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Preliminary note / Prethodno priopćenje

Virtual and Empirical Prelude for Land Record Modernisation

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ABSTRACT. The land record modernisation is vital for nations under developing economy. The modernisation of land records is tedious process. The written part of the cadastre is modified with ease by use of computers. The map portion of the cadastre is critical for modernisation. The land record modernisation with two procedures and their associated enigma is analysed in this paper. The predominant source of error while performing overlay analysis with digitised land records on satellite images is land slope and the limiting land slope of 8° 15′ 00″ is recommended through virtual analysis. The empirical analysis identified the land area suitable for total station or chain survey. The land area less than 900 m² requires chain survey and land area greater than 900 m² requires total station survey. The crucial part of land record modernisation is to identify errors and error sources to create reliable land record to cater needs of land under current development zone. The land under future development zone needs to be segregated to identify suitable area for total station or chain surveying.

Keywords: cadastral surveying, CAD simulation, error allowance, resurvey analysis.

1. Introduction

The Land record modernisation is a vital part of infrastructural and economic development in a country. Land records pertaining to ownership and rights are classified as cadastral land records (URL 1). Cadastral infrastructure of land records in a country depends on the reliability, technology and socio-economic factors. Land record is an integral part of cadastral infrastructure (Butorac 2017). The land record modernisation is accomplished by two methods. The first method is to scan, digitise existing land records. The second method is by resurvey of land using total station that may include using Global Navigation Satellite System (GNSS) or without GNSS. Scanning and digitizing of land records implemented through scanner and digitizing software installed to a Personal Computer (Donald 2014, Patel 2014). Resurvey needs comparatively more investment of money, time and labour than scanning and digitizing. The developing countries with larger

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land area and confined finances have to adapt a strategy to cater present and future needs in land records modernisation (Behera and Faizi 2014). The strategy may be to scan and digitize land record to supplement the current need for the land that is under the present development sector. Land record modernisation through resurveying of land will be considered in the future land development sector. Scanned and digitised land records are used in overlay analysis on satellite image for land records modernisation. Typically, in overlay analysis digitized land records seldom fit the satellite image accurately (Gopikrishnan 2015). The parts of image that does not fit properly to the digitized land records are to be analysed. The analysis aims at identifying the effect of land slope in the satellite image and digitized land record. Because the slope of land was neglected in the conventional chain surveyed land records. Further, slope of land is not reckoned from 0° to 3° and considered as relatively flat (Kanetkar and Kulkarni 1994). The slope effect in this study is analysed using the method of virtual analysis.

The virtual analysis minimizes the need for repeated georeferencing of digitized land records for fitting over satellite image. In the case of resurvey, land records prepared by conventional chain survey are having less discrepancies for small land parcels. The data obtained by chain survey and total station survey of small land parcel shows meagre variations.

