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Full Length Research Paper

An investigation of 1:5000 scale photogrammetric data for cadastral mapping uses: A case study of Kastamonu-Taskopru

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Cadastral surveys have been carried out in Turkey using different methods such as graphical, photogrammetrical, orthogonal, tachometric and digital techniques. National cadastral works require large scale maps with sufficient position and elevation accuracy, especially when they are used for projecting technical services in metropolitan areas. The applications of this project include using cadastral data as a basis to inform building decisions in these areas. Maps can be produced with various techniques, but there are some that can provide information that is time saving, offering user efficiency through computer-based technologies. One such technique is the rapidly evolving science of photogrammetry. Photogrammetric techniques provide digital maps that are easy to produce and use. In this study, 1:5,000 scale photogrammetric maps produced by the General Directorate of Land Registry and Cadastre (GDLRC) and the Photogrammetry and Geodesy Department Presidentship were collected for the Taskopru Township in Kastamonu County, Turkey. The ownership cadastres for this town were delineated by the GDLRC using digital photogrammetric techniques. This data format was analysed to determine if it is useable with cadastral mapping and information systems. A series of 1:5,000 scale photogrammetric maps belonging to the flat and hilly areas were evaluated. At densely populated places in the centre of the town, the cross points of parcel coordinates were measured and calculated with classical techniques. In less densely populated areas, such as empty fields, the cross points of parcel coordinates were measured and calculated with Global Positioning Systems (GPS). Control measurements for each map, measurement data and map data (parcel cross coordinates and parcel surveys) were crosschecked for flat and hilly area. The accuracy of the 1:5,000 scale photogrammetric maps was then assessed statistically. Finally, the photogrammetric maps were determined as either useable or unusable for the production cadastral maps in this region.

Key words: Turkish cadastre, photogrammetric map, cadastral map, information system.

INTRODUCTION

The Republic of Turkey was founded in 1923. The original Turkish cadastral system was based on the initial cadastral work carried out during the Ottoman Empire. With the some exceptions, all of the lands within the Ottoman Empire were under state ownership. After the Land Law of 1858, this system transitioned to a private ownership system. After the foundation of the Republic of Turkey, private ownership policy continued and was legislated with Civil Law and Cadastre Law that was borrowed from on other European countries (Demir et al, 2008; Çete and Uzun, 2005; Demir and Çoruhlu, 2006). From its origin to the present day, different systems have been used in cadastral works that comprise the Turkish cadastral system. The multiple systems used include graphic, classic, photogrammetric and electronic tachometry methods. The result is a cadastre that is not uniform for all regions of Turkey.

Other countries have maintained some form of the photogrammetrical mapping for cadastral procedures.

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Germany, Holland, Switzerland and Israel used 1:5,000 scale maps for cadastral mapping during different time periods. The 1:5,000 scale maps generally have been used for rural or forest areas in Turkey (Barr and Stöppler, 1981; Eberhardt, 1993; Rokahr, 1998; Wakker et al., 2003; Hawerk, 2003; Gavish and Doytsher, 2002; Steudler et al., 2005). In Australia, cadastral mapping is typically at scales of 1:2,000 to 1:4,000 in urban areas and 1:10,000 to 1:50,000 in rural areas. Cadastral maps in Australia represent boundaries that vary in graphical accuracy, with urban coordinates deviating by a few metres out of position and in rural areas by tens of metres out of position (Williamson, 1996). The Scottish cadastre is an example of more detailed mapping. One of the first of these projects involved the mapping of the island of Rhum in the inner hebrides during the 1960s and involved the production of very detailed topographic base maps for the entire island with full contouring at an interval of 25 ft (7.5 m), amounting to 16 individual base sheets at a 1:5,000 scale. These maps were produced from extensive aerial photography and required over 300 ground control points to be established in the field (Petry, 2009).

In 2002, a set of cadastre laws for the year 2014 were developed. The GDLRC decided to undertake all of the cadastral studies of Turkey. The tasks associated with these studies are listed below:

1. Reconstituting the cadastre bases produced to date by applying the required transformation and adaptation steps to the national coordinate system in a digital format.
2. Producing new cadastral maps in the national coordinate system with the required accuracies.
3. Setting up a suitable geodetic network to produce these systems (Demir and Coruhlu, 2008).

Cadastral projects have been accelerated in recent years by the involvement of the private sector. This research project aims to complete the Turkish cadastre, with the property cadastre slated to be completely finished by the end of this year. Nevertheless, Turkey's cadastre has problems associated with the digitising base. The renewal project, in association with the private sector, is intended to solving problems associated with the non-digitised cadastral areas of the country. This project uses two methods: the 1:5,000 scale photogrammetric method and the digital (GPS and total station) method. The 1:5,000 scale maps are being investigated for suitability in rural cadastral mapping by Turkey's cadastral organisation.

The aim of this study is to determine if data from 1:5,000 scale photogrammetric map formats can be used for cadastral mapping and information systems. The 1:5,000 photogrammetric methods used are investigated for the position and area accuracy of the resultant cadastral bases. These results are then processed statistically. Finally, the existing status of the cadastral works and the problems of Turkish photogrammetric cadastre are described in detail.

Cadastral works and the cadastral process in Turkey

Cadastral works were carried out in the Ottoman Empire period to develop the early Turkish cadastral bases. With some exceptions, all of the Ottoman Empire was in state ownership. In the first year of the Turkish Republic, private ownership policies developed and were legislated by the Civil Law and Cadastre that was transferred from western countries. In the Turkish Republic, the institutional structure for the cadastral system, consisting of the Land Registry and Cadastre Directorates, was established in 1936. The first cadastral law of Turkey was the 'Land Title Law' of 1934.

