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GEOGRAPHICAL CENTERS OF ADMINISTRATIVE-TERRITORIAL ENTITIES OF THE RIVNE REGION OF UKRAINE: ESSENCE, SIGNIFICANCE AND PECULIARITIES OF DEFINITION

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Abstract. The geographical centers of territories belong to the category of important geographical constants and are traditionally perceived as single and unambiguous points. The purpose of this work is to determine the coordinates of the geographical centers of the new administrative-territorial entities of the Rivne region of Ukraine in order to establish special information and memorial signs that will have cognitive, unifying, educational, tourist and local history significance. Methodology – geographical centers were determined in the Pulkovo-1942 and WGS-84 coordinate systems based on the results of vectorisation of the boundaries of territories at a scale of 1:10,000 as centers of gravity of the respective figures (Digitals and AutoCad software products were used). As a result of the work performed, it was found that this methodology allows obtaining a sufficiently high accuracy of the results (7.1 m), in contrast to the use of publicly available and convenient resources (OpenStreetMap, QGIS). The novelty of the study is that the geographical centers of the amalgamated territorial communities and administrative districts of Rivne region are identified for the first time and the proposed approach can be implemented for similar studies of other territories with a possible prospect of a new type of tourism – geocentric.

Keywords: geographical centers, coordinates, Pulkovo-1942, WGS-84, territory, Rivne region.

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1. Introduction

Geographical centers of territories belong to the list of stable geographical parameters (the main quantitative geographical characteristics, which also include the area of the territory, the length of its borders, the coordinates of extreme points, the highest and lowest elevation, etc.), which allow to get a proper idea of their geographical location, integrity, and individual characteristics. Such information is used for comparative analysis of the relevant indicators of different territorial entities of the same classification level, so they are naturally perceived as a quantitative measure of territorial uniqueness.

Geographical centers can perform a number of important functions, among which researchers (Karpinskyi et al., 2002; Shevchenko, 2006; Ostapchuk, 2019) primarily identify:

- cartographic and geodetic (as base points when choosing the most appropriate cartographic projections and determining the reference of the local coordinate system);
- tourist and local lore (as attractive objects in the development of appropriate tourist routes);
- cognitive (as locations that reflect the physical and geographical features of the territory);
- unifying and educational (as visual elements of cultural and educational development, patriotic education and consolidation of citizens).

Accordingly, the geographical centers of territories (continents, countries, and individual parts of it) are perceived as single, unambiguous and permanent points. And such points on the ground have the right to be equipped with special memorial signs.

There are more than enough examples of such a plan, for example, the geographical center of Europe (Barladin & Horodetskyi, 2005; Ostapchuk, 2018). It should be a single and universally recognised point, because it should not be defined and interpreted arbitrarily, but should follow the rules accepted in scientific practice. In reality, however, there are more than two hundred such centers in Europe, and many of them have appropriate symbolic memorials. In the chronological order of their installation, here are

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some of them: in Suchowola (Poland), Kremnica (Slovakia), Dilove (Ukraine), Purnushkes (Lithuania), Kourzim (Czech Republic), Tallya (Hungary), and Monnuste (Estonia). There is even a corresponding inscription on a stone pillar in the forest massif on the western slope of Mount Dylen (the German-Czech border). The wide geography of the memorials, which covers various European countries, is noteworthy.

Without going into the reasons for such large geographical discrepancies, which may include different calculation methods, ways of calculating, differences in the inclusion of the borders of Europe, etc., it is quite clear that their emergence and large number are primarily related to political (many countries want to be the center of Europe) and purely commercial interests (attractive tourist locations are a profitable business). It is proposed to use even the most famous geographical centers of Europe, located in different countries, to create one or more thematic tourist routes, which will help to expand the range of international tourist products and improve mutual understanding between peoples (Ostapchuk, 2018). From these positions, along with already existing ones (for example, religious, hunting, literary, musical, wine, coffee, dental, etc.), the possibility of a new type of tourism – geocentric, which involves traveling to the geographical centers of various territories, looks promising.