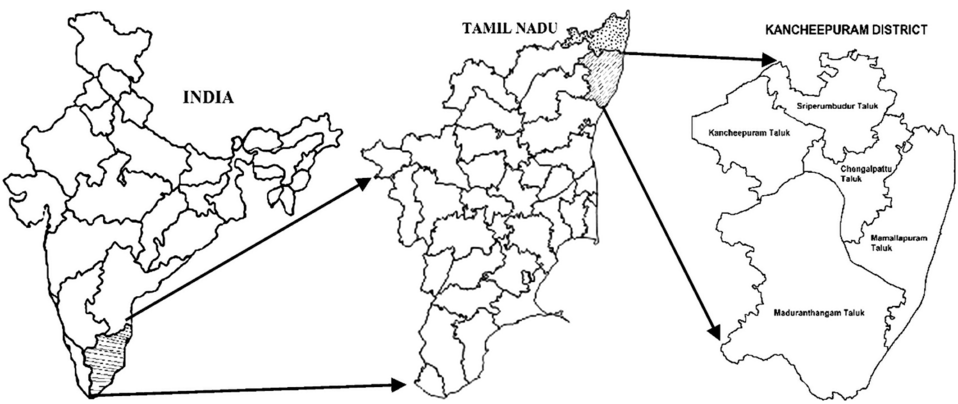

Fig. 1. *India projected with Tamil Nadu and Kancheepuram district.*

The resurvey is to be justified with reference to land area that is useful in identifying approximate size of land parcel, which requires resurvey. The empirical analysis provides necessary data to infer the limiting area of chain survey or the minimum area that requires total station survey. The virtual analysis in this study aides identifying the suitable slope limit that will provide amicable results in overlay analysis. The empirical analysis in this study aides in identifying suitable land parcel size that requires total station survey. The selected study area to carry out the analysis is Konathi village in Chengalpattu taluk of Kancheepuram district in state Tamil Nadu, India. Chengalpattu taluk comprises of 97 villages and located adjacent to Chennai that is capital city of the state Tamil Nadu. Figure 1 shows India projected with Tamil Nadu and Kancheepuram district. Therefore, Chengalpattu taluk undergoes the fast industrial, infrastructural development resulting in frequent updating of land records.

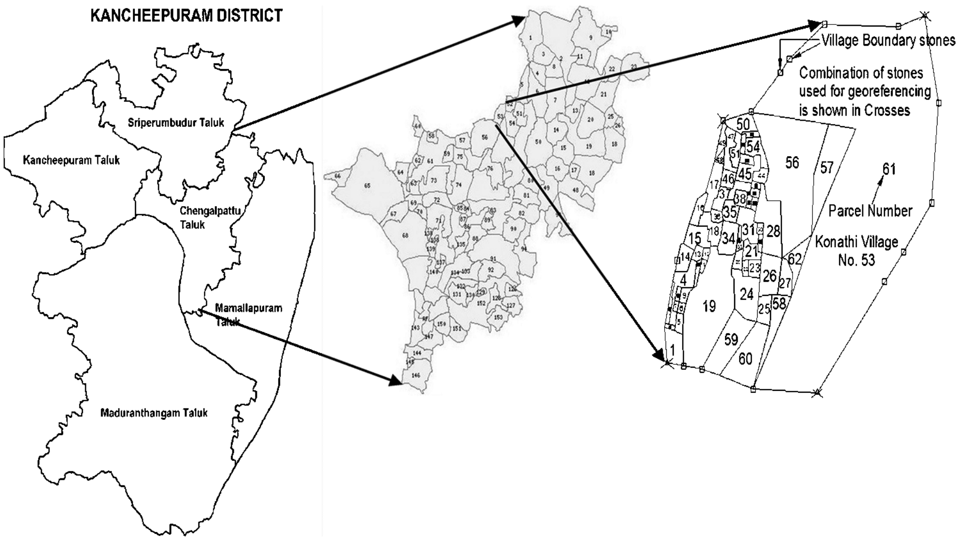

Fig. 2. *Kancheepuram district projected with Chengalpattu taluk with village boundaries with projection of Konathi village.*

Land record changes are influenced by buying and selling of land for industrial, infrastructural and residential developments. Konathi village lays in lower left coordinates of 80° 01′ 30″ E, 12° 49′ 00″ N and right top corner of 80° 02′ 30″ E, 13° 50′ 30″ N. Land record changes are influenced by buying and selling of land for industrial, infrastructural and residential developments. Figure 2 shows Kancheepuram district projected with Chengalpattu taluk with village boundaries with projection of Konathi village. The software used in this analysis is Arc GIS, Auto Cad and Microsoft Excel. The Auto Cad was used for plotting the total station surveyed data and Microsoft Excel for processing total station surveyed data. Quick bird satellite image with resolution of 0.61 m was used in this analysis. The Arc GIS software was used to perform overlay analysis of scanned and digitised conventional land records on the satellite image.

