Analysis of the Usability of the Maps from the Former Cadastre of Lands in Terms of Parcels Area Registered in the Cadastral Documentation

Silvia GAŠINCOVÁ[1], Juraj GAŠINEC[2], Ľubica HUDECOVÁ[3], Pavel ČERNOTA[4], Hana STAŇKOVÁ[5]

[1] Assoc. prof., MSc,; Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Košice, Institute of Geodesy, Cartography and Geographical Information Systems, Park Komenského 19, 04001 Košice, Slovak Republic; tel.: +42155 602 2846, email: silvia.gasincova@tuke.sk,
[2] Assoc. prof. MSc.; Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Košice, Institute of Geodesy, Cartography and Geographical Information Systems, Park Komenského 19, 04001 Košice, Slovak Republic; tel.: +42155 602 2846, email: juraj.gasinec@tuke.sk,
[3] MSc.; Department of Surveying, Faculty of Civil Engineering STU in Bratislava, Radlinského 11, 810 05 Bratislava, Slovak Republic; tel.: +421 59 274 530, email: lubica.hudecova@stuba.sk
[4] Assoc. Prof. MSc.; Faculty of Mining and Geology, VŠB – Technical University of Ostrava 17.listopadu 15/2172 708 33, Ostrava-Poruba, Czech Republic; tel.: +420 597 321 234, email: pavel.cernota@vsb.cz,
[5] Assoc. prof, MSc.; Faculty of Mining and Geology, VŠB – Technical University of Ostrava 17.listopadu 15/2172 708 33, Ostrava-Poruba, Czech Republic,, 17.listopadu 15/2172 708 33, Ostrava-Poruba, Czech Republic; tel.: +420 597 321 299, email: hana.stankova@vsb.cz

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Abstract

Contents of the present paper is to analyze the useful of maps of the cadastre in terms of accuracy recorded in cadastral documentation and elaborates on the territory of the Slovak Republic and specifically selected cadastral area analyzes and quantifies the geodetic village known, but the general public is not quite obvious causes of changes in plot areas related to climate projection imaging planes to land cadastral maps made in different map projections. The aim of this paper is the changes in the Slovak Republic to quantify, describe a clear mathematical dependence and point out that this issue can not be accessed across the board.

Keywords: cadastre of real estates, cadastral documentation, cadastral map, stereographic projection, Křovák´s projection

