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Research Article

Methods of Spatial Statistical Analysis of Socioeco-Nomic Data and Their Visualization on Karakalpak-Stan Labor Market Maps

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Abstract

Thematic maps illustrating socio-economic indicators are commonly developed without examining whether the territorial patterns displayed on these maps are statistically significant. This may lead to misleading interpretations of spatial distributions and regional differences. The aim of this study is to pilot and evaluate a set of spatial statistical methods, including the Global Moran's Index, Local Indicators of Spatial Association (LISA), Getis–Ord Gi* statistics, and classification quality assessment based on the Goodness of Variance Fit (GVF) criterion, for analyzing and mapping data on job creation across 17 administrative units of the Republic of Karakalpakstan during the period 2017–2024. The analysis was conducted using the number of newly created jobs per 1,000 residents as the principal indicator. Spatial relationships were examined through a k-nearest neighbor spatial weight matrix, while the statistical significance of the identified spatial patterns was assessed using a permutation test with 9,999 permutations. The results revealed no stable global spatial autocorrelation throughout the study period, with Global Moran's I values ranging from -0.219 to 0.183. Although a statistically significant value was identified in the base spatial weight matrix for 2017, this result was not reproduced when alternative spatial weight matrices were applied, indicating the absence of consistent spatial dependence. The findings also demonstrate a reduction in inter-district differentiation over time. Specifically, the coefficient of variation decreased from 58.9% in 2018 to 28.5% in 2024, suggesting a more balanced distribution of newly created jobs among administrative units. Furthermore, the correlation between planned and actual job creation values ranged from 0.96 to 0.998. This strong relationship suggests that the geographical distribution of new employment opportunities was predominantly determined by administrative planning mechanisms rather than by naturally emerging spatial diffusion processes. Overall, the study demonstrates the importance of applying spatial statistical methods to improve the reliability and interpretation of thematic socio-economic maps.

Keywords

Spatial Statistics, Thematic Cartography, Moran Index, LISA, Jenks Classification, Job Creation, Karakalpakstan

1. Introduction

A map has long ceased to be merely a way of showing where an object is locat-ed. In socio-economic geography, it serves as a research tool: it identifies areas where phenomena are concentrated, areas of lag, and directions of process spread

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[10, 11]. However, a thematic map alone does not prove the existence of a pattern. The same data set at different scale intervals can look like a clear "zone" or a mosaic, and the reader's eye tends to find clusters even where val-ues are randomly distributed [9].

Spatial statistics methods allow for the quantitative verification of carto-graphic impressions. Their original idea is formulated in W. Tobler's "first law of geography": nearby objects are more strongly connected than distant ones [7]. P. Moran's global index indicates whether such a connection exists in the territory as a whole [2], LISA's local spatial association indicators proposed by L. Anselin indicate exactly where it manifests [1], while Getis-Ord Gi* sta-tistics highlight "hot" and "cold" points [3, 4]. In foreign practice, these meth-ods have become a standard part of GIS analysis and are implemented in open libraries [13], but in Uzbekistan's regional cartographic research, they are still used sporadically.

The Republic of Karakalpakstan is convenient for testing these methods. The region is heterogeneous in terms of natural conditions and settlement: the densely populated southern oasis with Turtkul, Beruniy, and Ellikkala districts differs sharply from the northern districts of the Aral Sea region. At the same time, public employment is one of the main directions of state policy in the re-gion, and data on job creation are collected annually across all districts in a unified "plan-fact" format.

The aim of the study is to demonstrate how spatial statistics methods complement thematic mapping of socio-economic data and, using the example of job creation in the Republic of Karakalpakstan for 2017-2024, to verify whether regions with high and low job creation intensity form statistically sig-nificant spatial clusters.

2. Materials and Methods

Departmental data on the planned and actual number of jobs created and persons provided with income-generating employment for 15 districts and the city of Nukus for 2017-2024 (totaling 17 territorial units) were used. Bozatau district has been accounted for since 2020, and Takhiatash district since 2018, i.e., since their formation; therefore, the sample size was 15 units in 2017, 16 in 2018-2019, and 17 in 2020-2024. The amounts for the districts are fully consistent with the source's final lines. The number of permanent population at the beginning of the year is taken from the Statistics Agency’s database (indicator 2.01.02.0001) [15]; the sum by district coincides with the republic’s population size for all years.