1.1. Prominence of GNSS and Total Station

The GNSS and Total station are state of the art technology which are basis for accurate and precise survey. The GNSS provides common accessible positioning satellite signals that can be accessed from a positioning system receiver (Zrinjski et al. 2019). The current GNSS contributors are Global Positioning System (GPS) from United States of America (USA), Galileo from European Union (EU), Global Navigation Satellite System (GLONASS) from Russia and Beidou from Peoples Republic of China (PRC). These satellite systems provide signals at common band width which are free to use for any person using a satellite receiver. GNSS is employed in fields such as mapping of land for cadastre, roads, water bodies, mining, construction, tectonic plate movements and routing. The time and cost incurred for surveying and manpower is reduced to the minimum possible level (Gleason and Egziabher 2009). The earth crust or tectonic plate movements are effectively monitored by using GNSS. The twenty-four hours and seven days a week availability of the GNSS through satellite signals makes it suitable for observing any perpetual process on the surface of earth. GNSS when connected to sensors of suitable applications like mean sea level monitor, bottom pressure gauge monitor, temperature sensors in forest and earthquake sensors it can save lives. The mean sea level raise or reduction at a particular location because of tectonic plate movements combined with sea bottom pressure will result in Tsunami. The forest fire can be averted by identifying raise in forest temperature based on location. The earth crustal movements are slow and minute. Therefore, GNSS stations for observing the crustal movements are to be established. The perpetual observation of GNSS signals validation and verification will showcase elaborate crustal movements.

The total station when combined with the use of GNSS measurements will foster the process of measuring minuscule readings of tectonic plate movements. The tectonic plate movements are effectively measured by the use of total station (Solarić et al. 2017). Robotic total stations linked with GNSS receivers can effectively monitor open pit mining by producing mining volume data (Brown et al. 2007). The data is useful in monitoring and controlling mining activities. The total station also contains survey modules such as resection, bisection, offset, missing line measurement, roads module for alignment, remote elevation, setting out, area and volume. Apart from basic Electromagnetic Distance Measurement (EDM) and angle sensors, the survey modules available in a total station are dependent on make and cost of the total station. The module remote elevation in total station can measure height of distant objects through the mode of intermediate ranging. The intermediate ranging method provides heights of objects or points of interests through the sensor-based calculation for angle measurement performed by in-built computer in the total station (Peng 2019). The use of total station and GNSS can be extended to develop models to measure land parcel boundary distances through statistics. The location factors are identified using multivariate analysis (Maleta and Bielecka 2018). The multivariate analysis is performed using the survey data obtained from total station and GNSS. The GNSS and total station are advanced technologies for surveying. The survey can be extended to various applications depending on the requirement. The requirement of land record modernisation and its associated issues are analysed in this paper. Land record modernisation will have two phases. The first phase is to scan and digitise the paper-based land record for land under current development zone. The second phase uses the resurvey of land holdings under future development zone. The methodology adapted in this analysis as follows.

2. Methodology

The land record modernisation is achieved by two methods. The first method is scanning combined with digitising. The first method needs to be analysed for mismatch of digital land records in overlay analysis with satellite image.

The major source of error in overlay analysis is the land slope because the satellite image is orthorectified. The limiting land slope must be identified, because the digital land records must comply with the cadastral survey error limits for ratification. The limiting land slope value can be identified through virtual analysis.

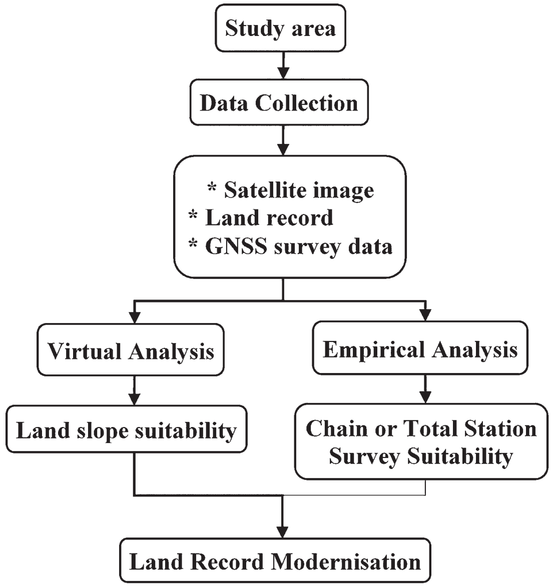

Fig. 3. *Work flow diagram.*

The virtual analysis is performed in the Auto CAD software. The second method for land record modernisation proposes resurvey of land. The second method needs to be analysed to find feasibility of utilizing the total station for resurvey. The feasibility is found through empirical analysis. The empirical analysis provides the reliability level of chain surveying based on the extent of land area. The work flow diagram is presented in Figure 3. The detailed explanation of each analysis as follows.

2.1. Virtual Analysis

The first method of land record modernisation is initiated by scanning, digitising conventional paper-based land records. The selected study area maps are collected from Tamil Nadu Survey and Land Records Department.