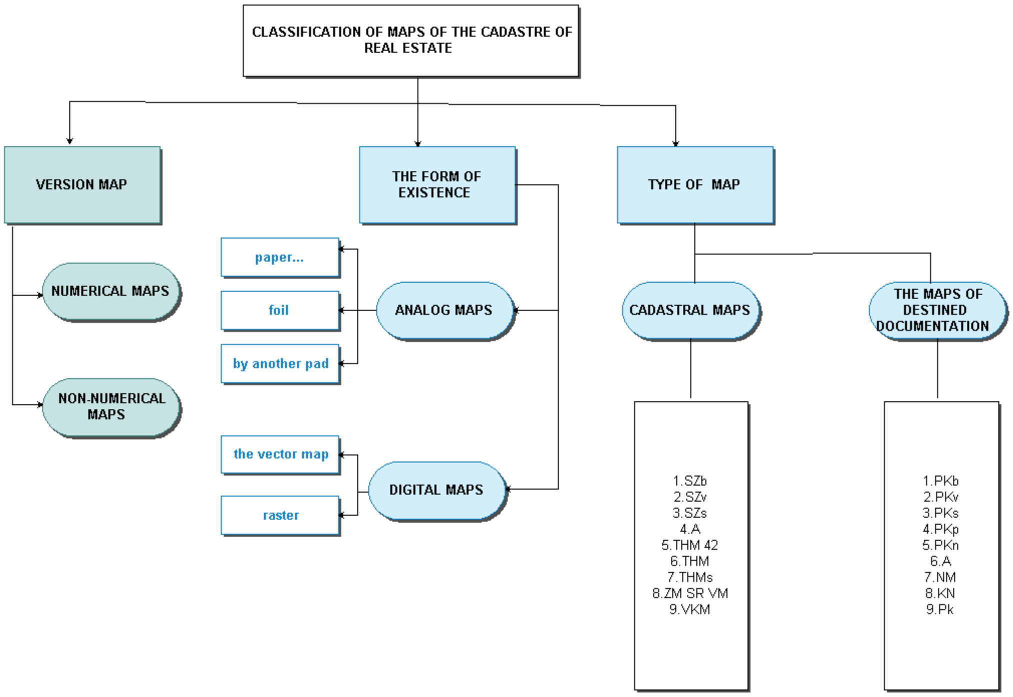
Introduction

The cadastre of real estates (hereinafter referred to as „the cadastre“) is the geometrical determination, registration and description of real estates. The cadastre contains the data on the rights to the real estates, namely on the ownership right, lien, easement rights, the right of pre-emption if it should have the effect of lien, as well as the data on the rights arising from the administration of the state property, or the property of municipality, or the administration of assets of higher territorial units, on the tenancy rights to land if they last or have lasted at least 5 years (hereinafter referred to as „the right to the real estates“) [10]. The Real Estate Cadastre in the Slovak Republic is currently modified by the Act of the National Council of the Slovak Republic No. 162/1995 [10] on the real estate cadastre and the entries of ownership andother property rights to the real estates (Cadastral Act), as amended. Cadastre consists of cadastral documentations arranged by cadastral units. Cadastral documentation consists of a file of geodetic information and a file of descriptive information by land registry, the content and structure is defined by executive regulation to the Act on Land Registry. The main part of the geodetic information file is exactly cadastral map. This is a planimetric map of a large scale, which is primarily used for the registration of real estate and the geometrical determination – that display on the cadastral map. The current cadastral maps are drawn up in Křovák´s universal conformal conical projection with the coordinate system – Datum of Uniform Trigonometric Cadastral Network.

Categorization of the cadastre maps

According terminological dictionary [8] is defined as a cadastral map planimetric large scale map, showing all properties and land area registered in cadastre. Land in the cadastral map shows the projection of its borders to the image plane and become parcel number and the types of lands. Given the fact that the mapping in our country was going through long-term development in the land registry documentation can meet with different kinds of maps, ie copy maps in various cartographic distortion and using different technologies surveying work. In terms of forms of existence, according to the embodiment of origin and cadastral maps can be categorized as follows (Fig. 1.).

The paper is devoted to the quality and usability of the former land registry maps to the territory of Slova-



Legend:

- *SZb – a coherent projection with non defined coordinate system, the original maps drawn up in years 1856 - 1863,*
- *SZv – maps created in a cylindrical projection (Fasching coordinate system), the original maps drawn up in years 1908 to 1927,*
- *SZs – stereographic projection, the original maps drawn up in years 1864 - 1927,*
- *A – the original cadastral map in S-JTSK drawn up in years 1928 - 1950 according to the instructions A for cadastral surveying work,*
- *THM 42 – the technic-economical map (Gauss-Krüger projection),,*
- *THM – technic-economic map created S-JTSK without calculating coordinates of detailed points,*
- *THMs – the technic - economic maps created S-JTSK of calculating the coordinates of detailed points of directly measuring the extent,*
- *ZM SR VM – the large scale base map,*
- *VKM – the vector cadastral map,,*
- *PKb – the original land registry map (non-defined projection),*
- *PKv – the original land registry map (Fasching projection),*
- *PKs – the original land registry map (stereographic projection),*
- *PKp – taken over land cadastre map,*
- *PKn – sketch cadastral, which was created downloading map of land consolidation or other unsatisfactory precision within cadastre temporary correction after 1933,*
- *A – the original cadastral map according to the instructions A for cadastral surveying work,*
- *NM – maps created in uniform land registry,*
- *KN – cadastral map,*
- *Pk – land registry map.*

Fig. 1. Categorization of the cadastre maps
Rys. 1. Kategorie map katastralnych

kia issued in the stereographic projection and Fasching projection. Using the example of a specific cadastral area is pointed out how the exhibit patterns of distortion in mathematical cartography plot areas that are displayed on the maps of this kind.

The quality of a cadastral map

The quality of maps is generally assessed based on the accuracy of the maps. Map accuracy is the precision and accuracy of mapping graphics, possibly accurate maps. Accuracy is assessed by standard error values and limit deviations, which represent the criteria for punctuality [4].[6], [11].

