Accuracy Assessment of UAV for Cadastral Application

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KEYWORDS

Unmanned Aerial Vehicles, Point clouds, Orthomosaic, Digital Elevation Model, Digital Terrain Model

ABSTRACT

This study aims to produce accurate geospatial 3D data from unmanned aerial vehicle (UAV) images. An image of approx. 1 km2 area of the Banepa-10, Kabhrepalanchok district was captured using a DJI Mavic Pro drone. Pix4dmapper programs were used to generate the solution. The horizontal and vertical accuracies of the obtained UAV solution were computed by comparing the coordinates of 5 Ground Control Points (GCPs) with coordinates measured using the static DGPS observation method. The root mean square error (RMSE) was calculated during geo-referencing of Orthomosaic and obtained a value of 0.006.Mainly, three comparisons were made for parcels digitized from the Orthomosaic image w.r.t to Total Station and Tape measurement ; Area, Perimeter and Centroid Position. Cadastral survey using Total station, UAV and Tape measurement were confirmed to be comparable in terms of accuracy, completeness, and expenditure of time. From the result of this study, the area as well perimeter of parcels obtained from georeferenced orthorectified UAV image seems to be closer with the area as well as perimeter from total station survey compared to those obtained from tape measurement. If the area is pre-demarcated and clearly visible in Orthomosaic image, then information can efficiently be gained. Some ambiguity could be seen in the comparison of digitized parcels whose boundary information was not clear.

1. INTRODUCTION

1.1 Background

The land survey of Nepal dates back to 1930 B.S; with the gradual development in land administration, the cadastral mapping and land recording system in Nepal was started in 1980 B.S. (Dangol and Kwak, 2013). With the formulation of the Land Survey and Measurement Act, 2019 B.S. up-to-date land ownership and records were formalized with the maintenance of a map-based land record system. Cadastral mapping of entire Nepal was prepared through the traditional plane table survey where 38 districts are mapped in grid sheet and remaining at free sheet. However, due to the advancement in technologies Survey Department began to use the Total Station, an electronic instrument for cadastral mapping. A concept for conducting the survey using a Total Station has been devised to reduce the number of conflicts, improve mapping accuracy, and facilitate the implementation of a land information system. Since 2006 A.D., the initiative has been conducted in two municipalities (Banepa and Dhulikhel) (Dangol and Kwak, 2013). In comparison to traditional plane table surveying, this technique for obtaining spatial data proved to be quite efficient. There was additional study into using GPS technology and high-resolution satellite photos to capture datasets for cadastral surveys. However, these strategies have yet to be put into effect on a broader scale.

Unmanned Aerial Vehicles (UAVs) are remotely controlled or fly with complex automation system aircraft. With the recent development in UAVs and the improvement in automatic navigation technology and stable imaging devices, UAVs can perform aerial operations at different altitudes, according to the mission requirements, and they are able to obtain high-spatial-resolution images and produce ortho-photos, digital surface models, and topographic maps. In addition, UAV aerial photogrammetry has been studied in relation to its application in cadastral surveys in recent years (Chio and Chiang, 2020). Many attempts have been made to use aerial photography for cadastral surveys. UAV has emerged as the most efficient technology for mapping large areas for cadastral surveys and many attempts are being made to use aerial photograph (UAV imageries) for cadastral surveys in which countries like Bhutan, Srilanka, India and Cyprus have applied this technique for updating the existing cadastral maps (Tamrakar, 2012). Manyoky et al. (2011) performed a study on UAV in cadastral application and found that UAV delivers comparable results with respect to data acquisition, processing and evaluation, and time of survey and provides a valuable alternative to other traditional methods. Studies by the ortho-mosaics generated from the high-resolution UAV photos are at least as accurate as conventional terrestrial surveying methods that showed geometrical accuracies with a maximum of 3 centimeters (Rijsdijk and van Heinsberg (2013).

