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The Russian-Ukrainian border — emergence and sustainability

Abstract. The article analyses the issues of emergence and sustainability of the Russian-Ukrainian border. Methods of analysis of sustainability of administrative and political borders by means of electronic cartographic bases of administrative-territorial division for different years are implemented. A section of border sustainability within the framework of the Geographical Information System (GIS) “Administrative-territorial division of the Russian-Ukrainian borderlands” and a series of maps demonstrating dynamics, sustainability and segmentation of the state border between Russia and Ukraine are developed. A general methodological basis for analysis of sustainability and emergence of borders with the use of geoinformation technologies is elaborated. A historical and geographical analysis of the formation of the Russian-Ukrainian state border is performed.

The paper presents classification of the Russian-Ukrainian border into segments, a detailed description of the degree of sustainability and history of emergence of the state border. As a result of estimating classification, various values of the index are obtained, confirming the fact of differentiation of the state border by sustainability and emergence. Four groups of border sections according to the degree of sustainability are allocated, which enables structuring the historical and geographical description of the border and drawing conclusions on the origin, present and future of transboundary processes.

Keywords: sustainability of borders, emergency of borders, status of borders, administrative-territorial division, Russia, Ukraine

JEL codes: R19, Y91

Introduction

The modern state border between Russia and the Ukraine emerged as a result of giving a new status to the administrative border that had existed for decades. The remoteness of emergence and the duration of existence of its segments have significant differences. Since emergence and sustainability are some of the most

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important characteristics of administrative and political boundaries, this issue occupies a special place in the studies of the territorial organization of society. The functions and statuses of borders change following reforms of administrative-territorial division (ATD). State borders form a socio-geographical zone within which there are transborder processes and phenomena that have a significant impact on society. In order to identify particular features of this phenomenon, special attention is paid to the study of functions and classification of boundaries. At present, there is a steady trend of transition of the state border between Russia and Ukraine from a “semi-permeable border” type to an “alienating borders” type [Zhurzhenko, 2013]. In this regard, the study of the emergence and degree of sustainability of the state border becomes especially relevant.

The issue of border sustainability is covered in a number of Russian and foreign publications. A team of authors from the Pskov State Pedagogical University presents in their work the results of historical and geographical analysis of changes in the administrative-territorial division of the Pskov region, shows the formation of modern borders of the region and gives an assessment of the historical maturity of regional boundaries. Their paper considers the sustainability of political and administrative boundaries as a synonym of their historical maturity, which is determined by age (duration of existence). Based on the results of the analysis, typologies of borders by prescription and duration of existence are given, the result of which is “integral” typology of regional borders based on two indicators [Manakhov et al., 2010]. In foreign literature, the sustainability of borders is often considered in the context of historical changes in the administrative division of the territory and is classified according to duration of existence [Wagner, 1971].

The study of interstate and administrative boundaries is necessarily in close connection with the analysis of changes in the administrative-territorial division of bordering countries and regions. Transformations in administrative-territorial division have a direct impact on the settlement and territorial structure of the Russian-Ukrainian bordering areas [Popkova, 2007].

Analysis of sustainability of the state border of Russia is performed with the use of geoinformation technologies, which enable discovering new directions of historical and geographical research of territorial organization of the Russian society. The aim of this study is to assess the sustainability of the Russian-Ukrainian border using methods of mathematical and cartographic modeling, as well as conjugate description of the emergence of individual parts of the border. Within the framework of the research, there were the tasks to process historical and cartographic sources with the ATD grid for different years, develop and implement a section of border sustainability in the GIS “ATD of the Russian-Ukrainian border”, where key coefficients were defined, calculated and visualized.

Material and methods of research

Digitalization of ATD borders was realized on the basis of the “Marks Atlas” [The Great World..., 1910: 17], which presents maps of the Russian Empire with administrative boundaries as of 01.01.1910 and the “Industry Atlas. Issue V. Publication of the Presidium of the Supreme Soviet of the National Economy of the USSR” [Industry Atlas..., 1929], which presents maps of the provinces, as of 01.01.1927, in the MapInfo 7 environment, On the basis of the modern borders of the Russian Federation and the hydrographic network of the Russian Federation, a raster (scanned version of the map “Rural population density in the European part of the USSR”) was registered in the GIS environment and the subsequent digitization of ATD boundaries in the “Direct conical equal-intermediate projection of Kavraysky (European part of the USSR)” mode, was carried out.