The quality of existing cadastral maps

The current maps recorded in the cadastral documentation are drawn in a Datum of Uniform Trigonometric Cadastral Network in altitude and the Baltic Vertical Datum – After Adjustment (BPV). Geometric fundamentals of of these maps are survey control point STN 73 0415 [7]. Characteristic of positional accuracy display detailed maps points in graphical form the map is a basic mean coordinate error m_{xy} (1), where m_x and m_y are The basic mean errors display the point on the basis of the resulting coordinates, in the direction of the coordinate axis *x* and *y*. The detailed points must be displayed so that the characteristic accuracy of the display m_{xy} does not exceed the standard value of 0.16 mm on the map.

$$m_{xy} \doteq \sqrt{0,5(m_x^2 + m_y^2)} \tag{1}$$

Characteristic of relative accuracy of determining säradníc *x*, *y* pair of detailed points is the basic standard error of *d* m_d directly connecting the following points calculated from coordinates. Coordinates of detailed points must be designed so:

- charakteristic of mxy not exceed criterion u_{xy} (Tab. 1),
- charakteristic of md not exceed criterion u_d (2),

$$u_d = 1,5.\frac{d+12}{d+20}.u_{xy} \tag{2}$$

Tab. 1. The class of precision of survey
Tab. 1. Klasy dokładności badania

The class of precision	u_{xy} (m)
1.	0,04
2.	0,08
3.	0,14
4.	0,26
5.	0,50

Tab. 2. Quality point of the detailed geodetic control
Tab. 2. Jakość punktów szczegółowej kontroli geodezyjnej

code	
1	Numerically defined point in the Datum of Uniform Trigonometric Cadastral Network (m_{xy} = 0,08 m).
2	Numerically defined point in the Datum of Uniform Trigonometric Cadastral Network without any real stabilization in the terrain (m_{xy} = 0,08m).
3	Numerically defined point in the Datum of Uniform Trigonometric Cadastral Network through terrestrial surveying methods of connecting to actively geodetic basics (m_{xy} = 0,14 m).
4	Numerically defined point in the Datum of Uniform Trigonometric Cadastral Network through terrestrial surveying methods without an active geodetic basics (m_{xy} = 0,26 m).
5	Numerical determination of point coordinates of the point designated cartometrically (m_{xy} without distinction).

Precision of the mapping is divided into precision classes 1–5. Cadastral maps are made in the 3rd or 4th class of precision. Fourth class of precision is used, for example. in mapping forest land or using photogrammetric mapping method.

In the Slovak Republic has in any cadastral unit managed by the cadastral map in vector format, while the quality of data in a map depends precisely on how it is produced. Data quality is characterized by the so-called. quality code, [9] defined and this information is provided for users in the content not only maps, but also indications provide a basis of documentation land registry.

From the point of view of quality [2], [3] in the real estate cadastre we distinguish four types of vector cadastral map:

- vector cadastral map with quality code 1: generally, these are maps that were created as a result of field measurements, or by redesigning the resulting map with numerical results,
- vector cadastral map with quality code 2: created by vectorizing a numeric map based on the coordinates of the detailed points determined by cartometry from the map in a paper form,
- vector cadastral map with a quality code 3: basically it is a map that created the digitization of non-numeral maps of the cadastre,
- vector cadastral map with quality code 4: created by digitizing a map that is not created on a mathematical basis (step maps, sketches without scale, etc.).

The individual detail points of the cadastral maps are designed with a precision that was based on the measurement method applied, the physical environment and of course the instrumentation used [11]. Measurement accuracy in geodetic practice normally characterized by a mean co-ordinate error mxy (1). In terms of value of this error it is therefore every detailed point of a certain quality, which in vector format cadastral map reflects the so-called. The quality of a detailed code of (T) (Tab. 2).

The quality maps of the former land registry

The first mapping carried out for the cadastre was in our area (the former Austria-Hungary) carried out in years 1817–1861, Slovakia began to charting since 1894 and the maps drawn at a scale of 1 : 2880 formed the basis of so-called. a stable cadastre. Except for a small part of the area shown in the so-called. Non ddefined coordinate system, the majority of the first cadastral maps on the territory of Slovakia made in stereographic projection and the Faschingovom (cylindrical) projection. It is these kinds of maps refer to as the former land registry maps. Of course, time was for "unification" Maps in opera cadastre these maps at scale, updated, or redrawn maps as a coherent view and some have converted to vector - digital form, but their origin, precision and scale of these modifications have not changed.