According to this law, technical parts of cadastral works could be contracted to private individuals or legal entities in appropriate areas. Because of the increased need to register land parcels in the 1980s, the same article was put into the 1987 Cadastre Law. However, because of the lack of technical personnel and appropriate equipment, this article was not executed until 2004. At that time, the agricultural policy of 'direct income support' came into effect for farmers in Turkey. Because there was no accurate graphical data for agricultural parcels in some regions, there was an urgent need for cadastral work to support the policy. As a result, the law was put into practice. Only technical parts of the cadastre work were contracted to private surveyors in some areas as a pilot programme for the system. Today, cadastral work is being increasingly carried out by the private sector (Demir, 2000; Cete and Uzun, 2005).

The Turkish cadastral system was subdivided into two different cadastral periods based on the technical perspective: the written and linear cadastre periods. The written cadastre period refers to cadastral information explained in words instead of linear data. In the written cadastre, real estate boundaries were determined in land document with north, south, east and west ownership. The linear cadastre period can be subdivided into four types; graphic, classic, photogrammetric and electronic tachometry methods. Detailed information can be found in Demir et al., 2008, Demir and Çoruhlu, 2008 and Demir, 2000. It is possible to find that information the use of 1:5,000 scale photogrammetric for cadastral mapping as an subtitle.

The use of 1:5,000 scale photogrammetric data for cadastral mapping of Turkey

In Turkey, cadastral works have been conducted using five types of methods. Currently, the digital cadastral and photogrammetric cadastral methods are used for property cadastre applications as per cadastre law 3402. Table 1 summarises all of the cadastral maps produced using different production methods up to end of the 2007.

Table 1. Turkish cadastral maps according to the production method (Küllüoğlu, 2010).

No	Production method	Number	%
1	Digital	154.008	29.53
2	Polar	127.118	24.38
3	Graphic	95.943	18.40
4	Photogrammetric	83.116	15.94
5	Orthogonal	61.271	11.75
Total (end of the 2007)		521.456	100.00

Table 2. Turkish cadastral maps according to scale (Küllüoğlu, 2010)

No	Scale	Sheet number	%
1	1:500	27.704	5.31
2	1:1000	206.558	39.61
3	1:2000	133.575	25.62
4	1:2500	21.746	4.17
5	1:5000	126.885	24.33
6	Others	1776	0.96
Total (end of the 2007)		521.456	100.00

Table 2 documents map production according to scales.

Photogrammetric methods were used after the 1950s. These methods were frequently used to accelerate cadastral works. The photogrammetric method was used specifically in areas where the land cover and topography was suitable. Consequently, insensitive land titling work was carried out in the interior parts of the country. As a result, 1:5,000 scaled cadastral maps were produced for many parts of Turkey. These maps generally represented rural areas (İnam, 1999; Durduran, 1995), as can be seen from Tables 1 and 2. The 1:5,000 scale maps have a large usage percentage for cadastral mapping purposes in the Turkish Republic. Accelerating this process is a very important issue, but increasing accuracy is also paramount. Digital photogrammetry provides as a new solution, such as 1:2,000 and 1:1,000 scale photogrammetric maps.

METHODOLOGY

In this study, we used the original digital photogrammetric maps and control points. To measure the control points and parcel corner points, we used GPS. Maps and map information should be produced using a current coordinate system. The first goal of the study was to find an available control point and coordinate system within the study area. A total of 22 coordinate points in the project area were found. In addition, 42 new points were created to develop a measure of the parcel corner coordinates. After the creation of the new points, all of the points were measure using GPS devices. A 3D correspondence test was used for all of the photogrammetric controls and new points. Finally, all of the control point coordinates were transferred into the photogrammetric map measurement system because it is necessary to use the same coordinate system to compare GPS and photogrammetric parcel corner coordinates. Statistical formulas were used for the verification of the GPS and photogrammetric parcel corner coordinates in this study.

Study area

The Taskopru regions of the Kastamonu province were chosen for examination in this study. GDLRC produced 1:5,000 scale photogrammetric maps in the Taskopru region in 2007 using digital photogrammetric methods. Information for the photogrammetric maps is presented in Table 3. The study area consists of 35 villages that belong to the Taskopru district and the surrounding farming areas (Figure 1). The project area covers a total of 61,285 ha. All of the 1:5,000 scale photogrammetric maps were produced by GDLRC. The aims of this mapping effort were to create a property cadastre of the parcel corner coordinates. General information on the study area is presented in Table 3. In this study, two characteristic areas were determined and selected.

The first was the flat area that sloped between 0 and 10%. The second study area was hilly, with a slope of 11% and higher. Tables 4 and 5 show flat and hilly area information, including the sheet name, the evaluated parcel numbers and the village name.

The 1:5,000 scale photogrammetric data and the GPS data for the parcel corner coordinates in the study area were provided for this study. A total of 561 parcel corner coordinates were measured via GPS belonging to 119 parcels in the flat study area. In the hilly area, a total of 249 parcel corner coordinates were measured via GPS belonging to 63 parcels. In addition, all of the 1:5,000 digital photogrammetric maps have digital parcel corner coordinates.

Verification analysis used to produce cadastral data

The most important data in the determination of the accuracy of

Figure 1. Study area

Table 3. Photogrammetric map characteristics.

Projection	UTM
Datum	ITRF96
Elipsoid	GRS80
SMM	33°
DG	3°
Referans epoch	1998.00
Type	Digital

created cadastre bases are the coordinate values. The magnitude of differences in coordinates representing the same points gives the accuracy of the digital cadastre bases. In this analysis, the coordinates obtained from 1:5,000 digital photogrammetric sheets are called yp and xp, and the coordinates obtained from the land by actual GPS measurements are called yz and xz.