In view of the above, it is of scientific interest to determine with due accuracy the location of the geographical centers of the new administrative-territorial entities of the Rivne region, which has not been done before, in order to install special memorial signs in the relevant locations that will have informational value and will perform tourist and local history, cognitive, and unifying and educational functions.

Each administrative-territorial unit is interested in filling its budget. Therefore, the comprehensive development of tourism infrastructure, which can offer not only traditional European-style recreation centers and estates, equestrian clubs, picnic and fishing areas, attractive cycling and hiking routes, existing architectural, historical and natural monuments, but also new interesting objects, seems to be quite appropriate and promising. The presence of these locations will also serve to promote proper patriotic education of the younger generation and a sense of pride in their small homeland. Moreover, on the websites of administrative-territorial entities, it is advisable to accompany the photographs of memorials of geographical centers with reliably determined coordinates of their location. This makes it possible, given the current level of technical support and navigational and cartographic knowledge of the population, for everyone to plan and carry out independent trips to such places of interest.

The relevance and prospects of the transformation of regional tourism in the context of decentralisation and the need to solve various problems are evidenced by numerous publications (Beidyk et al., 2019; Dzhaman et al., 2023; Liashenko & Koper, 2023; Ostapenko et al., 2023).

2. Analysis of research

When analysing scientific works on the definition of geographical centers of territories, it should be noted that they often contain rather contradictory information. In particular, in the literature of even recent decades, when defining the geographical center of Ukraine, points with coordinates with distances of more than 100 km are given (Ditchuk, 2000; Karpinskyi et al., 2002; Hrytsevych, 2003; Horodetskyi & Isaiev, 2004; Shevchenko, 2006; Kyselov et al., 2021).

In this regard, it is rightly noted (Karpinskyi et al., 2002) that it is traditionally accepted in publications on this topic, as a rule, "not to provide the characteristics of the cartographic materials used, the volume and parameters of the measurements made, as well as an assessment of the accuracy of the results obtained. The absence of these data makes it impossible to conclude on the reliability of the results".

As a result, this had a negative impact on the coverage of the geographical center of Ukraine in the literature, where different locations were mentioned (for example, the town of Vatutine in Cherkasy region, the urban-type settlement of Dobrovelychkivka in Kirovohrad region, the village of Ruzhycheve in Oleksandriia district of Kirovohrad region, the village of Zvirivka in Novoukrayinskyi district of Kirovohrad region, the village of Shevchenkove in Zvenyhorod district of Cherkasy region).

The authors of the above-mentioned publication (Karpinskyi et al., 2002) considered the geographical center to be the center of gravity of a closed system, and to determine it, 8,686 points along the perimeter of the land border and the coastline of the Black and Azov Seas were downloaded from a digital topographic map of Ukraine at a scale of 1:200,000. The coordinates of the geographical center of Ukraine were calculated: B = 49°01.1′N; L = 31°23.4′E (northern outskirts of Shpola, Cherkasy region). The mean square error of the geographical center position was determined as follows:

$$m_c = \pm\sqrt{m_p^2 + m_F^2}, \quad (1)$$

where m_p is the total root mean square error of the point position on the map; m_F is the root mean square error of the geographic center determination function. It was ±0.24′, which corresponds to 407 m on the ground.

In order to avoid unacceptable distortions and to specify the location of the geographical center of the territory of Ukraine, the State Committee on Natural Resources engaged the Research Institute of Geodesy and Cartography of the State Service of Geodesy, Cartography and Cadastre, which, with the participation of the same authors, officially published its coordinates on the basis of more points and using more accurate cartographic materials: 49°01′39′′N; 31°28′58′′E (northern outskirts of the village of Maryanivka village, Shpolyansky district, Cherkasy region) (Verkhovna Rada of Ukraine, 2005).

The difference with the previous location was more than 6.8 km. The results demonstrated the importance of using detailed input cartographic data in this type of research.

The identification of geographical centers of a lower administrative-territorial rank is also of considerable interest, as evidenced by foreign and domestic publications (Affholder, 2003; Kokmeijer, 2008; Dzhaman et al., 2010; Kornus, 2011; Ostapchuk & Nimkovych, 2017).