Calculations of age of emergence, duration of existence, coefficients of variability of status and the mosaic coefficient of border sections are carried out on the basis of the database formed from materials of ATD reference books and comparisons of administrative-territorial division over different years [1929]. By means of application of geo-information tools it was possible to perform historical and geographical analysis of the studied territory and the state border segment, as it was first proposed in “Modeling in socio-economic cartography” [Tikunov, 1985]. A series of maps of sustainability of the Russian-Ukrainian border was developed on the basis of indices resulting from expert and mathematical analysis.

In this study, the modern state border is considered in the context of segments of regional borders. Each segment refers to the borders of administrative-territorial units of the second order and thus unique, because it is the border between only a single district of Russia and a single district of Ukraine. Such a classification gives an opportunity to examine in detail the genesis of modern borders, their history and territorial differences. Thus, 73 segments of the interstate Russian-Ukrainian border are allocated.

The study has a key feature — consideration of the emergence of the borders from modernity to the past. Modern segments are combined into groups by belonging to the border of regions of the Russian Federation for a logical and convenient description. There are six such groups — Bryansk, Kursk, Belgorod, Voronezh, Rostov and Crimean.

A brief historical and geographical review of the border

The study and description of the border is performed from north to south, from Bryansk to the Crimean segment. In the north-west, the border between Russia and Ukraine begins at the point of crossing three state borders - Belarus, Russia and Ukraine. Now the Friendship Monument “Three Sisters” stands here, it

was built in 1975. The area of contact arose in 1919, when the territories of the northern counties of the Chernigov province were transferred to the RSFSR. The border of Russia and Ukraine (RSFSR and Ukrainian SSR) in its modern shape was formed (was finally determined) by the end of 1928.

The peculiarity of the Bryansk segment is that it was formed after the transfer of part of the counties of the Chernigov province to the Gomel province and to the newly formed Bryansk province [Tarkhov, 2005]. It was finally shaped in an existing form and status in 1944, when the Bryansk region was established [Administrative-territorial division of the Bryansk region..., 2011]. The further western segment long existed as part of the border of the Mogilev and Chernigov provinces. The second and third segments of the Klimovsky district have a more complex history of emergence. In June 1918 in Pochep a congress of the northern counties of the Chernigov province was held, at which — on the basis of a referendum held earlier — it was decided to join the northern counties to Russia. In May 1919 the northern counties of the Chernigov province became part of the new Gomel province, which was included in the RSFSR [Administrative-territorial division..., 1923–1987]. Thus, having existed for over 150 years, county borders changed their status, and subsequently, changed belonging to certain administrative units several times.

The fourth and part of the fifth Klimovsky segments were fully formed in 1926 when the Semyonovskaya county of the Gomel district was transferred to the Glukhov district of the Ukrainian SSR. Thus, the border line was partly formed from the old county, partly on the basis of districts.

Pogar segment had the status of inter-county border for more than 150 years. The outline of the border has undergone minor changes in the area of contact with the territories of the former Znoby-Trubchev district. In the Trubchevsky segment, where the border had existed for over 150 years, changes were made in 1924–28. Part of the territory of Trubchev district, namely the village of Znoby-Trubchevskaya and the surrounding area ultimately became part of Ukraine.

The Suzemsky segment is a special case: it was the most stable and has not experienced changes for 250 years, since the creation of the Oryol governorship. That is, the status of the border and the administrative-territorial units on both sides of the border changed, but the configuration remained unchanged.

The Sevsky segment is similar to the Trubchevsky by emergence and history. Several territories were transferred from the Sevsky district to Ukraine. Near the 11th segment this was part of the territory of the Podyvotskaya county (the settlements of Sytnoe and Rashkovichi); near the 12th segment this was the Nikitskaya village; near the 13th segment these were the settlements of Fotovizh, Smolino, Smykarevka, Muraveina, Baranovka and Demyanovka. Part of the old segment of the provincial border is now the interdistrict border between the Yampolsky and Glukhov districts of the Sumy Oblast.

Detailed historical and geographical analysis of the border on the basis of geo-informative tools, gave the ground for classification and standardization of the emergence of the border segments. Thus, the Bryansk border can be divided into segments formed on the basis of county borders of the Chernigov province (Western and Pogarsky), segments of “compensation” partially formed in the mid-1920s as a result of the transfer of territories from the RSFSR in favour of the Ukrainian SSR (Semenovsky, Trubchevsky and Sevskiy segments), and also the Suzemsky segment formed on the site of the provincial border. The transfer of several territories of the northern borderlands from the RSFSR in favour of the Ukrainian SSR was carried out as “compensation” due to the accession of Taganrog and nearby areas, as well as the Shakhtinsky district to the RSFSR.