The εx and εy errors are calculated as in Equations (1) and (2) shown below, with the assumption that for a parcel corner point, the digitised coordinates of the point are in the same direction and approach the real values of coordinates whose land coordinates are digitised.

$$\varepsilon_y = y_p - y_z \quad (1)$$

$$\varepsilon_x = x_p - x_z . \quad (2)$$

Using these values, we developed Equations (3) and (4) below:

$$m_x = \pm\sqrt{\frac{[\varepsilon_x \cdot \varepsilon_x]}{n}} ,$$

$$m_y = \pm\sqrt{\frac{[\varepsilon_y \cdot \varepsilon_y]}{n}} ,$$

$$m_p = \pm\sqrt{\frac{[\varepsilon_x \cdot \varepsilon_x]+[\varepsilon_y \cdot \varepsilon_y]}{n}} \quad (3)$$

$$m_0 = \pm\sqrt{\frac{[\varepsilon_x \cdot \varepsilon_x]+[\varepsilon_y \cdot \varepsilon_y]}{2n}} , \quad (4)$$

where the mean error in the x direction (mx), the mean error in the y direction (my) and the mean square error (mp) are calculated. By assessing the εy and εx measurement differences for every sheet separately, we can determine whether they possess a normal distribution that is analysed by constructing error distribution histograms and by employing the χ^2 test (Çoruhlu, 2007; Inam, 2005; Demir and Çoruhlu, 2008).

The data sources could be analysed by comparing parcel corner points obtained from sheet and surveying results. The displacement value of parcel corner points is calculated as in Formula (5) from the differences of the points given in Equations (1) and (2). The mean error of εi is calculated as in Formula (6), where ms is the mean error of data obtained from land and sheet. The result of the calculation in Equation (7) is used to determine the size of the test.

$$\varepsilon_i = \sqrt{\varepsilon_{xi}^2 + \varepsilon_{yi}^2} \quad (5)$$

$$m_\varepsilon = s^2 = \frac{[vv]}{n-u} \quad (6)$$

$$T_i = \frac{|\varepsilon_i|}{m_\varepsilon} \quad (7)$$

Table 4. Information from the flat study area.

Number	Sheet name	Evaluated parcel numbers	Village name
1	F32-b-01-a	30	Olukbaşi
2	F32-b-02-a	32	Çambaşi
3	F32-b-07-b	22	Yeniler
4	F32-b-08-c	15	Kiliçli
5	F32-b-11-b	9	Eskioğlu
6	F32-d-10-b	11	Pirahmetli

Table 5. Information from the hilly study area.

Number	Sheet name	Evaluated parcel numbers	Village name
1	F32-a-20-c	15	Dağbelören
2	F32-b-16-d	10	Bekirli
3	F32-b-19-a	33	Alasökü
4	F32-d-04-d	5	K.Kalinkese

The theoretical standard deviation is a value that describes the main group, the numerical value of which can rarely be known. Consequently, if the real error ε is standardised by dividing by the experimental standard deviation rather than theoretical standard deviation, the random variable t_f is obtained (Demir and Çoruhlu, 2008).

$$t_f = \frac{|\varepsilon_i|}{m_\varepsilon} \tag{8}$$

The experimental standard deviation is calculated as in equation (9) from the real errors given the number of unknowns (Solak, 2010).

$$S^2 = \frac{[\varepsilon\varepsilon]}{n}, \quad S^2 = \frac{[vv]}{n-u} \tag{9}$$

T-table values are then compared with the calculated T value. According to the result of this comparison:

if $T_i \langle t_{f,1-\alpha}$ the variation in each parcel's corner points is harmonious

if $T_i \rangle t_{f,1-\alpha}$ the variation in each parcel's corner points is not harmonious.

RESULTS AND DISCUSSION

The difference between the parcel corner coordinate GPS measures and the photogrammetric measurement were determined. The results are discussed using statistical parameters that are not only the coordinate difference but also the area difference for the two study area types. For this reason, this section is subdivided into two parts: The first part consists of comparing parcel corner coordinates, and the shape depends on the photogrammetric and GPS parcel information and statistical tests for two types of the study areas. The second part is comprised of comparing area base information with the study area and the statistical information.

Comparing spatial base results and the statistical analysis of the study test fields

In this study, we developed two types of parcel corner coordinates for the study area. A total of 561 parcel corner coordinates were evaluated for 119 parcels on six sheets in the flat area. All of the GPS and photogrammetric corner coordinates were compared, and the differences and statistical information were calculated (Table 6). Table 7 shows the precision of the sheets on the flat area that depends on the all of the parcel corner coordinate differences and statistical events.

According to Table 5, the entire sheet spatial mean square error is approximately one metre. All of the x and y mean errors have the same numerical information. It is possible to see that the usable values for the 1:5,000 scale photogrammetric data depend on the statistical formulas.

Shifts, shrink and some rotations that occurred in the photogrammetric cadastral parcels are compared with GPS cadastral parcels in the national coordinate system using a Computer Aided Design (CAD) environment. The actual mean square error values are given in Table 7. Here the aim is to provide a graphical representation of the cadastral parcels that is measured using photogrammetric and GPS methods. Figure 2 compares cadastral parcels coming from two different methods.

As seen from the small part of sheet F32-b-01-a in Figure 2, there are only small problems associated with the parcel corners, but there is problem with the border (black arrow) on the sheet. This particular problem is

Table 6. Summary of compared corner coordinates for sheet number F32-b-01-a.

City : Kastamonu
Town : Taşköprü
Sheet : F32-b-01-a
Village : Olukbaşi

m_ε= **0.99**

No	Sheet		GPS		Difference		$(\varepsilon_{yi})^2$	$(\varepsilon_{xi})^2$	Vi	Ti	Decision
	y_p (m)	x_p (m)	y_z (m)	x_z (m)	ε_{yi}	ε_{xi}					$t_{\infty,0.95}$=1.96
1	604490.60	4594869.38	604491.71	4594868.22	-1.11	1.16	1.23	1.34	1.60	1.62	Matching
2	604503.31	4594868.09	604503.12	4594867.61	0.19	0.48	0.04	0.23	0.51	0.52	Matching
3	604526.54	4594868.58	604525.85	4594867.34	0.69	1.24	0.48	1.53	1.42	1.43	Matching
4	604547.92	4594866.90	604548.17	4594866.02	-0.25	0.88	0.06	0.78	0.92	0.93	Matching
5	604553.83	4594841.61	604554.34	4594840.66	-0.51	0.95	0.26	0.90	1.08	1.09	Matching
6	604569.90	4594754.24	604570.34	4594753.59	-0.44	0.65	0.20	0.42	0.78	0.79	Matching
7	604579.90	4594711.86	604580.42	4594711.67	-0.52	0.19	0.27	0.04	0.55	0.56	Matching
8	604589.77	4594684.84	604589.50	4594683.60	0.27	1.24	0.07	1.54	1.27	1.28	Matching
9	604612.35	4594612.43	604611.54	4594612.03	0.81	0.40	0.65	0.16	0.90	0.91	Matching

Table 7. Sheet precision of the flat study area.