Regarding the position of the geographical center of the Rivne region, according to (Korotun et al., 2000), its geographical coordinates were first calculated by J. Kudlik: 51°02′N, 26°33′E (Mokvin village, Kostopil district). However, only quantitative values are given, and there are no references or explanations regarding the materials used, calculation methods, or accuracy of the results.

Later, our research, based on digital mapping materials at a scale of 1:10,000 (the total number of digitised points along the border of the region was 9,708) using modern software (Ostapchuk & Nimkovych, 2019), does not confirm this location of the geographical center of the Rivne region. The coordinates determined by us in the respective coordinate systems are:

Pulkovo-1942: B=51°02′09.5′′N; L=26°23′18.2′′E;

WGS-84: B=51°02′08.8′′N; L=26°23′12.1′′E;

(0.8 km north-west of Maryanivka village, Kostopil district).

As we can see, there is a rather large difference in the value of longitude, where the difference is about 10′. Taking into account that for the territory of Rivne region, the arc length of the 1′ meridian is 1853-1854 m, and the parallels are 1144–1195 m, the discrepancy reaches more than 11 km, which is unacceptable.

3. Research methods

The history of cartographic research shows various approaches to finding the central points of territories (methods of equal areas, average coordinates, integral estimates, conditional individual estimates, etc.), but the method of determining the center of gravity of a figure has gained general recognition in the world scientific practice.

When calculating the center of gravity, you need to know the coordinates of the reference points x_i and y_i and their weights f_i. The general form of the equations for finding the center of gravity is given as:

$$x = \frac{\sum_{i=1}^{n} f_i x_i}{\sum_{i=1}^{n} f_i}; \quad y = \frac{\sum_{i=1}^{n} f_i y_i}{\sum_{i=1}^{n} f_i}. \qquad (2)$$

To perform the calculations, it was decided to use the above Eq. (2), and to take the areas of elementary figures into which the territory under consideration can be divided as weights. One of the recommended and available products in which the above algorithm for determining the weight of a flat body can be implemented is AutoCad.

Since modern mapping Internet portals use the WGS-84 world geodetic coordinate system, we consider it appropriate to define the coordinates of the geographical centers of the territories of the newly formed administrative districts and amalgamated territorial communities of Rivne region in this system. Given that the 1942 coordinate system (SK-42) was used in the construction of large-scale paper topographic maps, it was decided to provide the coordinates of geographic centers in the geodetic coordinate system (DATUM) – Pulkovo-1942, in order to avoid confusion and to allow the use of familiar traditional maps. It should be borne in mind that topographic maps of Ukraine at a scale of 1:100,000 and smaller have been allowed for free sale and download on the Internet, while maps at larger scales are currently inaccessible to ordinary citizens due to the current restriction.

4. The results of the research

According to official data, Rivne region has a total area of 20,047 km^2 with 1,026 settlements (NGO Portal "Decentralization", 2024). The region includes 4 administrative districts and 64 amalgamated territorial communities:

- Varash district (united former Volodymyrets and Zarichne districts) – area: 3,323.5 km^2, 116 settlements, 8 communities;
- Dubno district (united former Demydivka, Dubno, Mlynivka and Radyvyliv districts) – area: 3,294.2 km^2, 303 settlements, 19 communities;
- Rivne district (united the former Bereznyi, Hoshcha, Zdolbuniv, Korets, Kostopil, Ostroh and Rivne districts) – area: 7,216.6 km^2, 439 settlements, 26 communities;
- Sarny district (united the former Dubrovytsia, Rokytne, and Sarny districts) – area: 6,212.7 km^2, 168 settlements, 11 communities.

Currently, the most detailed input cartographic materials for this task are the digitised boundaries of the former territories of basic-level councils (before the administrative-territorial reform) at a scale of 1:10,000 in the Digitals software, obtained with the authors' participation. The number of points of the digitised boundaries of the former territories of basic-level councils depended on the area and curvature of the contours and ranged from 80 to 1000 for each of them. The total number of digitised boundary points across the region was 54,027.