The Kursk border is also not stable and homogeneous in origin. Chomutovsky and Sumskey (designated by the name of the adjacent region of Ukraine) segments were characterized by stability and formed on the site of the provincial border. The Rylsky and Sudjansko-Belovsky (Miropol) “compensation” segments, delimited as a result of transfer to Ukraine of a number of counties of the Putivlsky district and the Krenichansk County of the Sujan district respectively. The Glushkovsky segment was partially formed on the basis of both county and provincial borders. It is also worth noting that the Rylsky segment of the border has a complex structure and is divided into 3 subsegments. The first one is part of the county border of the Krupetskaya district. The second section is part of the county border of the Putivlsky County. And the third section is part of a somewhat transformed county border.

The modern Belgorod border was formed as a result of the transformation of the configuration of the borders of the Kursk, Voronezh and Kharkiv provinces in the mid-1920s. “Compensatory” segments here are of significant length, among them the Hrayvoronsky county, as a result of transfer of the southern part of the Hrayvoron county to Ukraine. The Schebekin segment includes the site, which was formed in 1925 when the south-western part of the territory of the Murom county was transferred to Ukraine and the longest section obtained as a result of the delimitation when part of the territory of the RSFSR was transferred to Ukraine in 1927–28 (the Staritsa, Prilypki, Izbickoe settlements and their environs). The Valuisky segment was finally shaped after the transfer of the Troitskaya and part of the Urazovskaya counties to the Ukrainian SSR. The Belgorod and Volokonovsky segments, which are similar in origin, formed on the place of the provincial border.

The Voronezh border is a single segment, as the configuration of the boundary has not experienced changes. The administrative-territorial division of adjacent territories has changed. But here the state border became the successor of the provincial Voronezh-Kharkiv border.

The Rostov border was formed in connection with administrative-territorial separation in the Eastern Donetsk Basin. In 1920, the Donetsk district was

included in Ukraine, which included the Donetsk and part of the Taganrog districts of the former Don Army Province, including the city of Taganrog with the adjacent territory. Due to the fact that Taganrog played an important role in the South-East of Russia and was extremely necessary as a deep-water port, the transfer of the Taganrosky, Aleksandrovo-Grushevsky (Shakhtinsky) and Ekaterinensko-Kamensky districts to the RSFSR was initiated. As a result, in 1925 parts of the Donetsk province of the Ukrainian SSR were transferred to the RSFSR [Borisenok, 2005]. So, the following aggregative segments can be identified. The Northern segment - the remaining stable section of the provincial border, extending south to the river Derkul. The Stanichno-Lugansk segment was formed as a result of the transfer of Krasnaya Talovka and the settlement of Talovoye to the Ukrainian Republic in 1926. The peculiarity of the Donetsk and Taganrog segments is that in modern configuration they exist less than 100 years.

The key feature of the Crimean border is the stability of the border location and the variability of its status. The last configuration change happened on March 3, 1955, when the northern part of the Arabat Arrow was transferred to the Kherson region.

Border sustainability indices

In the next phase of the study, as a result of standardization of the set of indicators of emergence and sustainability of the interstate border, the sustainability index based on the key factor of border emergence is calculated. Indicators of duration of border existence are ranked on the basis of emergence. That is, the highest rank was received by segments with the maximum duration of existence in the status of a border of an administrative-territorial unit of the third order (provincial/regional), and similarly in the case of a border of the second order (county/district). For example, in segments where the border of at least the second order exists for more than 100 years, the coefficient is 1, for 90 years and more it is equal to 2, for 80 years and more it is equal to 3 years, for less than 80 years it is equal to 4. The indicator of changing the status of borders is also used to calculate the index. Segments that have changed the status a maximum number of times since the time of their emergence received the lowest rank. The mosaic coefficient is calculated, enabling estimation of the degree of homogeneity of border segments. The highest rank on this indication is assigned to segments where at the maximum length complete homogeneity of emergence is revealed in the absence of changes. The lowest ranks are given to the segments where the maximum number of changes per border kilometer happened, for example, the Rodionovsky segment of the Rostov border and the Southern-Rylsky part of the Kursk border.