Sheets	n	$[\varepsilon_x.\ \varepsilon_x]$	m_x (m)	$[\varepsilon_y.\ \varepsilon_y]$	m_y (m)	m_o (m)	m_p (m)
F32-b-01-a	139	75.45	± 0.74	59.60	± 0.65	± 0.70	± 0.99
F32-b-02-a	99	54.02	± 0.74	38.21	± 0.62	± 0.68	± 0.97
F32-b-07-b	64	28.42	± 0.67	32.04	± 0.71	± 0.69	± 0.97
F32-b-08-c	143	51.89	± 0.60	42.98	± 0.55	± 0.58	± 0.81
F32-b-11-b	73	20.17	± 0.53	25.22	± 0.59	± 0.56	± 0.79
F32-d-10-b	43	14.23	± 0.58	16.10	± 0.61	± 0.59	± 0.84

n: number of parcel corner coordinates

probably operator error in plotting the parcels. Another example for the flat is shown in Figure 3. Generally, the same coordinate difference appears based on the measurement and statistical results. All of the corner coordinates are harmonious given the results of the statistical test. Nevertheless, we have two border problems in this example (green and black arrows). One extra border has a GPS point, and the other one is a photogrammetric result. The photogrammetric measurement was taken in 2007, and the GPS measurement was taken in 2009. This problem is probably arising from the different times of measurement. In other words, different frames were sampled at different times.

The 1:5,000 scale photogrammetric cadastral maps have ± 1.5 to ± 2.5 m precision range for parcel corner coordinates (Erdi et al., 1996). In this particular sheet describing the flat area, there is no problem with the parcel corner coordinates. An issue that does exist, however, is that there are no landmarks at the parcel corner coordinates for photogrammetric measurement, a situation that is sometimes known to cause undetermined borders.

The other study area type is the hilly area. Table 8 compares the coordinate difference between photogrammetric and GPS methods along with statistical information. Information on the precision of the sheets in the hilly areas is presented in Table 9. This information shows the mean square error for the parcel corner coordinates on the hilly area.

According to Table 9, the total of all of the sheet spatial mean square errors is approximately 120 cm. As indicated, the mean square and root mean square difference indicated the same values between the flat and hilly areas. The flat area has a high parcel corner coordinate precision level in accordance with the hilly area, meaning that photogrammetric solutions have a problem with this topography.

Shifts shrink and some rotations occurred in the photogrammetric cadastral parcels from the hilly area when they were compared with the GPS cadastral parcels from the national coordinate system in a CAD environment. The actual mean square error values are given in Table 9. A graphical representation of the cadastral parcels that was measured photogrammetric and with GPS methods

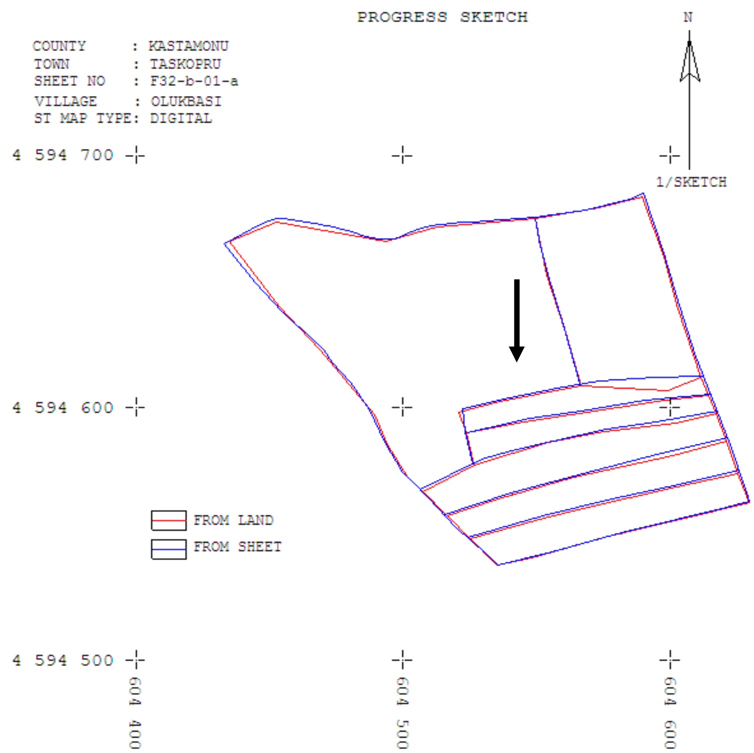

Figure 2. Superimposed cadastral parcels on one part of sheet number F32-b-01-a using a CAD environment.