Given that Digitals allows you to find the center of a closed figure, but this location does not coincide with the center of gravity of a flat body, the vector mapping data was imported into the AutoCad environment.

With this in mind, the procedure for determining geographic centers was as follows. First, such locations were determined for the territories of basic-level councils, then for amalgamated territorial communities, and then for the territories of newly formed administrative districts (Tables 1–2).

Table 1. Coordinates of geographical centers of territorial communities of Rivne region

No. p/n	Name of the community	Pulkovo-1942		WGS-84		The nearest settlement (lake)
		B	L	B	L	
1	Antonivska	51°22′16,4″	26°19′26,9″	51°22′15,9″	26°19′19,9″	Netreba
2	Babynska	50°36′26,2″	26°32′55,8″	50°36′25,7″	26°32′48,9″	Babyn
3	Berezivska	51°32′52,4″	27°26′17,9″	51°32′52,0″	27°26′10,9″	Hlynne
4	Bereznivska	50°58′01,0″	26°52′19,8″	50°58′00,6″	26°52′12,8″	Khotyn
5	Bilokrynytska	50°39′03,3″	26°26′23,3″	50°39′02,8″	26°26′16,4″	Horynhrad-2
6	Bokiimivska	50°28′22,2″	25°30′23,0″	50°28′21,6″	25°30′16,1″	Smordva
7	Boremelska	50°30′15,8″	25°12′54,5″	50°30′15,2″	25°12′47,5″	Zolochivka
8	Buhrynska	50°32′15,1″	26°29′47,5″	50°32′14,6″	26°29′40,6″	Novostavtsi
9	Varaska	51°29′01,5″	25°46′58,6″	51°29′01,0″	25°46′51,5″	Lake White
10	Varkovytska	50°30′46,3″	25°57′46,9″	50°30′45,8″	25°57′40,0″	Zhorniv
11	Velykomezhyritska	50°40′18,9″	26°52′49,4″	50°40′18,4″	26°52′42,5″	Kolodiivka
12	Velykoomelianska	50°33′55,4″	26°06′13,0″	50°33′54,9″	26°06′06,1″	Hlynsk
13	Verbska	50°16′35,9″	25°33′41,0″	50°16′35,3″	25°33′34,1″	Verba
14	Vyrivska	51°13′59,0″	26°52′42,5″	51°13′58,6″	26°52′35,5″	Oleksiivka
15	Vysotska	51°44′19,3″	26°34′18,4″	51°44′18,9″	26°34′11,3″	Verbivka
16	Volodymyretska	51°31′15,3″	26°05′22,2″	51°31′14,8″	26°05′15,1″	Zelene
17	Holovynska	50°53′56,4″	26°14′40,5″	50°53′55,9″	26°14′33,5″	Holovyn
18	Horodotska	50°41′07,6″	26°08′10,1″	50°41′07,1″	26°08′03,2″	Ponebel
19	Hoshchanska	50°37′43,7″	26°42′21,7″	50°37′43,2″	26°42′14,8″	Krasnosillia
20	Demydivska	50°24′38,8″	25°18′19,4″	50°24′38,2″	25°18′12,5″	Demydivka
21	Derazhnenska	50°52′33,3″	26°06′15,4″	50°52′32,8″	26°06′08,4″	Bychal
22	Dubenska	50°24′06,8″	25°44′45,3″	50°24′06,3″	25°44′38,4″	Dubno
23	Dubrovytska	51°34′41,0″	26°34′23,1″	51°34′40,6″	26°34′16,0″	Dubrovytsia
24	Diadkovytska	50°36′41,4″	25°59′35,5″	50°36′40,9″	25°59′28,6″	Ploska