Table 1. *Geo-referencing coordinates and residual error of Konathi Village map.*

Link	X Source	Y Source	X Map	Y Map	Residuals
1	1842.009460	–4748.553270	70.035381	13.821775	0.0000
2	2241.577861	–3370.165765	70.039733	13.833758	0.0001
3	1789.575284	–3428.551612	70.035588	13.833517	0.0002
4	1350.085239	–3800.886911	70.031452	13.830470	0.0001

The paper-based land records are scanned and uploaded in .jpeg format (Mishra 2015). Boundaries or significant points in the study area map are identified and GNSS surveying is carried out. The GNSS coordinates is used to georeference the scanned land records (Singh 2016). The georeferencing is carried out precisely to minimise the Root Mean Square (RMS) error. The RMS error inferred during georeferencing is provided in Table 1. Georeferencing converts the scanned land record into a digital map. The land parcels are digitized to create a new layer of land record that is similar to the scanned land record.

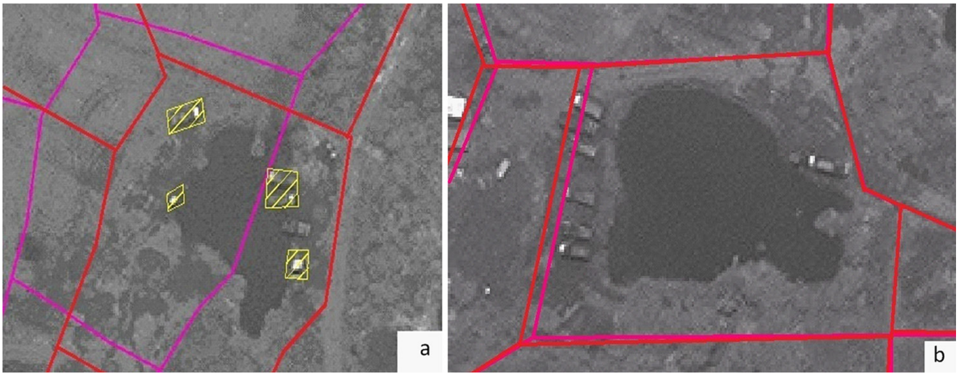

Fig. 4. *Magenta line shows digitised land record, red line shows true boundary (a) Depicts huge boundary variation due to land slope, (b) Shows boundary variation due to minute slope variation.*

While overlay analysis, the digitized land record will mismatch the ground feature boundaries in many locations of the satellite image. The satellite image used is orthorectified so the major source of error is the natural slope fluctuation of earth. Figure 4 (a) and 4 (b) show mismatch of digitised land record with true boundary of the parcel because of huge and minute slope variation of the land parcel. The digitised land record is shown in magenta and true boundary is shown in red colour. The slope variation from 3° and above can cause error in overlay analysis of digitized land record on satellite image. The scanned and digitised land records used in overlay analysis should confirm to the error limitation standards recommended by Tamil Nadu Survey and Land records Department. The recommended error limit is one link for one full chain in linear measurement. The error for area is limited to 5% of the total surveyed area. One link is 20 cm for 20 m metric chain. The slope of land is not considered while plotting the conventional land record.

Therefore, the virtual analysis is carried out using Auto computer aided design software (CAD). The horizontal and the ensuing slope distance limit are obtained by slope simulation in CAD. The analysis is carried out by drawing two lines measuring 10 m from the same point horizontally in orthographic mode. Resulting horizontal lines are superimposed over one another. Two vertical lines 5 m each are drawn parallel at 90° on the 0 m and at 10 m distance of the horizontal lines. The vertical line at 0 m is assigned name V1 and the line at 10 m on the horizontal lines is assigned name V2. Consequently, assign names L1 and L2 to the horizontal lines. Use horizontal line L1 with base at 0 m; rotate it in anticlockwise direction to 1° in CAD. Measure the distance of the rotated line L1 from V1 to V2. The end of rotated line L1 is adjoining to vertical line at V2. The adjoining distance is the slope excess that will cause mismatch of digitized land record on the satellite image.

Afore explicated procedure is repeated until the slope excess exceeds the linear measurement error recommended by Tamil Nadu survey and Land records Department. The inferred data are tabulated in Table 2 and from Figures 5 to 7. The slope elevation is also measured for relative comparison.