Coefficients of duration of border existence in different statuses, coefficients of variability of status and mosaic of border segments obtained as a result of

historical-geographical and geo-informative analysis of the Russian-Ukrainian border formed the basis of the integral index [Tikunov, 1997]. The algorithm for obtaining the integral index includes the normalization of the system of initial indicators by dispersions:

$$\hat{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j}, i = 1, 2, 3, \dots, n; j = 1, 2, 3, \dots, m;$$

$$\bar{x}_j = \frac{1}{n} \sum_{i=1}^n x_{ij}; \sigma_j = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_{ij} - \bar{x}_j)^2}.$$

The normalized values \hat{x} are presented as a matrix for the calculation of Euclidean distances (d_{ik}) connecting each pair of border segments included in the calculation and reflecting their differences:

$$d_{ik} = \sqrt{\sum_{j=1}^m (\hat{x}_{ij} - \hat{x}_{kj})^2}, i = 1, 2, 3, \dots, n; j = 1, 2, 3, \dots, m.$$

When making typological classification, from the obtained values, d_{ik} the largest distance is selected, and the two border segments that it binds become cores of homogeneous border types (clusters). Clusters are formed by the distribution of the remaining border segments between the two cores according to the minimum Euclidean distances. In the case of allocation of more clusters, each of the remaining sections are inserted as a kernel to allocate the third core and all subsequent segments, and the rest are distributed among the three cores in order of minimality and d_{ik} the variant with the smallest intra-group differences is found. The resulting series of groupings can be analyzed on the basis of absolute and relative coefficients of heterogeneity and, with their help, the optimal number of clusters can be chosen:

$$A_k = \frac{100 \left\{ \sum_{k=1}^K \sum_{j=1}^n \sum_{i=1}^n \left[\sum_{p=1}^P (x_{ip} - x_{jp})^2 \right]^{1/2} I_{ik} I_{jk} \right\}}{\sum_{i=1}^{t_{max}} \left[\sum_{p=1}^P (x_{ip} - x_{jp})^2 \right]^{1/2}},$$

$$k = t_{min}, t_{min} + 1, \dots, t_{max};$$

$$O_k = \frac{100 \left\{ \sum_{k=1}^K \sum_{j=1}^n \sum_{i=1}^n \left[\sum_{p=1}^P (x_{ip} - x_{jp})^2 \right]^{1/2} I_{ik} I_{jk} \right\}}{\sum_{i=1}^{t_{max}} \sum_{j=1}^n \sum_{i=1}^n \left[\sum_{p=1}^P (x_{ip} - x_{jp})^2 \right]^{1/2} I_{ik} I_{jk}},$$

$$k = t_{min}, t_{min} + 1, \dots, t_{max} - 1,$$

where k is a number of formed groups (clusters), p is a number of coordinates for distance calculations, t_{min} , t_{max} are minimal and maximal numbers of groups,

I_{ik} is an indicator demonstrating the presence (1) or the absence (0) of a border segment in the group k .

A sharp increase in values A_k or O_k under the decrease in the number of allocated clusters indicates a rise in heterogeneity within the allocated clusters, and, on the contrary, a smooth rise in coefficients is a sign of its steady increase. The threshold, followed by a sharp increase of heterogeneity is optimally taken as the final number of clusters. The typological classification showed that such threshold in this set is 4.

For most accurate justification of construction of sustainability models for the Russian-Ukrainian border, evaluation classification is performed. Since this algorithm enables obtaining synthetic characteristics of the estimated position of territorial objects according to a single scale and ranking border segments on the basis of these estimates, and because the coefficients are the basement for estimation, such a model is most applicable for classification. The choice of differentiation measures between border segments is to calculate the difference vector d^0 . It shows the extent of remoteness of real objects from hypothetical one, which has the best or worst evaluation conditions. In order to identify groups (clusters), vector values, pre-ranked in an ascending order, are divided into homogeneous groups. To do this, the increments of the subsequent ranked values of the vector of evaluation characteristics d^0 over the previous ones were calculated. From the set of increments, the minimum is found; segments bounded by it are merged into the first group. This increment was excluded from further analysis and a new minimum increment that allowed the segments to be merged into a second group was found, and so on. This classification procedure, in the process of gradual formation of groups (clusters), allows objects not to lose their individual characteristics, border segments are hierarchically ordered among themselves, which is required for the creation of evaluation maps.