The quality maps drawn up in non defined projection and stereographic coordinate system

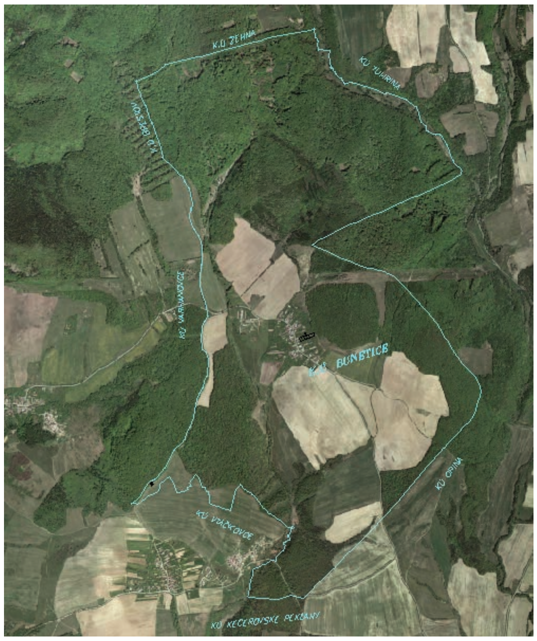


Fig. 2. The orthophotomap of the cadastral unit of Bunetice
Rys. 2. Ortomapa katastralna jednostki katastralnej Bunetice

The non defined coordinate system was used in mapping within the stable cadastre, which was founded by patent dated 27.12.1817, as a display and an inventory of all land according to Bern municipalities uniformly throughout the territory. Mapping was chosen Cassini´s projection (cylindrical transversal projection) reference area was chosen Zachow ellipsoid. To derive the mapping scale 1: 2880.

Positional accuracy:

– it is given by the projection (nonconformist) and trigonometric network.

– failure to comply with projection – indefinable measuring length bias,

– trigonometric network – insufficient settlement

– the accuracy of the analyzes are not known,

– deformation can be expected about 2–5 meters in position shifts and rotations of the entire network.

Geometric accuracy:

– by determining the ratio of 1/200 (length measured from the maps it could not differ more than 1/200 of the length of the measured in terrain of declination,

– given the scale of the map 1: 2880 is for small lengths can not be done, nor show:

- 5m lenght = +/- 0,025 m , 0,1 mm on the map = 0, 29m,
- 10m lenght = +/- 0,05 m , 0,1 mm na mape = 0, 29m,
- 100m lenght = +/- 0,50 m.

Mapping of stereographic projection introduced on the territory of former Hungary a Czech surveyor Horský in relation to more accurate trigonometric network. This is the double conformal azimuthal see the general location (ellipsoid – sphere – plane), to calculate the Bessel ellipsoid. Start plane system chosen at trigonometric point Gellérthegy and reflected on her territory of Hungary from the opposite surface of the reference point on the of the Gauss sphere.

Positional accuracy:

– is given by the projection (conformal) and trigonometric network,

– definable measuring scale error- but large (0.5 cm to 20 km),

– trigonometric network : quality adjustment,

– deformation can be expected about 2–3 meters in position.

Geometric accuracy:

– same non defined projection.

The quality of maps drawn up by Fasching projectioní

Positional accuracy:

– is given by the projection (conformal) and trigonometric network,

– definable scale error- reduced compared stereographic projection.

Geometric accuracy presnosť:

– method of surveying community table : accuracy same stereographic projection,

– when using the polygon method - comparable with the 3rd class of precision.

An example of quality analysis of maps of the former land registry

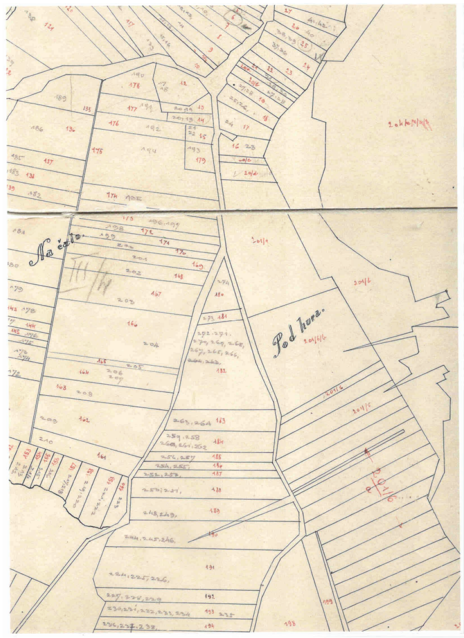


Fig. 3. Example of original maps of the cadastral unit of Bunetice
Rys. 3. Przykład oryginalnej mapy katastralnej jednostki Bunetice

Reconstruct the original quality of the land cadastre maps is quite difficult if the map does not contain plot of construction, respectively. others still preserved buildings on the basis of which it would be possible by direct measurement in terrain of declination to assess the quality maps according to the indicators defined in STN 01 3410 [6] for basic and special maps. In other words, if the map contains only land registry plot of land parcels, where the fracture points are not preserved in terrain of declination. Process re-derivation of the original conjecture precision geodetic and cartographic works will be demonstrated on the example of the cadastral area of Bunetice (Fig. 2.).