25	Zarichnenska	51°45′09,6″	26°01′42,6″	51°45′09,1″	26°01′35,5″	Pryvitivka
26	Zdovbytska	50°27′18,8″	26°14′41,8″	50°27′18,3″	26°14′34,9″	Lidavo
27	Zdolbunivska	50°30′57,1″	26°15′36,3″	50°30′56,6″	26°15′29,4″	Zdolbuniv
28	Zorianska	50°42′42,8″	25°57′05,8″	50°42′42,3″	25°56′58,8″	Holyshiv
29	Kanonytska	51°27′41,4″	26°14′42,8″	51°27′40,9″	26°14′35,7″	Kanonychi
30	Klevanska	50°47′08,0″	26°01′50,5″	50°47′07,5″	26°01′43,5″	Ruda-Krasna
31	Klesivska	51°23′46,8″	26°51′44,9″	51°23′46,4″	26°51′37,9″	Lake Somine
32	Kozynska	50°15′02,9″	25°27′47,5″	50°15′02,3″	25°27′40,6″	Zarichne
33	Koretska	50°40′04,3″	27°05′16,5″	50°40′03,9″	27°05′09,6″	Richky
34	Kornynska	50°33′07,3″	26°20′44,0″	50°33′06,8″	26°20′37,1″	Porozove
35	Kostopilska	51°01′28,6″	26°16′19,4″	51°01′28,1″	26°16′12,4″	Trostianets
36	Krupetska	50°14′17,8″	25°18′54,8″	50°14′17,2″	25°18′47,9″	Honoratka
37	Loknytska	51°49′58,3″	25°46′32,8″	51°49′57,8″	25°46′25,7″	Liubyn
38	Malynska	51°05′21,2″	26°34′53,2″	51°05′20,7″	26°34′46,2″	Malynsk
39	Maloliubashanska	50°49′35,4″	26°32′21,5″	50°49′34,9″	26°32′14,5″	Mala Liubasha
40	Myliatska	51°42′28,3″	26°54′42,1″	51°42′27,9″	26°54′35,0″	Zhaden
41	Myrohoshchanska	50°25′18,6″	25°57′21,9″	50°25′18,1″	25°57′15,0″	Kostianets
42	Mizotska	50°20′55,2″	26°07′50,4″	50°20′54,7″	26°07′43,5″	Pivche
43	Mlynivska	50°33′29,5″	25°40′13,7″	50°33′29,0″	25°40′06,8″	Puhachivka
44	Nemovytska	51°12′17,0″	26°40′29,2″	51°12′16,6″	26°40′22,2″	Znosychi
45	Oleksandriiska	50°44′39,3″	26°19′36,3″	50°44′38,8″	26°19′29,4″	Oleksandriia
46	Ostrozhetska	50°39′57,8″	25°37′33,6″	50°39′57,3″	25°37′26,6″	Malyn
47	Ostrozka	50°22′14,4″	26°27′27,6″	50°22′13,9″	26°27′20,7″	Hremiache
48	Pidloztsivska	50°34′36,6″	25°22′14,4″	50°34′36,0″	25°22′07,4″	Pidloztsi
49	Povchanska	50°22′06,1″	25°31′26,1″	50°22′05,5″	25°31′19,2″	Povcha
50	Polytska	51°15′18,8″	26°04′57,7″	51°15′18,3″	26°04′50,7″	Polytsi
51	Pryvilnenska	50°27′07,5″	25°45′06,6″	50°27′07,0″	25°44′59,7″	Ivannia
52	Radyvylivska	50°07′06,7″	25°18′37,2″	50°07′06,1″	25°18′30,3″	Radyvyliv
53	Rafalivska	51°19′49,6″	26°03′08,2″	51°19′49,1″	26°03′01,2″	Lozky
54	Rivnenska	50°36′35,4″	26°14′56,1″	50°36′34,9″	26°14′49,2″	Rivne
55	Rokytnivska	51°18′01,4″	27°14′01,3″	51°18′01,0″	27°13′54,3″	Rokytne
56	Sarnenska	51°19′14,5″	26°28′12,7″	51°19′14,0″	26°28′05,7″	Chemerne
57	Semydubska	50°18′44,5″	25°55′13,9″	50°18′44,0″	25°55′07.0″	Sosnivka