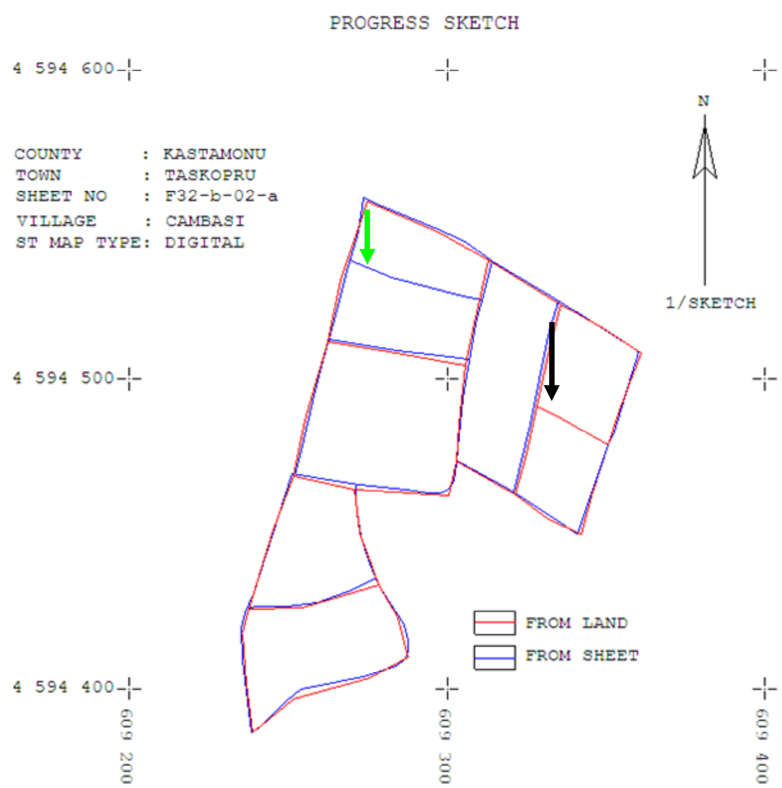

Figure 3. Superimposed cadastral parcels on the one part of sheet number F32-b-02-a using a CAD environment.

Table 8. A summary comparing corner coordinates for sheet number F32-b-19-a.

City : Kastamonu
Town : Taşköprü
Sheet : F32-b-19-a
Village : Alasökü

m_ε= **1.28**

No	Sheet		GPS		Difference		$(\varepsilon_{yi})^2$	$(\varepsilon_{xi})^2$	Vi	Ti	Decision
	y_p (m)	x_p (m)	y_z (m)	x_z (m)	ε_{yi}	ε_{xi}					t∞,0.95=1.96
1	618639.39	4579615.60	618638.52	4579615.94	0.87	-0.34	0.75	0.12	0.93	0.73	Matching
2	618684.98	4579646.03	618686.17	4579644.92	-1.19	1.11	1.41	1.24	1.63	1.27	Matching
3	618700.33	4579640.43	618701.53	4579641.50	-1.20	-1.07	1.44	1.13	1.61	1.25	Matching
4	618733.09	4579664.05	618731.98	4579663.31	1.11	0.74	1.23	0.55	1.34	1.04	Matching
5	618779.54	4579702.16	618780.85	4579701.52	-1.30	0.64	1.70	0.41	1.45	1.13	Matching
6	618813.81	4579638.64	618815.27	4579638.44	-1.46	0.20	2.12	0.04	1.47	1.15	Matching
7	618836.91	4579654.63	618838.00	4579654.98	-1.09	-0.35	1.19	0.12	1.15	0.89	Matching
8	618891.89	4579681.78	618890.58	4579681.99	1.31	-0.21	1.73	0.04	1.33	1.04	Matching
9	618857.72	4579755.01	618858.87	4579755.46	-1.15	-0.45	1.32	0.20	1.23	0.96	Matching
10	618891.38	4579761.30	618892.57	4579760.22	-1.19	1.08	1.42	1.16	1.61	1.26	Matching

Table 9. Sheet precision for the hilly study area.

Sheets	n	[Vx.Vx]	mx (m)	[Vy.Vy]	my (m)	mo (m)	mp (m)
F32-a-20-c	45	37.97	± 0.92	34.26	± 0.87	± 0.90	± 1.27
F32-b-16-d	96	63.06	± 0.81	71.71	± 0.86	± 0.84	± 1.18
F32-b-19-a	58	34.91	± 0.78	60.56	± 1.02	± 0.91	± 1.28
F32-d-04-d	50	43.48	± 0.93	33.36	± 0.82	± 0.88	± 1.24

is presented in Figure 4 comparing cadastral parcels from two different methods.

There was a large problem when comparing the flat areas derived from the two different methods, as seen in the small part of sheet F32-b-19-a (Figure 4), indicating two problems: the spatial difference of the some parcels (green arrow) and the lack of subdivided parcels on the photogrammetric parcels (blue arrows). Subdividing problems are similar in the flat area, which is likely due to an error from different times of measurement. The spatial corner coordinate problems depend on the undulated topography that comes from mapping procedure of the photogrammetry, which depends on the height accuracy.

Comparing area based results and statistical analysis of the study test fields

The area base results for the two types study areas are the same as in the previous section. In the flat area, all of the parcels areas were calculated using the CAD environment. Area error limit formulas for the photogrammetric sheet are shown in formula 10. In this formula, f is the error limit, M is the denominator of the scales and F is the parcel area. All of the parcel area error limits were calculated and interpreted, and some of the examples can be seen Table 10.

$$f = 0.0004M\sqrt{F} + 0.0003F \quad (10)$$

As seen in Table 10, there was a problem with some of the parcel areas. In the flat study area, there are 119 cadastral parcels, 23 of which have problems with error limits. Although only a few corner coordinates had problem error limits, a large percentage of areas have error limits, meaning that statistical methods should be used to investigate not only coordinates but also the areas. Additional statistical information is given in Table 11.

The flat area cadastre bases that were created separately with land and sheet observations were statistically assessed. Accordingly, statistical data that belong to the differences of the processed point in x and y directions were obtained. In this study, the Mann-Wald statistical test was selected; this test has an error probability $\alpha = 0.05$ (γ = max) for the testing creating values.