Characteristics of the cadastral unit:
Cadastral unit: Bunetice (807 435)
Region: Košický, District: Košice – okolie (806),
Area: 835 36 27 m2

The cadastral unit of Bunetice with listed area of approximately 835.3 hectares is currently under the responsibility of the Department of Cadastral District Office Košice-okolie. Prior to the declaration of validity ROEP (register of renewed land registration) was in the administrative area Bunetice valid cadastral map of the former land registry and ownership of the property was registered in the land register. For example of original cadastral map (Fig. 3) are shown in red numbers of the original parcels so. local parcel numbers, property rights in these parcels were registered in the land register, in its pozemkovoknižných liner. Blacks are given parcel numbers of these plots registered in the register E cadastral land registry, while the ownership of the property are currently registered on the ownership. Fig. 4 is an example of cadastral maps in vector form which is from the declaration in 2011 ROEP binding cadastral graphical material. Sivo fillings are marked parcel register E-codes that area was compared with the area registered in the land register before processing ROEP (Tab. 3).

The recalculation of parcels area registered in the land registry book operation in a stereographic projection was carried out on the basis of the scheme

$$\boxed{P_S} \Rightarrow \boxed{p_{\,Bessel}} \Rightarrow \boxed{P_K} \qquad (3)$$

Where P_s is the parcel plot in the imaging cartographic plane of the stereographic projection, the Bessel on the surface of the reference Bessel and P_K ellipsoid is its area in the coordinate system of the Krovak´s projection.

By neglecting the distortion in the conformation of the ellipsoid on the Gaussian sphere by expressing the relationship for calculating the length distortion module in the stereographic projection [1], we derive the relation for calculating the P_K area in the S-JTSK coordinate system from the area shown in the stereographic projection P_S (4).

$$P_K = \frac{m_{pl\,K}}{m_{pl\,S}} P_S = \left(\frac{m_K}{m_S}\right)^2 P_S = k_P P_S, \qquad (4)$$

where $m_{pl}K$ and $m_{pl}S$ are Modulus of area distortion in Krov's projection and stereographic projection. The graphical representation of the conversion factor $k_P = \left(\frac{m_K}{m_S}\right)^2$ in the territory of the Slovak Republic is shown in Fig. 5.

In order to verify the correctness of relationships derived from the stereographic projection projection

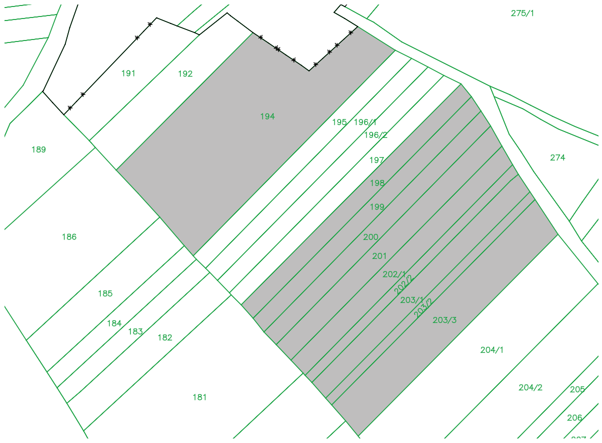


Fig. 4. Preview of the vector cadastral map
Rys. 4. Widok mapy katastralnej w postaci wektorowej

Tab. 3. Comparison and assessment of test plots registered in the land register, the graphic area of stereographic projection and assessments listed in the register E-KN
Tab. 3. Porównanie i ocena powierzchni testowych zarejestrowanych w księdze wieczystej, obszarze graficznym projekcji stereograficznej i ocenach wpisanych do rejestru E-KN

the parcels								
oper land registry book						register E-KN		
PK parcel	land register part containing one registration unit	registered area			graphics			area
		[austrian morgen]	[fathom]	[m^2]	[m^2]	parcel	property list	[m^2]
175	159	4	2081	30503	30895	194	235	30869
172	33		1659	5967	6229	198	236	6224
171	6		1659	5967	6111	199	177	6106
170	2		1659	5967	6205	200	176	6202
169	25		2045	7355	7669	201	175	7661
168	13		904	3251	3323	202/1	174	3321
	13	1	350	7013	7171	202/2	187	7166
167	4	1	314	6884	7157	203/1	237	7151
	4		810	2913	3031	203/2	174	3027
	4	2	416	13005	13519	203/3	237	13509

into the S-JTSK coordinate system, the dimensions of the PS of the tested parcels (Fig. 4) were calculated in the coordinate system of stereographic projection and after their conversion with the conversion coefficient k_p (Fig. 5) P_K the coordinate system – Datum of Uniform Trigonometric Cadastral Network.