End of Table 1

No. p/n	Name of the community	Pulkovo-1942		WGS-84		The nearest settlement (lake)
		B	L	B	L	
58	Smyzka	50°13′06,5″	25°44′27,6″	50°13′06,0″	25°44′20,7″	Stara Mykolaivka
59	Sosnivska	50°50′06,0″	27°04′15,1″	50°50′05,6″	27°04′08,2″	Hubkiv
60	Starosilska	51°37′32,6″	27°06′22,6″	51°37′32,2″	27°06′15,5″	Stare Selo
61	Stepanska	51°07′27,2″	26°23′20,5″	51°07′26,7″	26°23′13,5″	Volosha
62	Tarakanivska	50°20′17,7″	25°43′14,4″	50°20′17,2″	25°43′07,5″	Dytynychi
63	Shpanivska	50°40′12,0″	26°16′57,2″	50°40′11,5″	26°16′50,3″	Shpaniv
64	Yaroslavytska	50°37′25,8″	25°27′38,6″	50°37′25,3″	25°27′31,6″	Nadchytsi

Table 2. Coordinates of geographical centers of administrative districts of Rivne region

	The name of the administrative unit	Pulkovo-1942		WGS-84		The nearest settlement
		B	L	B	L	
1	Varash district	51°35′40,4″	25°59′40,0″	51°35′39,7″	25°59′33,3″	Velyki Telkovichi
2	Dubno district	50°23′24,9″	25°34′20,5″	50°23′24,1″	25°34′14,0″	Velyki Sady
3	Rivne district	50°44′05,9″	26°31′40,1″	50°44′05,2″	26°31′33,6″	Richytsya
4	Sarny district	51°25′34,0″	26°52′35,3″	51°25′33,4″	26°52′28,7″	Karasyn