In this regard, in the case of Nepal, the development of the cadastral system is very gradual with the use of plane table survey and introduction of the total station survey; so a shift in feasible technology is necessary for the efficient development of the cadastral system. In Nepal, unprecedented population growth and internal migration coupled with unplanned developmental activities has resulted in urbanization, which lack infrastructure facilities. (Karna et al., 2013) Thus, UAV techniques can be employed as modern technology for more efficient and effective improvement and addressing related issues regarding the cadastral system of Nepal. The technology can have priority according to the accuracy, time, cost, and security of the system. So with this advent, the feasibility study of UAV application regarding cadastral mapping was accomplished in Banepa municipality ward no. 10 from 2078/10/26 to 2078/11/1, according to the approval program of Survey Department in fiscal year 2078-79. In this study, our attempt is to find out the feasibility of orthophoto collected from UAV to update cadastral maps and databases in Nepal and to compare and analyze area of parcel obtained from total station as well as tape measurement with digitized UAV ortho-rectified image.

1.2 Objective

The main objective of this research is to assess ac curacy of orthophoto using UAV and its potential application on cadastral mapping. The other objectives are:

i. To prepare ortho-photo of the study area and assess its accuracy using check points

ii. To create a digital cadastral boundary map of the study area

iii. Compare and analyze digital cadastral boundary data with existing cadastral data of the study area

1.3 Study Area

The proposed study area lies in ward 10 of Banepa Municipality of Kavrepalanchok District. The study covers an area of approx. 100 Ha. and is selected so as to cover different topographic variations such as low land, gently sloping and steep hills and land use types such as residential, commercial, agricultural, forest, water bodies etc.

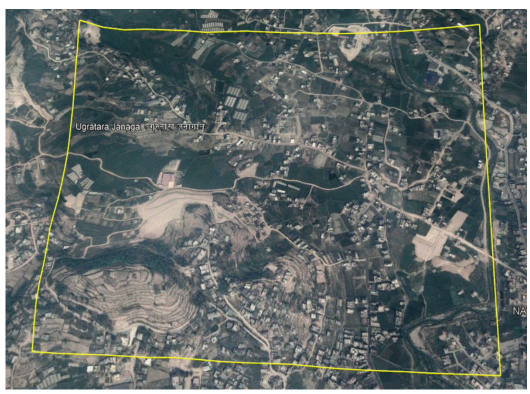

Figure 1: Study Area (part of Banepa-10, Kavrepalanchok)

2. METHODOLOGY

2.1 DGPS survey

DGPS Survey was performed using 4 highly precise Trimble R7 GNSS Receivers. A total of 5 ground control Points (GCPs) and 3 Check Points was established during the Survey. A minimum observation of 8 hours for base stations and 2 hours for Ground Control points was taken. DGPS Observation was done forming triangular network for network correction which gives relatively higher accuracy during the processing. An observation frequency of 1second and a cut-off angle of 15° was set.

2.2 Link with national network

DGPS Survey have been linked with two Third Order National Trig. Points available at Cihandada at Banepa Municipality and Point no. 120 Kavre Devisthan at Dhulikhel Municipality.

2.3 Traverse by total station

Traverse Survey was performed using angle-distance method for precise calculation of GCPs using 5” Geomax Total Station.

2.4 Error adjustment

Standard Error adjustment methods have been applied for Traverse calculation. The tolerance limit set by Standards of Procedure for Cadastral mapping purpose is ±60ccg. The angular closure error of the traverse computed was 47ccg within the tolerance limit.

The sum of interior angles of a closed traverse was calculated using the formula

$(n - 2)*(200^g)$.where n=5 is the number of sides of the traverse observed.

2.5 Coordinate obtained from traverse and DGPS

Coordinates calculation have been performed using standard software for DGPS observation data. Trimble Business Centre (TBC) was used for precise processing of the GCPs and linked with the National Trig. Points. The details of the processing have been attached in the annex.

2.6 Digital cadastral

Digital Cadastral Survey was performed using 5” Geomax Total Station. Precisely Calculated Ground Control Points was used as reference during the whole survey. Some offset points were also used to observe the details during the cadastral survey. For verification using ground measurement, tape survey was also done for some visible and distinct features.

2.7 UAV flight and image acquisition

Image acquisition was done using Mavic2Pro UAV. A flying height of 100m. and an overlap of 70% was maintained during the whole flight. The whole study area was covered in series of flights taken from various station.

2.8 Field Team for Surveying

For the field observation, different teams were mobilized according to the field activity. The field work was started on Magh 24,2078 and completed by Falgun 1,2078. All the technical teams were from the Survey Department. Separate teams were mobilized for separate field work like UAV Flight Survey, GNSS survey, Total Station Survey and Tape Measurement. Following table shows the list of technical staff involved for different field work.

Table 1: List of Team Members.