The absolute number of workplaces is unsuitable for cartograms and spatial tests, as it primarily reflects the size of the area. Therefore, the main indicator was the intensity of job creation per 1,000 residents:

$$r_i = J_i / P_i \times 1000, \quad (1)$$

where J_i is the actual number of jobs created in the i-th district, and P_i is the number of permanent residents at the beginning of the year. Additionally, the percentage of plan fulfillment was considered.

It should be taken into account that since 2022, the scale of the indicator in the source has increased sharply: from 22.8 thousand in 2021 to 216.1 thousand in 2022. This is due to the expansion of coverage (the report includes providing the population with income-generating employment), and not to the tenfold growth of the economy. Therefore, years are compared not by absolute levels, but by relative characteristics: the variation coefficient and Moran index, which do not depend on the scale of the indicator [6].

2.1. Matrix of Space Weights

Neighborhood was determined by the geographical coordinates of the district administrative centers. For each unit, the neighbors were considered to be the k = 4 nearest centers by distance on the sphere; the W matrix was normalized along the rows [5]. This option was chosen because, given the small number of units and the elongated shape of the region, the matrix of nearest neighbors ensures an equal number of connections for each district, including the remote Muynak district. To verify stability, the results were recalculated at k = 3, k = 5, and at weights inversely proportional to the distance.

2.2. Global Autocorrelation

The Moran index was calculated using the Formula (2):

$$I = (n / S_0) \cdot \Sigma_i \Sigma_j w_{ij} z_i z_j / \Sigma_i \Sigma_i z_i^2 \quad (2)$$

where z_i is the deviation of the value from the mean, value is the elements of the weight matrix, and S_0 is the sum of all weights. In the absence of autocorrelation, the mathematical expectation of the index is E (I) = -1/ (n - 1), i.e., -0.071 for n = 15 and -0.0625 for n = 17. A positive value above E (I) indicates a neighborhood of similar values, while a negative one indicates a "chess" alternation. Significance was evaluated using a permutation test: values were randomly redistributed 9999 times across regions, and pseudo-p was defined as the proportion of permutations with at least an extreme value of I. At low n, such a test is more reliable than normal approximation, but a z-score is also provided for comparability.

2.3. Local Indicators

The local Moran index was calculated for 2024 [1]:

$$I_i = z_i \cdot \Sigma j \, w_{ij} z_j \quad (3)$$

and Getis-Ord Gi* statistics [3, 4]. Based on the combination of the standardized zi value and its spatial lag Wz, the regions are classified as HH (high value surrounded by high values),

LL, HL, and LH (emissions). The significance of Ii was verified using conditional substitution (9999 iterations). Since 17 hypotheses are being tested simultaneously for 17 districts, the problem of multiple comparisons was taken into account [14].

2.4. Cartographic Classification

For the 2024 cartogram, four methods for identifying k = 4 classes were compared: equal intervals, quantiles, standard deviation, and natural Jenks boundaries (exact selection of all division options) [12]. The quality of division was evaluated using the GVF criterion [9]:

$$GVF = 1 - SDCM / SDAM \quad (4)$$

where SDAM is the sum of the squares of deviations from the total mean, and SDCM is the sum of the squares of deviations within the classes.

Calculations were performed in the Python (NumPy) environment using algorithms similar to those implemented in the PySAL library [13] and the Spatial Statistics ArcGIS toolkit; the cartogram is built on the vector boundaries of regions from the open geoBoundaries set [16]. Since the Bozatau and Takhiatash districts, formed in 2018-2019, are not included in this set, they are indicated by insignia in their administrative centers.

3. Results

Interdistrict differentiation and global autocorrelation. The calculation results for the years are presented in Table 1.

Table 1. *Job creation intensity and global Moran index by year.*

Year	n	For the republic, per 1,000 inhabitants.	Minimum (district)	Maximum (district)	V, %	I	z	pseudo-p
2017	15	21,8	16,4 (Amudarya)	42,9 (Kanlykul)	35,2	0,183	1,98	0,046
2018	16	9,3	5,4 (Beruni)	31,4 (Nukus)	58,9	-0,183	-0,94	0,141
2019	16	10,4	6,8 (Amudarya)	20,3 (Muynak)	38,5	0,150	1,75	0,069
2020	17	10,5	6,7 (Turtkul)	36,5 (Muynak)	56,6	0,074	1,09	0,123
2021	17	11,8	7,9 (Ellikkala)	24,5 (Muynak)	39,2	0,070	1,06	0,146
2022	17	110,9	46,1 (Takhiatash)	179,5 (Karauzyak)	36,0	0,034	0,77	0,212
2023	17	100,5	57,7 (Nukus city)	143,2 (Takhtakupir)	22,6	-0,104	-0,33	0,421
2024	17	73,3	35,7 (Nukus city)	131,0 (Nukus)	28,5	-0,219	-1,25	0,074

Note: V is the variation coefficient for districts; I is the Moran index at k = 4; pseudo-p is a one-sided permutation test (9999 permutations).
Source: Calculated by the author using departmental data and data from the Statistics Agency [15].