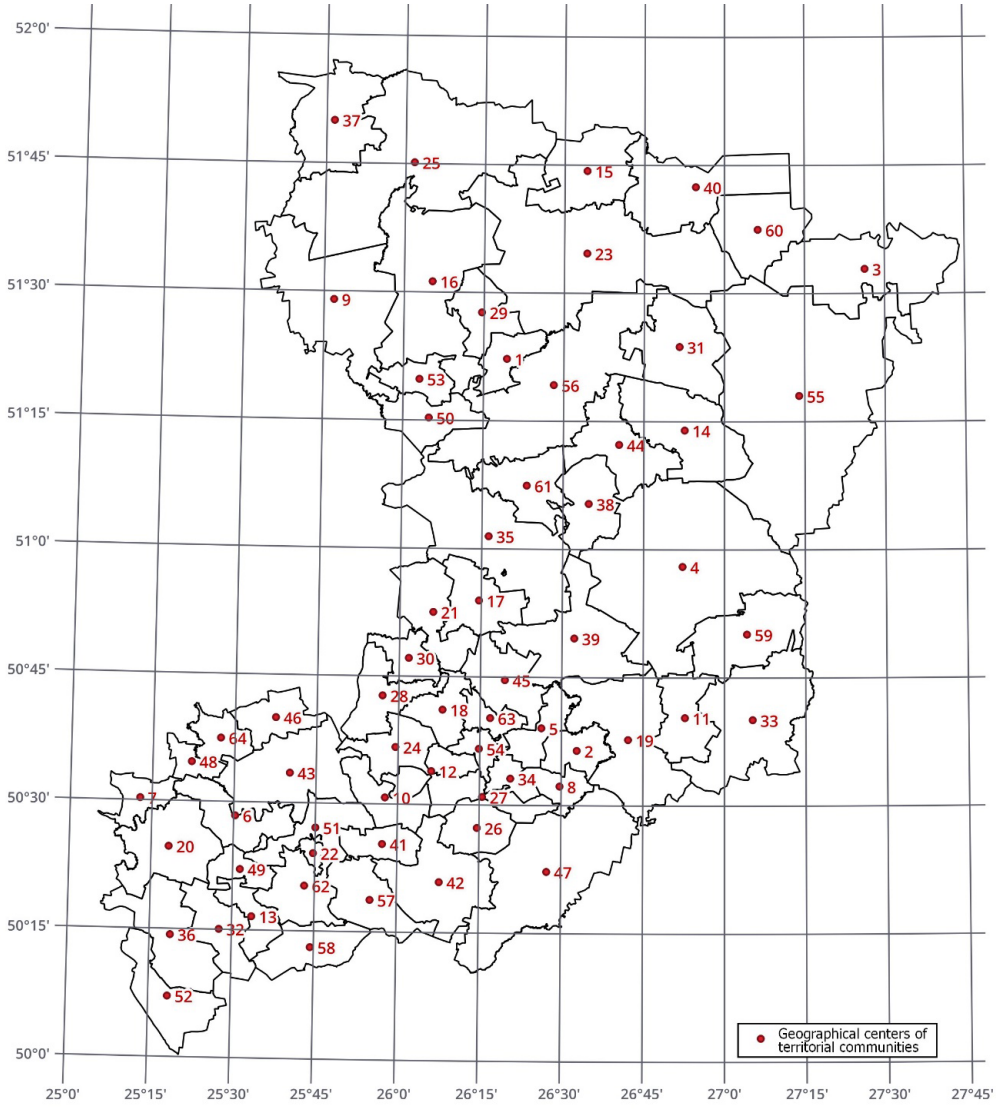

Figure 1. Location of geographical centers of territorial communities in Rivne region

The coordinates calculated by Eq. (2) are given in two geodetic reference systems – Pulkovo-1942 and WGS-84. The mean square error of the geographical centers was determined by Eq. (1) and is 0.71 mm, which corresponds to 7.1 m on the ground for 1:10,000 scale cartographic materials.

Figures 1–2 show a map of Rivne region with the geographical centers of territorial communities, administrative districts and the region (as noted above, the coordinates of the geographical center of the region were determined earlier). At the same time, in Figure 1, the numbers of center designations correspond to the serial numbers of territorial communities in Table 1.

It was also decided to determine the coordinates of the geographical centres of the new administrative-territorial formations of the Rivne region in a less time-consuming and faster way, using up-to-date information accumulated in publicly available open geodatabases, and special software products for their processing. In our case, they were the boundaries of administrative-territorial entities downloaded from the OpenStreetMap server and processed in the environment of the free cross-platform desktop geographic information system QGIS, which is designed to process and analyse geospatial data and prepare various cartographic products. It is worth noting that OpenStreetMap is one of the well-known international non-profit projects to create an open map of the world through the joint efforts of Internet users.

When comparing the results with the corresponding positions in Tables 1–2, it was found that the differences in the coordinates of the geographical centers of both territorial communities and administrative districts in Pulkovo-1942 and WGS-84 are almost identical and for latitudes are within 3.3'' (up to 102.0 m), for longitudes – up to 8.4'' (up to 167.3 m). Given the modern requirements for the accuracy of cartographic research, even for tourist purposes, such results look rough.