Table 2. *Angle, slope and slope elevation values.*

S. No.	Angle Value (D° M′ S″)	Slope Distance (m)	Slope Elevation (m)
1.	1°	10.0015	0.1746
2.	2°	10.0063	0.3492
3.	3°	10.0139	0.5241
4.	4°	10.0246	0.6993
5.	5°	10.0384	0.8749
6.	6°	10.0552	1.0510
7.	7°	10.0753	1.2279
8.	8°	10.0984	1.4054
9.	8° 15′ 00″	10.1047	1.4499
10	9°	10.1248	1.5643
11.	10°	10.1543	1.7633

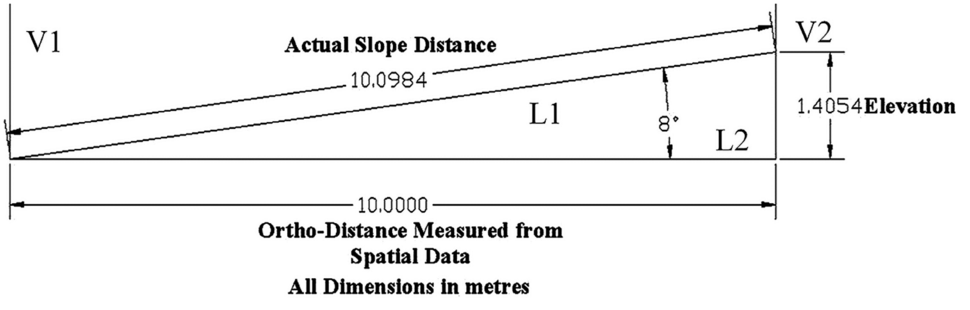

Fig. 5. *Slope distance, ortho distance and elevation distance for 8°.*

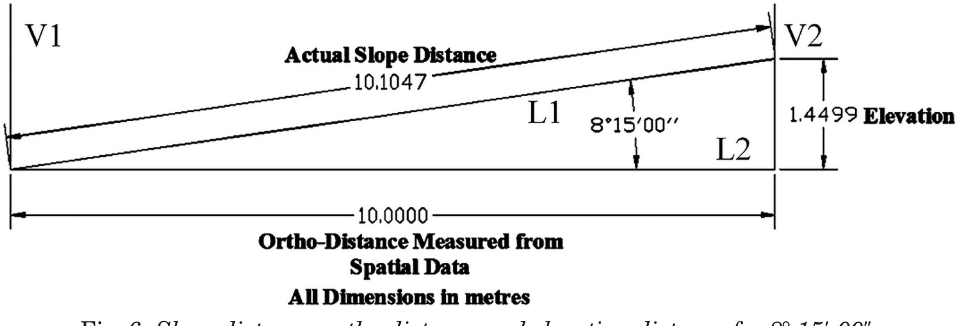

Fig. 6. *Slope distance, ortho distance and elevation distance for 8° 15′ 00″.*

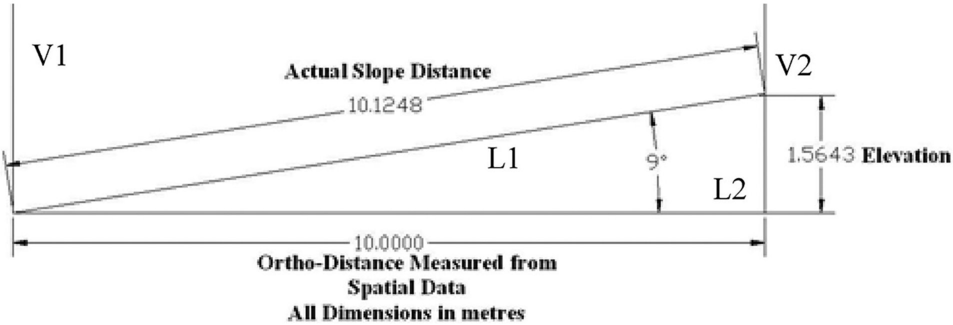

Fig. 7. *Slope distance, ortho distance and elevation distance for 9°.*

The Figure 5 shows the slope distance, horizontal distance and elevation subtended by the line for 8° slope. The Figure 6 shows virtual analysis details for slope formed by 8° 15′ 00″ and Figure 7 shows the simulation of 9° slope. The Figure 8 shows graph between slope angle and slope elevation. The analysis rendered identification of slope angle limit and concomitant slope excess. The optimum slope angle of 8° 15′ 00″ has slope excess of 0.1047 m. The error allowance for 10 m is ±0.10 m or 10 cm. the slope excess error when exceeds the limit, it will cause digitized land record mismatch in the overlay analysis with satellite image.