The data in the table (Tab. 4) present the consistency between the calculated areas and their areas registered in the register of the real estate cadastre E. It should be noted that if the areas of the P_S are calculated from the coordinates with an accuracy greater than *cm* (as determined in the Matlab environment), the dimensions in the columns of the P_K and E-KN (Tab. 4) are identical. It is easy to convince that we will achieve the same results if we use the coefficient kp for the whole cadastral unit of Bunetice $k_p = 0.9992$ (Fig. 7).

The data on parcel areas (Tab. 3 and Tab. 4) allow us to determine the accuracy of the breakdown of the parcels of the original map of the cadastral unit of Bunetice (Fig. 3).

Double the proportion a closed surface pattern (Fig. 4) of the coordinates can be determined from the sum of the areas of trapezoids

$$2P = (y_1 + y_2)(x_1 - x_2) + (y_2 + y_3)(x_2 - x_3) + (y_3 + y_4)(x_3 - x_4) + (y_4 + y_5)(x_4 - x_5) + (y_5 + y_1)(x_5 - x_1) \quad (5)$$

who, having come into the multiplication for general n square shape

$$P = \frac{1}{2}\sum_{i=1}^{n} x_i (y_{i+1} - y_{i-1}), \quad (6)$$

or

(7)

known as l'Huilerove formulas.

$$P = \frac{1}{2}\sum_{i=1}^{n} y_i (x_{i-1} - x_{i+1})$$

The real error surface ε_p is determined by the error analysis of differentiation of the relationship:

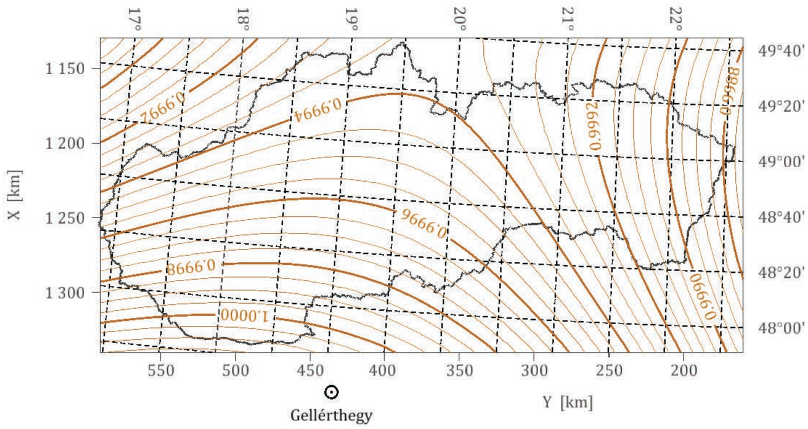


Fig. 5. The isolines of the coefficient of calculus
Rys. 5. Izolinie współczynnika różniczkowego

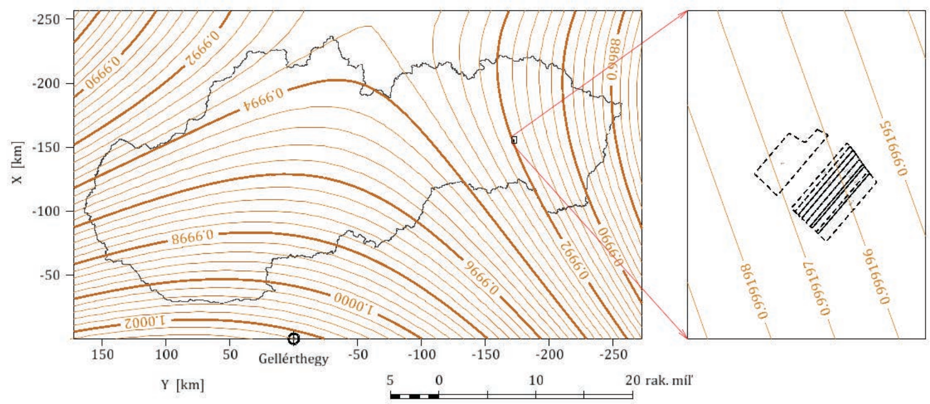


Fig. 6. The isolines of the coefficient of calculus of the area k_P in stereographic projection
Rys. 6. Izolinie współczynnika rachunkowego obszaru kP w projekcji stereograficznej