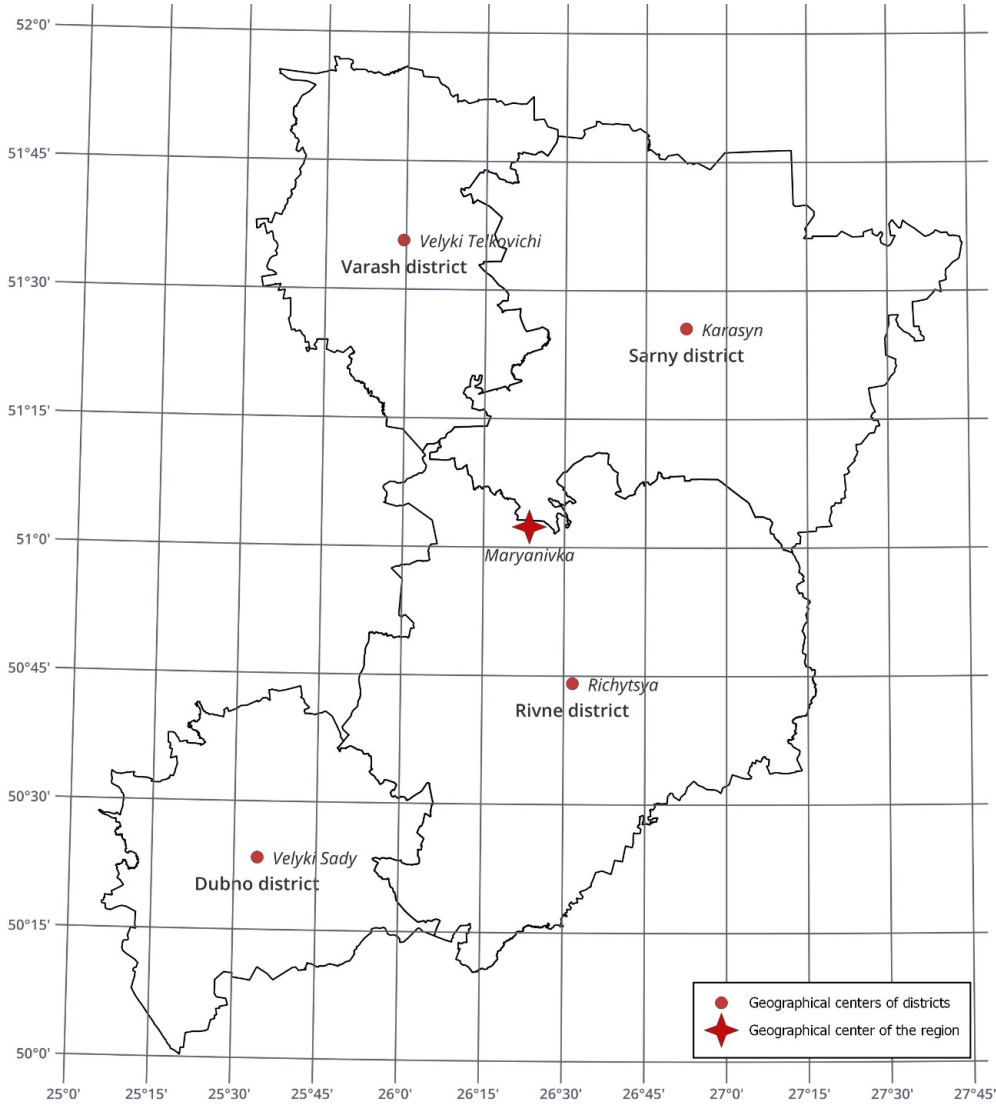

Figure 2. Location of geographical centers of administrative districts and Rivne region

5. Conclusions

Based on the most accurate and sufficiently representative mapping data at a scale of 1:10,000, using Digitals and AutoCad software, the coordinates of the geographical centers of the new administrative-territorial entities of Rivne region were determined for the first time. For the convenience of further use, this was done in two coordinate systems – Pulkovo-1942 and WGS-84. The analysis of publications known to the authors suggests that such a large amount of statistical data (54,027 digitised points) has never been used for this kind of research before, and the accuracy of the final results (7.1 m) has never been so high.

The coordinates of the same geographical centers were quickly determined using publicly available OpenStreetMap geospatial data in the convenient and open-to-use multifunctional QGIS software.

A comparative analysis of the results obtained shows that in the second case they are rough, since when compared to the first case, the differences for latitudes are up to 3.3'' (up to 102.0 m), for longitudes – up to 8.4'' (up to 167.3 m). Therefore, in order to correctly find the coordinates of geographic centers both for the purpose of determining sustainable geographic parameters and for tourism purposes, it is most appropriate to use the most detailed input cartographic materials with the use of modern software products.

The construction of memorials to the geographical centers of the amalgamated communities, administrative districts, and the region in designated locations will help to popularise these areas, promote cultural and educational development, improve patriotic education, and revitalise the local economy.

The proposed approach to determining the geographical centers of administrative-territorial entities of Rivne region can be used for similar cartographic studies of territories in other regions.

Since the modern world is witnessing a shift in tourist interest from ordinary leisure trips to thematic educational trips, the emergence of a new type of tourism – geocentric – may even look promising in this regard. The number of possible locations and routes for this seems to be quite sufficient. And open access to cartographic data with the coordinates of the necessary points on the websites of administrative-territorial entities and the use of navigation tools will enable those who wish to visit such places even on their own.

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