90	150.10	185.20	-0.10	0.10	-0.10	-0.20	-0.07	0.05	-0.07	-0.11
4	1072	120.00	148.00	126.00	152.00	120.20	148.50	126.10	152.10	-0.20	-0.50	-0.10	-0.10	-0.17	-0.34	-0.08	-0.07
5	332	240.00	112.00	233.00	120.00	240.40	112.08	233.90	120.08	-0.40	-0.08	-0.90	-0.08	-0.17	-0.07	-0.39	-0.07

1 - NW-NE	2- NW-SW	3 - SW-SE	4- SE-NE

6.0 RESULTS & DISCUSSION

Total Area of Village- (Pitambarpur Sasan)

RoR area: - 313.815 Acre
Cadastral map area: - 315.454 Acre
Image vector map: - 314.887 Acre

No. Of Plots (Pitambarpur Sasan): -

RoR - 1353
Cadastral map: - 1348
Image vector map: - 1353

The difference in RoR and Map (5 plots) is due to subdivision of original plots in RoR.

Pitambarpur Sasan

Matched plots(0-2%)	**1069**	**79.8%**
Gharabari	**178**	**13.0%**
Mismatch	**106**	**07.2%**
Total No. of Plots	**1353**	**100%**

STANDARD/FORMAT FOR MAP & GIS DATABASE GENERATION

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Mapping Standards	1:2,000
Spatial Framework	NSF
Ortho rectification Accuracy (RMS)	0.1 m
Projection	UTM
Datum	WGS 84
Map Frame size	One sheet
Map (Planimetric) Accuracy Minimum Mappable Unit (MMU) Accuracy of Mapping	0.1 m 10x10 cm 100/99
Map Format	Digital GIS Compliance
GIS Database Standards	1:2,000
Spatial framework	Mouza
Tie Point Intervals for Spatial Framework	Meter grid
Projection	UTM
Datum	WGS 84
Minimum Frame size	One sheets
Tic Registration Accuracy in meters	0.001
Planimetric Accuracy (1mm of scale) in m	0.02
Coordinate Movement Tolerance (CMT) Weed Tolerance (WT)	0.00001 0.001
Sliver Polygon Tolerance (SPT)	< 0.001sqm
Grid size (for Image/Raster layers)	100x100 m

Output Standards	1:2,000
Output Formats	Digital GIS Compliance
Output Framework	Admin Unit - Village
	User defined region AOI ·
	Spatial Framework grids
Output Media	CD-ROM/DVD
Output Projection	UTM / User defined
Output Datum	WGS 84
Output Format	GoeTiff, Shape file
Output Symbology	As per Layer Legend/DoLR standards

7.0 CONCLUSION

High-resolution space-borne remote sensing image data show a high level of detail and provide many opportunities to be used as base for cadastral map generation. Ortho images generated by using satellite data having 0.5 m spatial resolution are ideally suited for deriving cadastral plot vectors for plain areas. The obscured areas need ground survey intervention by DGPS & ETS. The habitation area vectors (very small polygons which cannot be resolved through 0.5 m data) of existing cadastral maps can be integrated to image vector maps to finalise the new cadastral maps of the villages. The image derived cadastral maps can be directly used by revenue official for tenant interaction, settlement activities and revenue administration.

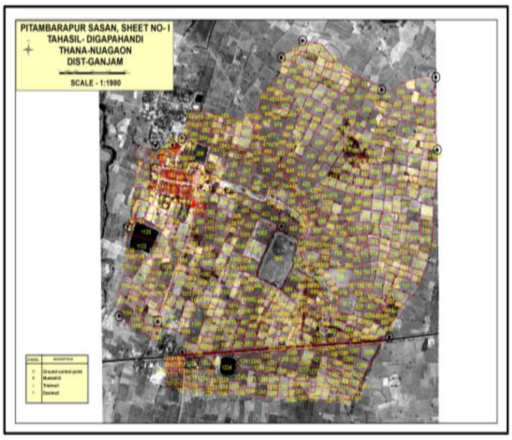
One of the significant observations of the study is matching of Total village area in Cadastral map area (after digitization), the image map of 2009 and RoR area.

The final cadastral map generated (fig. 6) by High-tech survey provides accurate matching of plot areas in 81% of plots. In total 80% of plots in both the villages derived by high-tech survey method shows acceptable level of accuracy considering the fact that the mode of area measurement by ground and automated method has significant variability. Including the Gharabari plots the total plot area in 95% (within 0-2% variations) of plots are matching with existing RoR.

It is also observed that the plot area of digitized cadastral map and the image map are matching but in case of certain plots the RoR area shows wide variation. The variation is more in case of Government lands, Temple/Trust lands, Common Property Resources and plots near to Village boundary etc. as the tenants trespassed to the vacant Govt. lands.

The adopted technology can be successfully used for Cadastral Resurvey and Cadastral GIS generation for plain areas of the state.

Fig 6



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REFERENCES

Siva Subramanian KS, Amitabh S and Manda S (2003) Evaluation of Digital elevation models created from different satellite images. *Proceedings of Map India Conference 2003,* New Delhi, India, Jan 2003

Jacobsen K (2003) Orthoimages and DEMs by QuickBird and Ikonos. *Proceedings of EARSeL* “Remote Sensing in Transition”, Ghent: 513 – 525

Jayaprasad P, Narender B, Pathan SK and Ajai Generation and validation of DEM using SAR interferometry and differential GPS supported by multispectral optical data, *Journal of the Indian Society of Remote Sensing* 36 (4): 313-322

Satirapod C, Rizos C and Wang J (2001), GPS Single Point Positioning with SA off: How accurate can we get? Survey Review, 36(282): 380-386.

Clavet D, Lasserre M, and Pouliot J (1993), GPS Control for 1:50,000-Scale Topographic Mapping from Satellite Images. *Photogrammetric Engineering & Remote Sensing*, 59(1): 107-111

Wilkie DS (1990) GPS Location Data: An Aid to Satellite Image Analyses of Poorly Mapped Regions. *International Journal of Remote Sensing*, 11(4): 653-658.

Barbarella M, Mancini F and Zanni M (2003) Rectification of high resolution satellite data: evaluating accuracy for map updating. *Proceedings of the ASPRS/MAPPS conference*

Barbarella M, Mancini F. and Zanni M (2003) Processing of high resolution satellite data for map updating. *Proceedings of 30th International Symposium on Remote Sensing of Environment*, Honolulu, Hawaii, USA, Nov. 2003.

NLRMP guidelines by LRD, Dept. of Land Resources, Govt. of India