Inter-district differences have significantly decreased. The variation coefficient reached 58.9% in 2018 and 56.6% in 2020, and decreased to 22.6-28.5% in 2023-2024; the ratio of maximum to minimum decreased from 5.8 to 3.7 times (Figure 1a). Moran index values fluctuate around the expected value of E (I) and change sign: the weak positive autocorrelation in 2017 and 2019-2022 is replaced by a negative one in 2018, 2023, and 2024 (Figure 1b). With the base matrix, the level of 0.05 was reached only in 2017 (I = 0.183; pseudo-p = 0.046); two more years later, the pseudo-p was less than 0.10 (0.069 in 2019 and 0.074 in 2024), with indices having opposite signs.

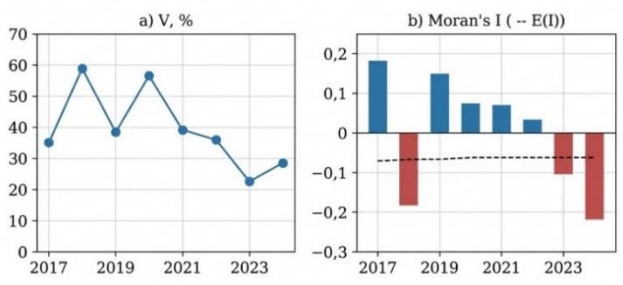


Figure 1. *Variation coefficient (a) and global Moran index (b) for the "employment per 1,000 residents" indicator, 2017-2024 (dotted line - expected value E (I)).*

Stability testing showed that individual significant results depend on the choice of the weight matrix. At k = 3, k = 5, and weights for the reverse distance (24 additional calculations), the 0.05 level was achieved in four cases: 2018 (k = 3; I = −0.277), 2021 (k = 5; I = 0.149), 2022 (reverse distance; I = 0.067) and 2024 (k = 5; I = -0.208). The significant value of 2017 in the base matrix is not confirmed by other matrices (pseudo-p = 0.057–0.307). In no year is significance reproduced for more than one of the four matrices, and the signs of significant indices differ. No significant values were obtained for the percentage of plan fulfillment (the lowest pseudo-p = 0.082 in 2021). Thus, no stable spatial clusters of job creation intensity have been identified; one can only speak of a weak trend toward changing the positive autocorrelation to a negative one in 2023–2024, i.e., toward the alternation of areas with high and low intensity.

Local structure in 2024. Local indicators are presented in Table 2, and the Moran scattering diagram is shown in Figure 2.

Table 2. *Local spatial association indicators, 2024.*

№	District	Working places	Population, thousand people	Per 1,000 inhabitants	z	Wz	I_i	pseudo -p	Type	Gi*
1	Nukus city	12 093	339,2	35,7	-1,96	0,06	-0,12	0,547	LH	-0,88
2	Amudarya	20 775	212,1	97,9	0,75	-0,38	-0,28	0,240	HL	-0,40
3	Beruni	19 548	205,1	95,3	0,63	0,05	0,03	0,420	HH	0,43
4	Bozatau	1 776	21,9	81,1	0,02	-0,47	-0,01	0,163	HL	-0,96
5	Kegeyli	5 700	74,8	76,2	-0,20	-0,20	0,04	0,327	LL	-0,51
6	Kanlykul	5 320	53,8	98,9	0,79	-0,41	-0,32	0,222	HL	-0,44
7	Karauzyak	5 281	54,4	97,1	0,71	-0,01	-0,01	0,536	HL	0,34
8	Kungrad	6 472	136,0	47,6	-1,44	0,15	-0,21	0,450	LH	-0,44
9	Muynak	2 736	33,6	81,4	0,03	-0,42	-0,01	0,193	HL	-0,84
10	Nukus	7 062	53,9	131,0	2,18	-0,97	-2,12	0,019	HL	-0,88
11	Takhiatash	4 990	76,8	65,0	-0,68	-0,02	0,01	0,447	LL	-0,40
12	Takhtakupir	4 176	38,9	107,4	1,16	-0,13	-0,15	0,472	HL	0,34
13	Turtkul	17 068	228,8	74,6	-0,27	0,27	-0,07	0,303	LH	0,43
14	Khojeyli	7 251	128,7	56,3	-1,06	-0,16	0,17	0,311	LL	-0,88
15	Chimbay	6 584	115,7	56,9	-1,03	0,68	-0,70	0,086	LH	0,87
16	Shumanay	4 644	58,0	80,1	-0,03	0,12	0,00	0,399	LH	0,23
17	Ellikkala	15 349	171,0	89,8	0,39	0,11	0,04	0,391	HH	0,43