After computing the mean values of the data, the mean error of individual observations, the number of classes, the theoretical values of relative class accumulations and the theoretical class accumulations, the Φ (Z_i) values

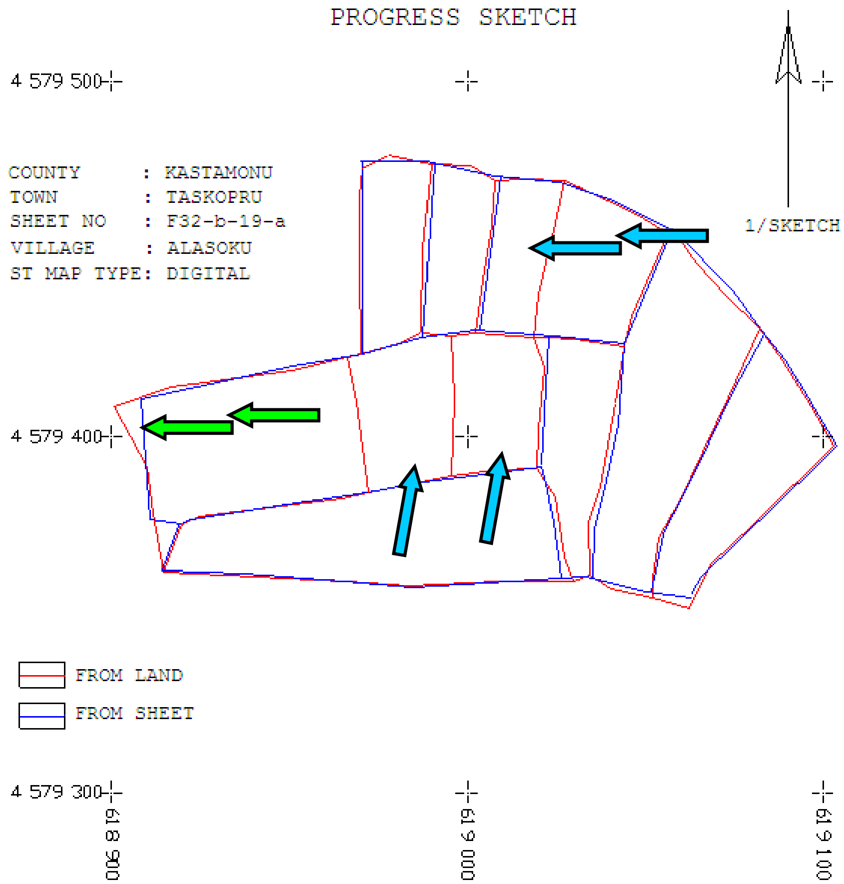

Figure 4. Superimposed cadastral parcel on one part of sheet number F32-b-19-a using a CAD environment.

Table 10. Comparing with the parcels area on sheet F32-b-01-a.

City	: Kastamonu
Town	: Taşköprü
Sheet	: F32-b-01-a
Village	: Olukbaşi

Parcel No	F sheet (m^2)	F GPS (m^2)	ΔF (m^2)	Formula criteria (m^2)	Control
1	1399.49	1315.07	84.42	72.92	No significant
2	1347.63	1329.22	18.40	73.32	Significant
3	1605.12	1596.40	8.72	80.39	Significant
4	899.89	895.63	4.26	60.12	Significant
5	862.32	742.82	119.50	54.73	No significant
6	7875.84	7768.76	107.08	178.61	Significant
7	3074.21	3175.14	-100.93	113.65	Significant
8	6188.17	6170.87	17.31	158.96	Significant
9	4593.51	4623.43	-29.92	137.38	Significant
10	5442.32	5442.82	-0.50	149.18	Significant

were calculated by preparing a table for each set of coordinate differences in the directions of the x and y axes for each sheet. The Z_i values corresponding to these values were taken from a standardised normal

Table 11. Relationship between areas and error limits in the flat study area.

Sheet	Inside the error limit				Total		Relative error (Difference/Area)
	Yes		No				
	P.S	%	P.S	%	P.S	%	
F32-b-01-a	25	83.33	5	16.67	30	100.00	1/136
F32-b-02-a	25	78.13	7	21.87	32	100.00	1/181
F32-b-07-b	18	81.82	4	18.18	22	100.00	1/93
F32-b-08-c	11	73.33	4	26.67	15	100.00	1/67
F32-b-11-b	7	77.78	2	22.22	9	100.00	1/45
F32-d-10-b	10	90.91	1	9.09	11	100.00	1/319
TOPLAM	96	80.67	23	19.33	119	100.00	1/112

P.S: Parcel number.

Table 12. Statistical results based on the flat area.

Sheet	Calculation (X_o^2)		Table (X_o^2)		Decision	
	y	x	y	x	y	x
F32-b-01-a	16.61	9.16	19.66	19.66	Harmonious	Harmonious
F32-b-02-a	7.55	13.85	16.90	16.90	Harmonious	Harmonious
F32-b-07-b	19.88	9.91	15.49	15.49	Not Harmonious	Harmonious
F32-b-08-c	13.35	14.33	19.66	19.66	Harmonious	Harmonious
F32-b-11-b	8.82	11.23	15.49	15.49	Harmonious	Harmonious
F32-d-10-b	4.51	5.77	12.57	12.57	Harmonious	Harmonious

distribution tables. Class boundaries xi and test values χ_0^2 were computed and the results were interpreted. The tables formed for each of the sheets are summarised in Table 12.

The statistical results related to the land and sheet cadastre bases are given Figure 5, in which histograms of frequencies and normal distribution curves of the histograms are shown.

Normal P-Plot graphics show the cumulative rates of a variable against the cumulative rates of the normal distribution and are depicted next to each of the histograms. The goal here is to determine where the normal distribution curve of variables is gathered. For sheet F32-b-01-a, it was determined that the ε_y distribution suits the normal distribution with 95% confidence, with a statistical value of χ_0^2 = 16.61. The εx distribution suits the normal distribution with 95% confidence and a statistical value of χ_0^2 = 9.16. The approximation of variables to the normal distribution curve according to the P-Plot tests is shown in Figure 5.

The hilly area study results and statistical results are given in Tables 13, 14 and 15. The other information regarding the hilly area can be seen in Figure 6. For sheet F32-b-19-a, it was determined that the ε_y distribution fits the normal distribution with 95% confidence, with a statistical value of χ_0^2 = 4.51, and the ε_x distribution fits the normal distribution with 95% confidence, with a statistical value of χ_0^2 = 6.60. The approximation of the variables to the normal distribution curve is shown in Figure 6 with P-Plots.