UAV Survey	
S.N.	**Name**
1	Prabesh Shrestha
2	Hemraj K.C.
GNSS survey	
1	Buddha Lama
2	Sundar Devkota
Total Station and Tape Measurement Survey	
1	Girija Pokhrel
2	Bikram Shrestha
Field Data Computation	
1	Prabesh Shrestha
2	Girija Pokharel
3	Sundar Devkota

3. ACCURACY ASSESSMENT

3.1 Area Comparison

The outputs are generated as per the survey and observation done during the Field work. The comparisons between area computed from Total Station survey, Tape measurement and area digitized from orthorectified geo-referenced UAV Image of 23 parcels selected over the study area has been presented in Table 2:

Table 2: Comparison of Image Parcel Area w.r.t Total Station and Tape Measurement.

Parcel Number	Area (Sq. m.)			Difference of Image w.r.t (Sq. m.)		% Error Image w.r.t	
	Image	Total Station	Tape	Total Station	Tape	Total Station	Tape
1	160.253	161.617	160.390	-1.364	-0.137	-0.851	-0.086
2	350.658	349.636	341.560	1.022	9.098	0.292	2.594
3	127.192	131.034	117.590	-3.841	9.602	-3.020	7.550
4	108.769	111.495	107.340	-2.726	1.429	-2.506	1.314
5	142.773	140.864	139.130	1.909	3.643	1.337	2.552
6	109.939	115.036	113.620	-5.097	-3.681	-4.636	-3.348
7	14.734	15.378	15.100	-0.644	-0.366	-4.371	-2.487
8	96.542	91.933	92.490	4.609	4.052	4.774	4.197
9	189.929	187.546	185.720	2.383	4.209	1.255	2.216
10	127.356	123.227	126.360	4.130	0.996	3.243	0.782
11	106.588	107.994	104.860	-1.406	1.728	-1.319	1.621
12	95.617	92.670	90.350	2.947	5.267	3.082	5.508
13	90.081	89.297	98.250	0.784	-8.169	0.870	-9.069
14	1011.370	1020.597	996.830	-9.226	14.540	-0.912	1.438
15	88.186	81.992	86.400	6.194	1.786	7.024	2.026
16	1484.570	1493.773	1491.200	-9.203	-6.630	-0.620	-0.447
17	101.578	99.470	98.400	2.108	3.178	2.076	3.129
18	211.843	209.613	207.210	2.231	4.633	1.053	2.187
19	86.604	83.047	84.700	3.557	1.904	4.107	2.199
20	107.725	105.343	104.700	2.382	3.025	2.211	2.808
21	72.755	69.528	69.740	3.227	3.015	4.435	4.145
22	128.136	122.284	118.450	5.852	9.686	4.567	7.559
23	148.752	149.368	152.230	-0.616	-3.478	-0.414	-2.338

The parcels derived from georeferenced ortho image of UAV were used for analysis and compared with the parcel obtained from total station survey as well as the parcel area from tape measurement. Due to time limitations, a total of only 23 parcels were digitized from UAV image and same parcel from total station survey and tape measurement were used. Among 23 parcels, 1 parcel obtained from Image and Total station survey was greater than 5% differences in area. It indicates that only 4.3% parcels were found with more than 5% area differences. It seems that there is low mismatch in area between parcel from image and parcel obtained from total station survey. Similarly, out of 23 parcels, 4 parcels obtained from Image and tape measurement were greater than 5% differences in area. It indicates that only 17 % parcels were found differences greater than 5 %. The above statistics shows that the area of parcels obtained from georeferenced orthorectified UAV image is closer with the area obtained from Total station survey than area obtained from tape measurement.

Figure 2 shows the plot of difference (in sq. meters) in area of each parcel measured in Orthomosaic image with respect to Total Station and Tape measurement. The x-axis shows the number of parcels, and the y-axis shows the positive and negative differences in square meters. As seen in the graphs, the minimum deviation seen with respect to Total Station measurement is in parcel number 23 and with respect to Tape measurement is seen in parcel number 1. The maximum deviation seen with respect to Total Station measurement is in parcel number 14 and with respect to tape measurement is also seen in parcel number 14.