The result of this classification is shown in Fig. 1, which enabled obtaining 4 groups of sections of the state border. The first group included the Suzemsky segment of the Bryansk section, the Glushkovsko-Suzhansky segment of Kursk, the Belgorod and Volokonovo segment of the Belgorod section and the united, longest Voronezh-Chertkov segment. The peculiarity of this group is the provincial origin of the border and its stability for 250 years or more. Territories with a stable grid of administrative and territorial units have a relatively high correlation with this group of borders, but they do not always coincide. The grid stability coefficient of administrative-territorial units, also presented in Fig. 1, is calculated on the basis of indicators of border mobility, variability of composition, grid and territorial status [Igonin, 2016]. This circumstance is due to territorial features of administrative reforms, which often did not affect the boundaries of the territories, especially provincial ones, but only changed the status of administrative units, their composition and borders within the provinces.



Figure 1. Sustainability of the Russian-Ukrainian border

The second group brought together segments of county origin with minor changes in the configuration of borders in over two centuries. The Donetsk and Taganrog segments are distinguished here, most of the borders of which were demarcated in the 1920s, but immediately received the status of republican. Among them there are virtually no areas classified as territories with a stable grid of administrative and territorial units.

The third group included segments with weak sustainability, but which contained areas of county origin. Most of the Crimean sites are also distributed, due to the recent change in the status of the border and its county origin. However, part of the adjacent territories exist consistently throughout the study period and are characterized by stability of the grid of administrative-territorial division.

The fourth group included the least sustainable segments - Trubchevsky, Sevsky and Shebekinsky, most of the length of these segments was formed anew in the 1920s or on the basis of county boundaries. The high mobility of the border here is due to both transformations at the provincial level and management decisions on compensatory transfer of territories in favour of the Ukrainian SSR.

Thus, within the framework of mathematical and cartographic modeling, a special unified index for assessing the sustainability of borders and a method of its calculation are developed. This was preceded by a preliminary geo-information

analysis of border sustainability in our previous work, which was based on expert assessments and ranking of indicators. The first classification of border segments is made in accordance to the historical and geographical principle in connection with the peculiarities of formation and change of administrative-territorial division. A sustainability level is defined for each of the 10 aggregated border segments. According to the results of geo-information analysis the hypothesis about the possibility of existence of a sustainability index on the basis of duration of existence indicators, variability and mosaic of border segments is formulated. In this paper, this hypothesis was confirmed by means of mathematical calculations and mathematical cartographic modeling. The results of calculations enabled forming a database of indicators for 73 segments of the interstate border. The final classification of segments is generally the same as the original one if considering a border as ten aggregated segments. Visual differences in the results are explained primarily by generalization of the initial classification, with significant internal differentiation of the aggregated segments. Significant differences in results for Lugansk, Donetsk and Crimean segments are explained by peculiarities of improvement of the border sustainability calculation methodology, where the factor of border location change obtains a greater significance than change in the administrative division of adjacent territories, due to the focus of the study specifically on the segments of the state border.

The similarity of the results confirms the possibility to replace the labour-intensive and largely subjective process of classification and typology with an unambiguously described algorithmic one. The developed index and the method of obtaining it give opportunity to make calculations automatically for any other segments of state and administrative borders. This is of practical importance for research of borderlands and territorial planning of countries and regions, as well as for addressing issues and challenges related to reforming administrative-territorial division.

Conclusions

The Russian-Ukrainian border is characterized by sustainability of its geographical position for eight decades. Key changes occurred in the 1920s as a result of the exchange of territories between the RSFSR and the Ukrainian SSR. All the changes were the result of management decisions, which were taken almost without regard for the national composition of the territories and the views of the population. The index method of assessing the interstate border sustainability enabled revealing significant territorial differences and features of border formation. The most sustainable segments of the border are those that are historically mature, often of natural origin, in particular, those situated along river beds. Long stretches of borders have been unchanged for a long time due to the peculiarities of administrative reforms and stability of large provinces. The

least sustainable segments in the central and northern part of the border have often been catalysts for regional cross-border cooperation, and these processes are now lost. Modern geopolitical trends strengthen the barrier function of the Russian-Ukrainian borderlands, which slows down the development of border territories. Despite this, such detailed research into state borders allows for a clear analysis of their emergence and sustainability, which will necessarily be a useful tool for identification of points of contact of neighboring territories. Historical and geographical studies of borders and borderlands contribute to a reasonable assessment of the ongoing changes in the territorial organization of society.

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