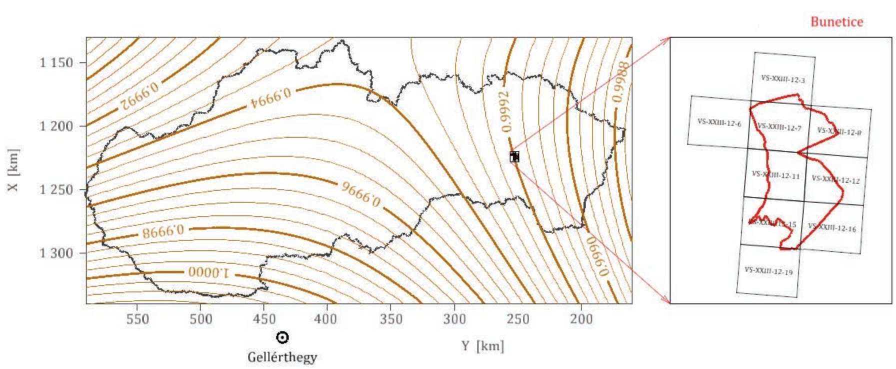


Fig. 7. The isolines of the coefficient of calculus of the area kP in Křovák's projection
Rys. 7. Izolinie współczynnika rachunkowego obszaru KP w projekcji Křováka

Tab. 4. Comparison of the area of the tested parcels
Tab. 4. Porównanie powierzchni testowanych parcel

parcel E-KN	k_P	Area [m²]		
		P_S	$P_K = k_P\, P_S$	E-KN
194	0.999197	30895	30870	30869
198	0.999196	6229	6224	6224
199		6111	6106	6106
200		6205	6200	6202
201		7669	7663	7661
202/1		7171	7165	7166
202/2		3323	3320	3321
203/1		7157	7151	7151
203/2		3031	3029	3027
203/3		13519	13508	13509

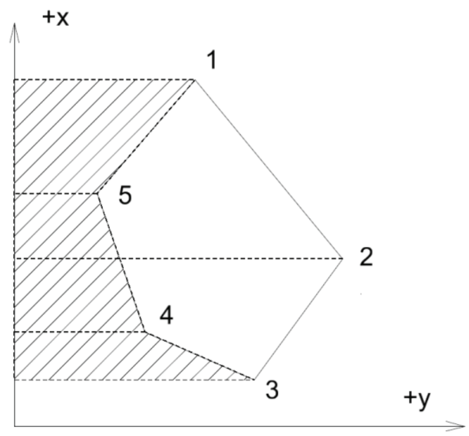


Fig. 8. The principles of the surface of the closed pattern from the coordinates
Rys. 8. Zasady powierzchni zamkniętej dla współrzędnych

$$2\,\varepsilon_P = (y_2 - y_5)\varepsilon_{x1} + (y_3 - y_1)\varepsilon_{x2} + (y_4 - y_2)\varepsilon_{x3} + (y_5 - y_3)\varepsilon_{x4} + (y_1 - y_4)\varepsilon_{x5} + +(x_5 - x_2)\varepsilon_{y1} + (x_1 - x_3)\varepsilon_{y2} + (x_2 - x_4)\varepsilon_{y3} + (x_3 - x_5)\varepsilon_{y4} + (x_4 - x_1)\varepsilon_{y5}$$

$m_x = m_y = m_{xy}$

we can write

$$4\,m_P^2 = m_{xy}^2((y_2 - y_5)^2 + (y_3 - y_1)^2 + (y_4 - y_2)^2 + (y_5 - y_3)^2 + (y_1 - y_4)^2 + (x_5 - x_2)^2 + (x_1 - x_3)^2 + (x_2 - x_4)^2 + (x_3 - x_5)^2 + (x_4 - x_1)^2)$$

or

$$4\,m_P^2 = m_{xy}^2(s_{25}^2 + s_{31}^2 + s_{42}^2 + s_{35}^2 + s_{14}^2). \qquad (8)$$

Equation (8) allows us to express the standard error of the closed area of a polygon, a general term [5].

$$m_P = \frac{m_{xy}}{2}\sqrt{\sum_{i=1}^{n} s_{i+1,i-1}^2}, \qquad (9)$$

which for simplifying assumption $m_p = \varepsilon\rho$ it can be used when calculating the median coordinate errors mxy break points of parcels of the original cadastral territory Bunetice (Fig. 3), including in himself not only very accurate cartographic mapping and preparation, but also errors in the processing of vectorization ROEP.

$$m_{xy} = 2\,\varepsilon_P \Big/ \sqrt{\sum_{i=1}^{n} s_{i+1,i-1}^2}. \qquad (10)$$

For example, sets of test parcels maps of the former land registry (Tab. 5) can be characterized by precision break points parcels of their average value . The stated value corresponds to a graphical comparison raster files cadastral maps in vector format.