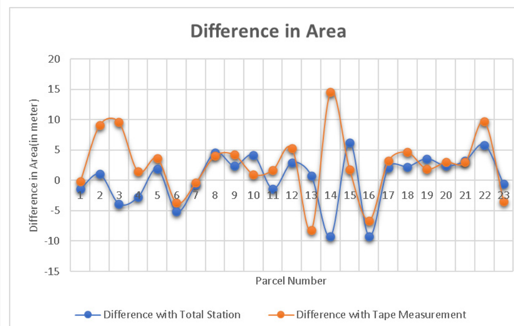

Figure 2: Plot of deviation of parcel area of image with total station and tape measurement

3.2 Perimeter Comparison

The perimeter of land parcels obtained from digitization of UAV images along with the perimeter obtained from Total station survey and Tape measurement is shown in Table 3:

Table 3: Comparison of Image Parcel Perimeter w.r.t Total Station and Tape Measurement.

Parcel Number	Perimeter (m.)			Difference of Image w.r.t (m.)		% Error Total Station w.r.t	
	Tape	Total Station	Image	Total Station	Tape	Total Station	Tape
1	56.58	55.95785	56.330219	0.372369	-0.249781	0.66	-0.44
2	77.51	78.556195	78.608177	0.051982	1.098177	0.07	1.40
3	43.83	46.155182	45.555086	-0.600096	1.725086	-1.32	3.79
4	44.35	45.223758	44.582872	-0.640886	0.232872	-1.44	0.52
5	50.4	50.449565	50.626621	0.177056	0.226621	0.35	0.45
6	43.4	43.847701	42.626155	-1.221546	-0.773845	-2.87	-1.82
7	21.28	21.469792	21.027082	-0.44271	-0.252918	-2.11	-1.20
8	39.7	39.638738	40.852109	1.213371	1.152109	2.97	2.82
9	54.95	55.283115	55.618224	0.335109	0.668224	0.60	1.20
10	45.5	45.009422	45.755819	0.746397	0.255819	1.63	0.56
11	41.8	42.398092	42.276811	-0.121281	0.476811	-0.29	1.13

Parcel Number	Perimeter (m.)			Difference of Image w.r.t (m.)		% Error Total Station w.r.t	
	Tape	Total Station	Image	Total Station	Tape	Total Station	Tape
12	39.55	39.935189	40.539609	0.60442	0.989609	1.49	2.44
13	41.07	39.018481	39.298142	0.279661	-1.771858	0.71	-4.51
14	128.7	129.621175	129.571766	-0.049409	0.871766	-0.04	0.67
15	41.3	41.802048	43.087454	1.285406	1.787454	2.98	4.15
16	163.27	163.295849	163.259666	-0.036183	-0.010334	-0.02	-0.01
17	41.15	41.483034	41.864823	0.381789	0.714823	0.91	1.71
18	57.7	58.023511	58.305439	0.281928	0.605439	0.48	1.04
19	37.92	37.612146	38.153945	0.541799	0.233945	1.42	0.61
20	43.7	43.764769	43.951566	0.186797	0.251566	0.43	0.57
21	38.47	38.598185	38.992482	0.394297	0.522482	1.01	1.34
22	45.2	47.455332	47.919713	0.464381	2.719713	0.97	5.68
23	50.4	50.125799	49.844987	-0.280812	-0.555013	-0.56	-1.11

The parcels derived from georeferenced ortho image of UAV were used for analysis and compared with the parcel obtained from total station survey as well as the perimeter of parcel from tape measurement. The above statistics shows that the perimeter of parcels obtained from georeferenced orthorectified UAV image is closer with the perimeter obtained from Total station survey than perimeter obtained from tape measurement.

Figure 3 shows the plot of difference (in meters) in perimeter of each parcel measured in Orthomosaic image with respect to Total Station and Tape measurement. The x-axis shows the number of parcels, and the y-axis shows the positive and negative differences in meters. As seen in the graphs, the minimum deviation seen with respect to Total Station measurement is in parcel number 16 and with respect to Tape measurement is also seen in parcel number 16. The maximum deviation seen with respect to Total Station measurement is in parcel number 15 and with respect to tape measurement is also seen in parcel number 22.