Fig. 8. *Slope angle vs. Slope elevation.*

2.2. Empirical Analysis

The resurvey of chain surveyed land utilizing total station is the amicable solution for obtaining precise land records. The precision level of chain surveyed land records must be identified. Because the precision is not sufficed to supplement present precise land records requirements while surveying vast land holdings. Precision of chain surveyed land records are suitable for small land holdings. Nevertheless, chain survey when adapted for vast land holdings cumulative errors hoard, resulting in considerable error. Chain survey is suitable for small land holdings but total station survey is suitable for vast land holdings. The area of land holdings that require chain survey or total station survey is identified using empirical analysis. The empirical analysis is carried out using total station survey data comparison with chain surveyed data of the same land parcel. The empirical analysis is performed by selecting relatively flat land of vast extent without obstructions. Chain survey in empirical analysis is executed by diagonal and offset method. The land records prepared by Tamil Nadu Survey and Land records department adopt this diagonal and offset method for land surveying. The empirical analysis is carried out by adhering to the standards of the Tamil Nadu Survey and Land records department to adapt it for survey applications.

A simulation of diagonal and offset method of chain survey framed with total station survey is executed to an extent of one hectare. A square field of one hectare is formed in the relatively flat land using total station. Two sides of square field are 100 m each. The two sides of square field are assigned names as horizontal (X) and vertical (Y). The boundary point connecting horizontal and vertical side of the field is assumed as commencement point of survey. The horizontal and vertical sides of the field are secerned using total station to 30 m and a ranging rod is fixed to the boundary point. Remnant of the horizontal and vertical boundary of the field after 30 m is equally secerned to 10 m using total station and marked by ranging rod on the ground. Square land parcels of ascending sizes of area are obtained until boundary limit of one hectare is reached. The survey work is shown in Figure 9. The ascending sizes of area of land parcels are chain surveyed by diagonal and offset method. The area obtained from 30 m, 40 m and up to 100 m distances on the sides of the square boundary field are examined with total station survey. The average values of chain survey area for parcels of increasing areas are tabulated in Table 3. The parcels formed by total station survey and their respective areas are tabulated in Table 4.