One of the y axes in the flat area and one of the x axes in the hilly area has a problem and is not harmonious. There are also area problems for the photogrammetric map parcels. Although a high percentage of the parcel corner coordinates are matching, sheet areas and axes present some problems, as seen in the previously presented tables in the Results and Discussion section. These problems arise from a lack of control points and the limited distribution of the control points within the study area for photogrammetric mapping. For this reason, it is important to use the control points for evaluating photogrammetric maps and map accuracy. It is also possible to use photogrammetric maps for cadastral mapping after a revision of the non-harmonious data.

Conclusion

Cadastral information is a basis for maps and is very important for many applications, including subdivision, zoning plan applications, special map making and property ownership rights. For this reason, cadastral parcel accuracy is a fundamental process. The 1:5,000 scale photogrammetric maps produced by GDLRC and

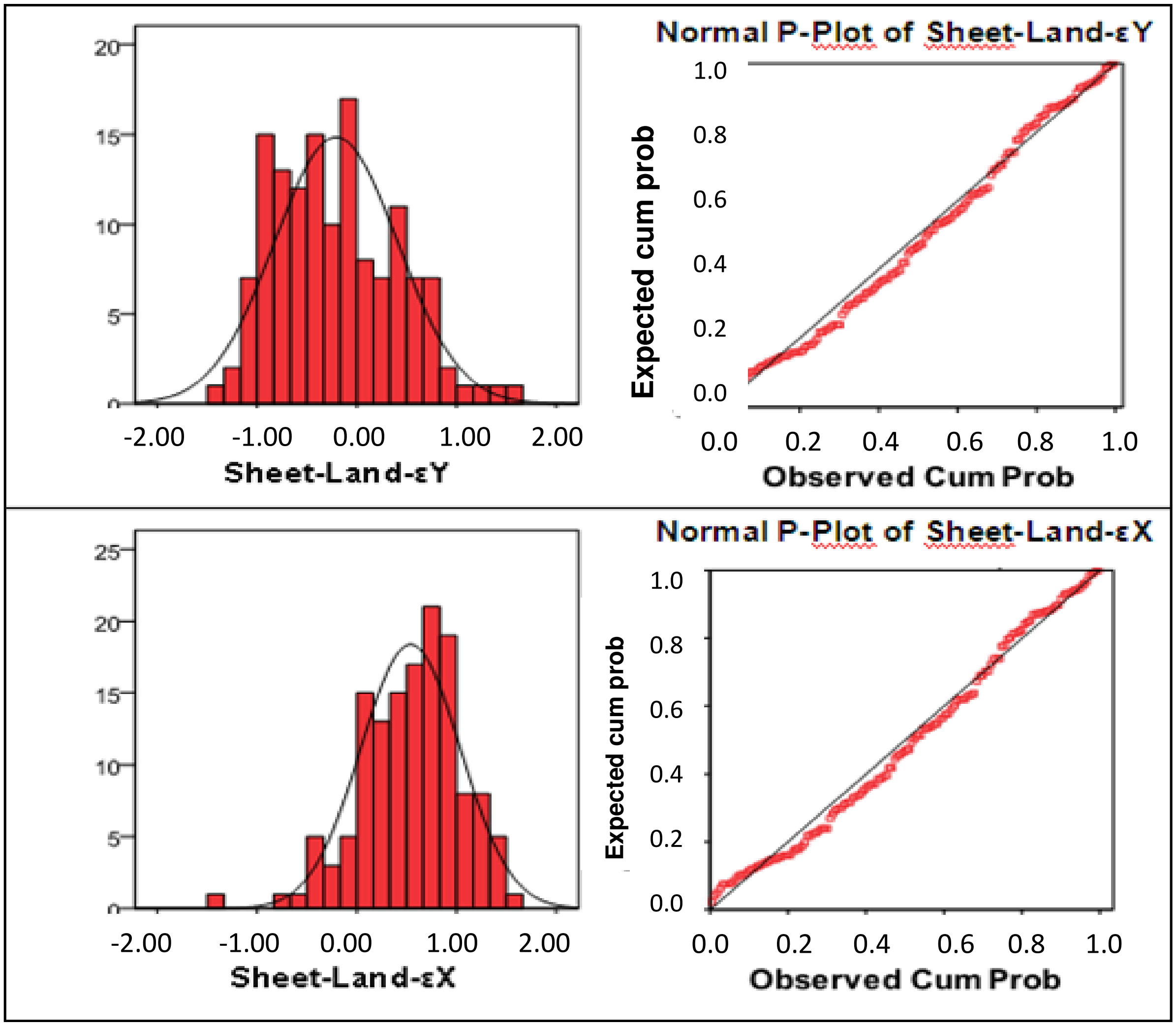

Figure 5. Coherence of the coordinate difference of sheet F32-b-01-a to the normal distribution.

Table 13. Comparing with the parcels area on the F32-b-19-a sheet.

City : Kastamonu
Town : Taşköprü
Shett : F32-b-19-a
Village : Alasökü

Parcel No	F Sheet (m^2)	F GPS (m^2)	ΔF (m^2)	Formula criteria (m^2)	Control
1	1464.73	1601.31	-136.58	80.51	No significant
2	2655.74	2571.00	84.74	102.18	Significant
3	3743.08	3856.17	-113.10	125.35	Significant
4	3283.58	3406.35	-122.77	117.75	No significant
5	1479.03	1502.11	-23.08	77.96	Significant
6	1855.36	1712.75	142.61	83.28	No significant
7	1327.32	1299.91	27.40	72.50	Significant
8	4479.71	4480.09	-0.39	135.21	Significant
9	2606.54	2548.18	58.36	101.72	Significant
10	2438.65	2616.66	-178.01	103.09	No significant

Table 14. Relationship between the areas and the error limits in the hilly study area.

Sheet	Inside the error limit				Total		Relative error (Difference/Area)
	Yes		No				
	P.S	%	P.S	%	P.S	%	
F32-a-20-c	3	20.00	12	80.00	15	100.00	1/125
F32-b-16-d	4	40.00	6	60.00	10	100.00	1/114
F32-b-19-a	24	72.72	9	27.28	33	100.00	1/73
F32-d-04-d	2	40.00	3	60.00	5	100.00	1/349
TOPLAM	33	52.00	30	48.00	63	100.00	1/189

P.S: Parcel number.