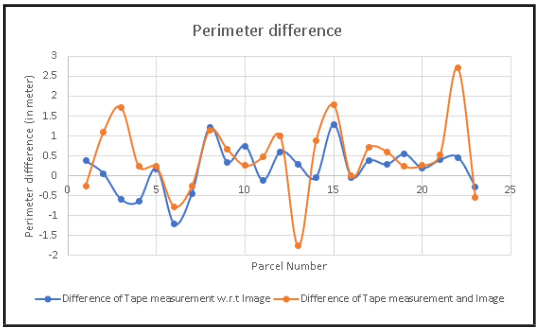

Figure 3: Plot of deviation of perimeter of parcel of image with total station and tape measurement

3.3 Positional Comparison

Positional Accuracy of the parcel boundary derived from Orthophoto, and Total Station Survey were assessed by identifying the shift in position of the parcels centroid coordinates calculated in terms of distance between them. Centroid Coordinates of each parcel derived from TS Survey as well as parcel derived from Orthomosaic image were calculated and the distance between them of the corresponding parcel boundary was measured using the Euclidean's Distance Formula:

$$\text{Distance}(\Delta d) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

Where, Δd is the deviation in meter

Table 4 Comparison of Image Parcel Centroid Position w.r.t Total Station Measurement.

Parcel Number	Centroid (Image)		Centroid (Total Station)		Deviation of Centroid (Image and TS)
	Easting	Northing	Easting	Northing	
1	352855.264	3058429.171	352855.277	3058429.067	0.105
2	352851.936	3058452.518	352851.952	3058452.485	0.036
3	352896.719	3058422.719	352896.841	3058422.743	0.124
4	352938.172	3058359.195	352938.210	3058359.115	0.088
5	352957.613	3058426.970	352957.398	3058427.113	0.258
6	352969.730	3058408.574	352969.867	3058408.411	0.213
7	352995.945	3058410.424	352995.907	3058410.448	0.045
8	352972.625	3058342.613	352972.522	3058342.738	0.162
9	352983.387	3058346.014	352983.416	3058345.950	0.070
10	352995.504	3058348.891	352995.471	3058348.857	0.048
11	353004.265	3058351.667	353004.224	3058351.532	0.141
12	353011.883	3058353.808	353011.853	3058353.751	0.065
13	353018.973	3058356.027	353018.883	3058355.913	0.146
14	353036.341	3058581.801	353036.484	3058581.757	0.150
15	353563.675	3058377.940	353563.547	3058377.975	0.133
16	353672.526	3058352.233	353672.610	3058352.202	0.089
17	353635.437	3058434.715	353635.437	3058434.638	0.077
18	353646.073	3058430.404	353646.009	3058430.357	0.079
19	353694.705	3058432.625	353694.660	3058432.799	0.180
20	353718.304	3058437.636	353718.222	3058437.571	0.105
21	353792.657	3058416.945	353792.683	3058416.987	0.050
22	352935.057	3058366.513	352935.189	3058366.250	0.294
23	352920.557	3058363.647	352920.417	3058363.589	0.151
			Average		0.122
			Standard Deviation		0.068
			RMSE Error		0.139

The standard deviation for the deviation of centroids from land parcels of image digitized and land parcels from total station survey is obtained by the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}} \qquad (2)$$

Where σ is the standard deviation, μ is the mean value of observation and N is the number of parcels measured. The standard deviation calculated for the deviation of centroid of land parcels obtained from total station and UAV image digitization is 0.068m. Similarly, the value of average deviation of centroid for land parcels is 0.122m.

Similarly, the Root Mean Square Error (RMSE) for the deviation of centroid of land parcels obtained from total station and UAV image digitization obtained by the following formula:

$$RMSE = \sqrt{\sum_{i=1}^{n}\frac{(\hat{y}_i - y_i)^2}{n}} \qquad (3)$$

Where RMSE is the Root Mean Square Error, y is the value of centroid deviation and n is the number of parcels measured. The RMSE calculated for the deviation of centroid of land parcels obtained from total station and UAV image digitization is 0.139m.

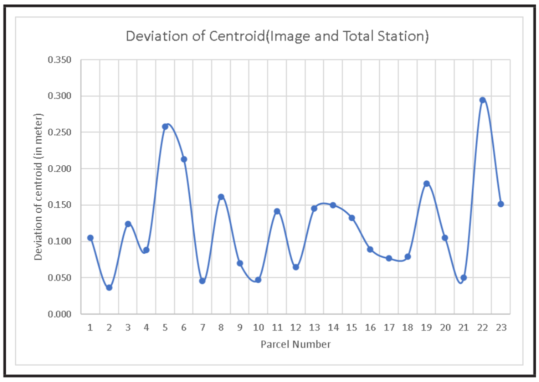

Figure 4: Plot of deviation of parcel centroid of image and total station with parcel number

4. CONCLUSION

Cadastral survey using Total station, UAV and Tape measurement were confirmed to be comparable in terms of accuracy, completeness, and expenditure of time. From the result of above study, the area as well perimeter of parcels obtained from georeferenced orthorectified UAV image seems to be closer with the area as well perimeter from total station survey than obtained from tape measurement. Difference in area and perimeter could be seen varying mostly due to the shape of the parcels. So, in some parcels difference in area could be seen higher whereas difference in perimeter is comparatively low.