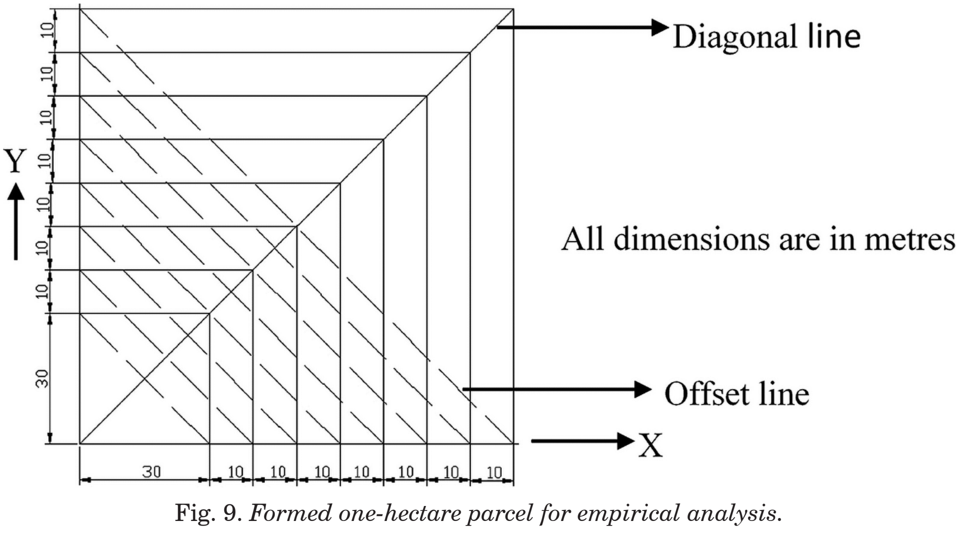

Fig. 9. *Formed one-hectare parcel for empirical analysis.*

Table 3. *Average values of chain survey parcels.*

Sl. No.	Average Value of Side 1 of Square Parcel (m)	Average Value of Side 2 of Square Parcel (m)	Average Area by Chain Surveying (m^2)
1	30.02	29.99917	900.5751
2	39.94833	39.91833	1594.674
3	50.08833	50.13333	2511.034
4	59.92000	59.85333	3586.419
5	69.99167	70.04500	4902.608
6	79.74167	79.86667	6368.713
7	89.57500	89.73167	8037.674
8	99.73667	99.48500	9922.377

Table 4. *Area obtained by total station survey.*

Sl. No.	Side 1 of Square Parcel (m)	Side 2 of Square Parcel (m)	Total Station Survey Area (m^2)
1	30	30	900
2	40	40	1600
3	50	50	2500
4	60	60	3600
5	70	70	4900
6	80	80	6400
7	90	90	8100
8	100	100	10 000

Table 5. *Comparison of Total station, chain surveying areas with error.*

Sl. No.	Area by Total Station Surveying (m^2)	Average Area by Chain Surveying (m^2)	Error in Area of Chain Surveying (m^2)
1	900	900.5751	–0.57509
2	1600	1594.674	5.326217
3	2500	2511.034	–11.03390
4	3600	3586.419	13.58150
5	4900	4902.608	–2.608250
6	6400	6368.713	31.28750
7	8100	8037.674	62.32592
8	10 000	9922.377	77.62283

The area obtained from total station survey is assumed as accurate and compared with the chain surveyed results which is tabulated in Table 5. The graph showing the variation of error in comparison with the total station surveyed area is shown in the Figure 9. The error is not constant but varies as the area increases. The error inferred at 30 m distance of one full chain length showed meagre variations. After one full chain length the error varied increasing and decreasing. The observations of the ground showed undulations between those measurements. Because of these measurements the graph shown in Figure 10 has showcased variations in error.

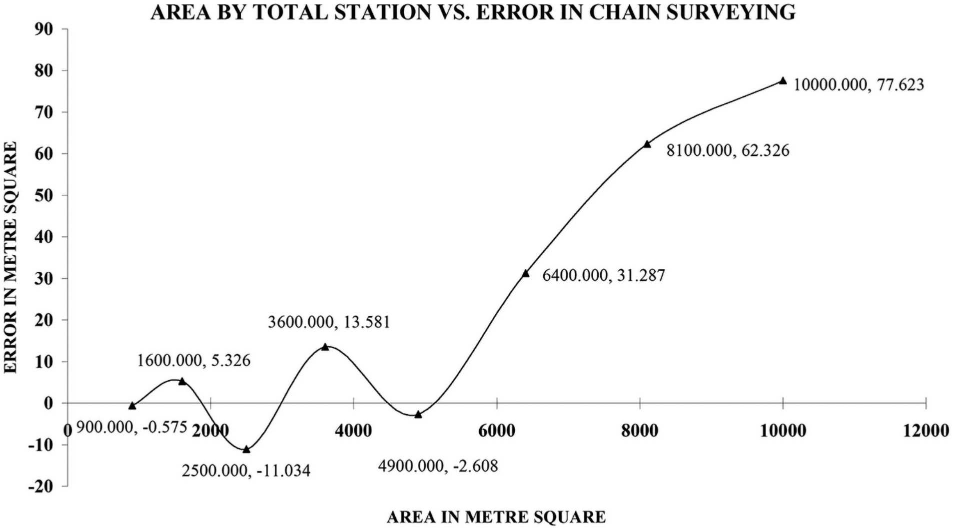

Fig. 10. *Total station survey areas vs. errors in chain surveying areas.*

2.3. Significance of the Analysis Method

The virtual analysis aids us to identify the limitation of scanned, digitised land record in overlay analysis with satellite image. The limitations are arrived through the error limitations recommended by the respective government agency. The virtual analysis can be applied to any geographic region where similar analysis is required to be performed. The virtual analysis for varying land slopes may be analysed for fostering the land record modernisation for the land which is under current development zone. The land record error limit varies from one country to another. Therefore, virtual analysis will act as a suitable platform to analyse digitised land records for performing overlay analysis with satellite image.