Table 15. Statistical results based on the hilly study area.

Sheet	Calculation (X_o^2)		Table (X_o^2)		DECISION	
	y	x	y	x	y	x
F32-a-20-c	4.09	3.12	11.05	11.05	Harmonious	Harmonious
F32-b-16-d	11.11	22.72	15.49	15.49	Harmonious	No Harmonious
F32-b-19-a	4.51	6.6	12.57	12.57	Harmonious	Harmonious
F32-d-04-d	11.89	5.57	12.57	12.57	Harmonious	Harmonious

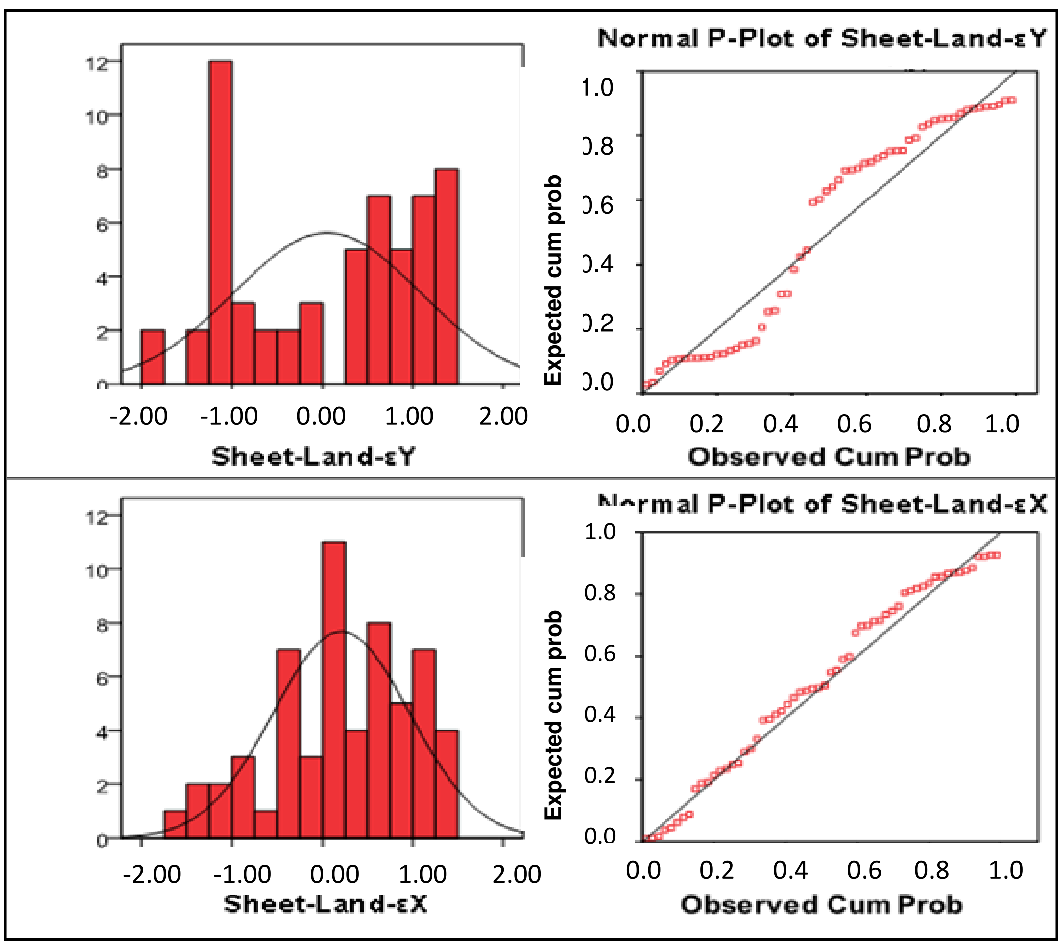

Figure 6. Coherence of the coordinate difference of sheet F32-b-19-a to the normal distribution.

the Photogrammetry and Geodesy Department Presidentship were originally created for cadastral mapping in Turkey. In this study, the goal was to determine if 1:5,000 scale photogrammetric maps are useable for cadastral mapping and information systems. According to these aims, we created new GPS point coordinates for the parcel corners and photogrammetric parcel point coordinates to compare with the GPS coordinates. Then we calculated the error limits of the coordinates and areas for the cadastral parcels to determine if they are compatible with the photogrammetric data.

As indicated by the results of the statistical test, accuracy analysis could be achieved for all of the points within the study area. With respect to this analysis, spatial errors associated with corner points ranged between 0.00 and 1.96 m for the flat area, while errors for spatial areas ranged between 0.03 and 2.31 m. Although all parcel corner coordinates are harmonious in the hilly area, 0.53% of the flat area coordinates are not harmonious. The overall spatial accuracy per sheet can be seen in Tables 7 and 9. Spatial accuracy ranged between ± 0.56 and ± 0.70 m for the flat area and between ± 0.84 and ± 0.91 m for the hilly area.

The statistical results of the 1:5,000 scale photogrammetric maps had some problems when the entire study area was taken into consideration. These problems are due to a lack of control points, the distribution of the control points, unknown parcel corners, undetermined borders, operator mistakes and the mid-range accuracy of some applications. It is possible to improve the quality of maps by creating some extra corner signs before the photographic flight. Because operator knowledge is very important for quality and precision in photogrammetry, remote sensing application improvements to accuracy can be made by increasing operator knowledge of the study and sample area. Finally, it can be said that 1:5,000 scale photogrammetric maps are generally useful for cadastral mapping in rural and forest areas, but the 1:5,000 scale is not accurate enough for city mapping. For this reason, 1:2,000 or 1:1,000 scale photogrammetric maps should be used for surveys of city centres and other densely populated areas. It is not possible to improve the accuracy of the 1:5,000 scale maps, and therefore, the 1:1000 scale maps should be useful for high precision requirements.

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