Fig. 7. Graphical representation of the are distortion mpl in territory of stereography projection

Graphic areas registered in the land register in stereographic projection was based on the relation 5, respectively.6. The layout axes and area distortion mpl demonstrated Fig. 7.

Conslusion

For example of cadastral unit Bunetice demonstrates the proposed contribution of at least part of the evolution of recording of real property rights in the Slovak Republic. Improving geodetic and computer equipment, as well as knowledge in mathematical cartography and GIS undeniably contributed to the improvement of [illegible] registered in the land registry and consequently improve the legal certainty the public

Tab. 5. Standard errors break points parcels of the former land registry maps
Tab. 5. Odchylenie standardowe punktów dla starych map ewidencji gruntów

parcel		Area in registry book		$\sum_{i=1}^{n} s_{i+1,i-1}^{2}$	m_{xy}
PK	KN-E	registered [m²]	graphic [m²]	[m²]	[m]
175	194	30503	30894.9	318627.43	1.4
172	198	5967	6229.2	340414.57	0.9
171	199	5967	6110.6	342873.23	0.5
170	200	5967	6205.2	346231.71	0.8
169	201	7355	7669.5	330646.26	1.1
168	202/1	7013	7171.1	363407.10	0.5
	202/2	3251	3322.9	393190.58	0.2
167	203/3	13005	13518.8	386396.78	1.7
	203/2	2913	3030.7	388758.10	0.4
	203/1	6884	7156.9	392216.24	0.9

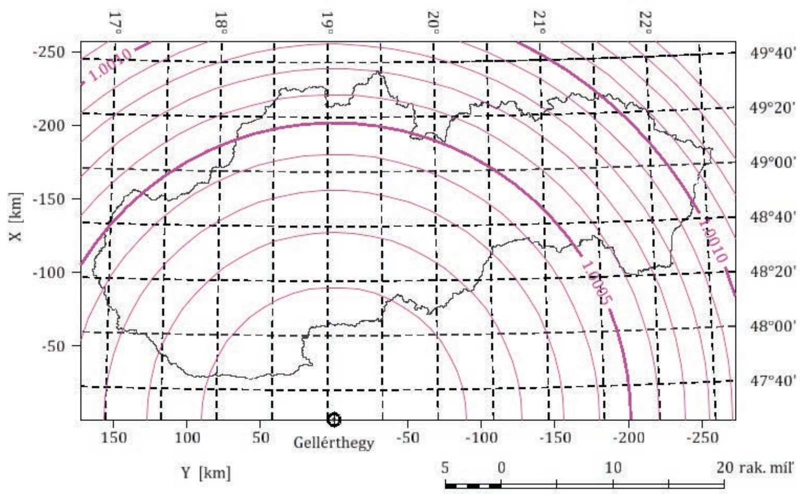


Fig. 7. Graphical representation of the are distortion mpl in territory of stereography projection
Rys. 7. Graficzne przedstawienie zniekształceń map w obszarze projekcji stereograficznej

to the land. Opening the border between the quality of the current vector cadastral map kept in electronic form on the exact mathematical foundations and historical maps in different coordinate screenings held in analog form generates inconsistencies in area of real estate, the public, as well as management of the state is due to their lasting value urgency social problem. For this reason, the quantitative expression of these irregularities knowledge about the quality of the original geodetic and cartographic works and very important for the description of cartographic research methods have their irreplaceable position.

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Analiza możliwości wyorzystania danych ze starych map katastralnych w celu uaktualninia danych w katastrze

W artykule przedstawiono wyniki analizy przydatności map katastralnych pod względem dokładności zapisów w dokumentacji katastralnej opracowanej na terenie Republiki Słowackiej oraz wyniki specjalnie dobranych analiz obszarów katastralnych i kwantyfikacji obszarów geodezyjnych. Dla ludności nie są dość oczywiste przyczyny zmian w obszarach działek wynikające z wykorzystania obrazów lotniczych do projekcji map katastralnych wykonanych w różnych rzutach. Celem artykułu jest określenie ilościowe zmian w katastrze w Republice Słowackiej, opisanie wyraźnej zależności matematycznej.

Słowa kluczowe: kataster nieruchomości, dokumentacja katastralna, mapa katastralna, projekcja stereograficzna, projekcja Křováka