The empirical analysis showcases the suitable land area limit for performing total station or chain survey. The chain survey is suitable for carrying out survey of area whose sides are less than or equal to one chain length. In this study the metric chain used is 30 m. Therefore, the total area obtained by one chain length is 900 m^2. The total station surveys are suitable for land area greater than 900 m^2. The study is carried out in relatively flat terrain of slope variation up to 3°. The study can aid in simulation that can identify the amicable results for different terrain slopes. The empirical analysis will ease the burden of resurvey of land parcels under future development zone. Because the limiting land parcel area requiring resurvey will be identified by the empirical analysis. The developing countries with limited resources and finance can adapt these methods to reduce the burden of land record modernisation. The results of the analysis and brief discussions are presented as follows.

3. Results and Discussion

The results of the virtual analysis emphasize land parcels with slope more than 8° 15′ 00″ are not suitable for overlay analysis on satellite image. Because there will be mismatch of the boundaries between the digital land records and satellite image. The orthorectified satellite image and the limiting error allowance of chain survey are crucial to the creation of digital cadastral data using conventional land record. The digital cadastral data are crux of the land records modernisation in a country with developing economy (URL 2). To cater the present cadastral need for developing country digitising land record is important, but error limits are crucial to be observed (URL 3).

The empirical analysis vitalises the need for identifying the reliable limit of chain surveying and dependability of total station surveying. The analysis showcased land parcel that is more than one chain length must be surveyed with total station. The suitability of chain survey is also identified through this analysis that recommends area below one chain length can be measured with chain. Because the errors are meagre that will not cause considerable misrepresentation of land parcels areas.

4. Conclusions

The digital cadastral land record creation, maintenance and development are crucial part of a developing nation. The land under current development requires reliable precise land record that acts as a catalyst for economic development. This paper focussed on the key issues of land records modernisation. The land records modernisation for land under current development zone needs to adopt error limitations prescribed by the governing agency. The error source for overlay analysis is identified and limitations are recommended in this paper. The land record modernisation for future development zones needs to be segregated as small land holdings and vast. For vast land holdings above 900 m^2 the land parcels must be surveyed with total station to minimise errors. For small land holdings less than 900 m^2 the land may be surveyed with chain that will suffice the requirements of land surveying precision. The limiting area for resurvey of land parcels is identified by the empirical analysis which showed land area suitable for chain or total station surveying.

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Virtualni i empirijski uvod u modernizaciju zemljišne evidencije

SAŽETAK. Modernizacija zemljišne evidencije važna je za nacije s gospodarstvom u razvoju. Modernizacija zemljišne evidencije težak je proces. Pisani dio katastra lako se modificira uz pomoć računala. Grafički dio katastra kritičan je u pogledu modernizacije. U ovom radu analizirana je modernizacija zemljišne evidencije kroz dva postupka i s njima povezanu enigmu. Prevladavajući izvor pogrešaka prilikom analize preklapanja s digitaliziranim zemljišnim podacima na satelitskim snimkama je nagib zemljišta te se preporuča ograničavajući nagib zemljišta od 8° 15′ 00″ kroz virtualnu analizu. Empirijskom analizom utvrđuje se površina zemljišta primjerena za izmjeru geodetskom mjernom stanicom ili lancem. Površina zemljišta manja od 900 m² zahtijeva izmjeru lancem, a površina zemljišta veća od 900 m² zahtijeva izmjeru geodetskom mjernom stanicom. Ključni dio modernizacije zemljišne evidencije odnosi se na utvrđivanje pogrešaka i izvora pogrešaka kako bi se izradila pouzdana evidencija zemljišta u svrhu zadovoljavanja potreba zemljišta u trenutnoj zoni razvoja. Zemljište u budućoj zoni razvoja treba biti izdvojeno kako bi se utvrdile odgovarajuće površine za izmjeru geodetskom mjernom stanicom ili lancem.

Ključne riječi: *katastarska izmjera, CAD simulacija, dopuštena pogreška, analiza ponovne izmjere.*

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