The advantage of UAV systems is the ability to quickly observe the surface of areas at low flying altitude while still meeting the accuracy requirements of cadastral surveying. As our above results suggests, the limiting factors for image orientation accuracy are the camera calibration, the image quality, and the definition of the ground control points in the image space. The application of UAV systems for cadastral surveying is appropriate for the capturing of land cover or single objects. If the area is already demarcated, information can efficiently be gained. Therefore, UAV systems proved suitable to be used in addition to the standard surveying methods to gain further data through the acquired images such as overview images or orthoimages. Moreover, another added value of using UAVs in cadastral applications is the effortless generation of elevation models and 3D objects. UAV method with appropriate photogrammetric evaluation methods offers a great potential to gain information from the captured data that are useful for cadastral applications. These derivates from UAV measurements can present a great additional benefit to users of cadastral data, such as real estate agencies and insurance companies. In areas where access can be difficult, e.g., after natural calamities or in third world countries, UAVs offer a valuable alternative to traditional field survey method for cadastral survey. With further developments of specific system technology, the usability of UAV systems will increase in cadastral surveying. In future, UAVs will be used where a need of high accuracy is required, and fast data capturing is demanded. Therefore, the use of UAVs is an opportunity for cadastral surveying. UAV also can play vital role for data collection to solve the problem of informal settlement, re-cadastral survey, and other engineering surveys esp. in flat terrain.

This study recommends the use of UAV in cadastral survey as followings:

i. UAV survey is suitable for cadastral survey for clearly demarcated land parcels visible in UAV images.

ii. It can be performed for project with low budget and low time with comparison to other surveying techniques.

iii. The use of RTK receivers UAV can help for the betterment of output result.

iv. UAV survey is appropriate for the open areas, and it is difficult to extract features in shadow area.

v. Application of cadastral survey with field verification is useful for cadastral map updating and keeping the record of land parcel.

4.1 Benefits of Cadastral survey using UAV images:

From this study, the benefits of UAV applications in cadastral survey are as followings:

a) Reduce field time and survey costs Capturing cadastral data with a drone is up to faster than with land-based methods and requires less manpower and is also less expensive.

b) Provide accurate and exhaustive data Total stations only measure individual points. One drone flight produces thousands of measurements, which can be represented in different formats (Orthomosaic, point cloud, DTM, DSM, contour lines, etc.). Each pixel of the produced map or point of the 3D model contains 3D geo-data. Due to low flying height, more clear and accurate information can be obtained with comparison to conventional photogrammetry.

c) Mapping an inaccessible area An aerial mapping drone can take off and fly almost anywhere. There is no longer limitation by unreachable areas, unsafe steep slopes, or harsh terrain unsuitable for traditional measuring tools. The data collection by UAV is not interrupted by highway traffics, railway tracks, river etc.

d) With less effort 3D model of earth surface With comparison to other methods, the UAV method allows for the derivation of much more information. Based on the image orientation, a digital elevation model of different grid and area sizes can be calculated. d. In addition, 3D models of objects such as buildings can be generated based on the captured UAV data which can be useful for 3D cadaster.

4.2 Limitations of study

The limitations of the study are illustrated below:

- Demarcation of Parcel were not visible in orthorectified image acquired using UAV. So, some differences could be seen in the parcel digitized from the images and the parcels plotted using the co-ordinates acquired from Total Station.
- The point cloud has been generated from the ortho pairs of images acquired from UAV. The resulting point cloud may contain errors, such as image shadows, mismatches, and lens distortion.
- The timeframe for the study was limited. So, only limited number of control points could be surveyed. The limited number of DGPS also took longer time for observation of control points.
- The processing of UAV images requires high-capacity computers and well-equipped workstations. Otherwise, it requires longer time for image processing.

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