Note: z is the standardized value; Wz - spatial lag; Ii - local Moran index; Gi is a z-estimate of the Getis-Ord statistics. Source: Calculated by the author.*

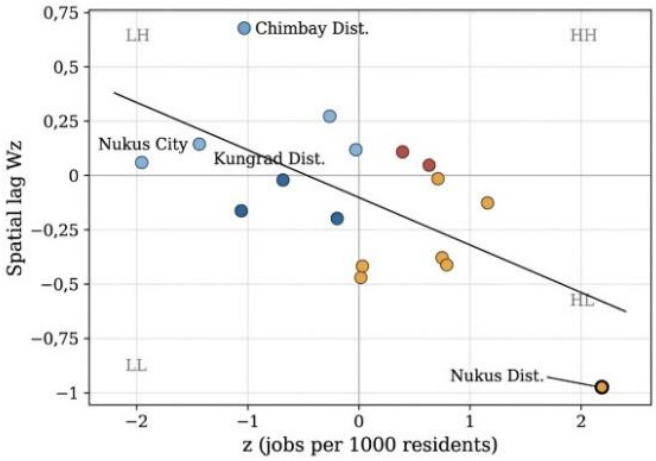


Figure 2. *Moran scattering diagram, 2024 (color is the type of area according to Table 2; the area with pseudo-p < 0.05 is highlighted with a bold outline).*

The slope of the regression line on the diagram is negative (I = -0.219). It is determined by two contrasting cases. The Nukus district (131.0 jobs per 1,000 residents, the highest in the republic) is surrounded by units with low values, primarily the city of Nukus and the Khojeyli district; this is the only significant local HL-type emission (Ii = -2.12; pseudo-p = 0.019). At the opposite pole is the city of Nukus: 12.1 thousand jobs have been created here, but in terms of population, this is the minimum of 35.7 per 1,000 residents. The share of the capital in the created jobs decreased from 14.2% in 2017 to 8.2% in 2024, while the share in the population remained unchanged at 16.9%.

The significance of the Nukus district should be interpreted with caution. When adjusting for multiple comparisons using the false discovery share control method [14], the threshold for the first-ranking district is 0.05/17 ≈ 0.003, and its value of 0.019 does not pass. However, the same area remains the HL emission for the accumulated indicator for 2020-2024 (445.6 jobs per 1,000 residents; pseudo-p = 0.009), i.e., its position is not accidental for an individual year, but repeats throughout the entire period.

The Gi* statistic for neither district exceeded the 1.96 modulus: the highest value was noted in Chimbay (0.87), and the lowest in Bozatau (-0.96). Therefore, there are no statistically significant "hot" or "cold" points. A weak similarity in values is visible only in the southern oasis group (Beruni and Ellikkala districts - HH type at Gi* = 0.43).

Selection of a cartographic scale. A comparison of classification methods is provided in Table 3.

Table 3. *Comparison of indicator classification methods for 2024. (k = 4).*

Classification method	Class boundaries, per 1000 inhabitants.	Number of districts in classes	GVF
Equal intervals	59,5; 83,3; 107,2	4 / 6 / 5 / 2	0,909
Quantiles	65,0; 81,1; 97,1	5 / 4 / 4 / 4	0,846
Standard deviation	57,7; 80,7; 103,8	4 / 4 / 7 / 2	0,883
Natural boundaries (Jenks)	56,9; 81,4; 107,4	4 / 6 / 6 / 1	0,927

Source: Calculated by the author.

The best division quality is provided by the natural Jenks boundaries (GVF = 0.927), while the worst quality is provided by quantiles (0.846). The quantile scale artificially equalizes the number of districts in the classes and spreads out close values into different classes (for example, 80.1 and 81.4), so for this indicator, it visually exaggerates the differences. The Jenks scale highlights the only high-class district-Nukus-and thereby aligns with the LISA result. The final map (Figure 3) is constructed using the cartogram method on the vector boundaries of areas according to Jenks classes; a significant local discharge is highlighted with a thickened contour. The central part of the republic, with its small areas, is included in the survey [16].

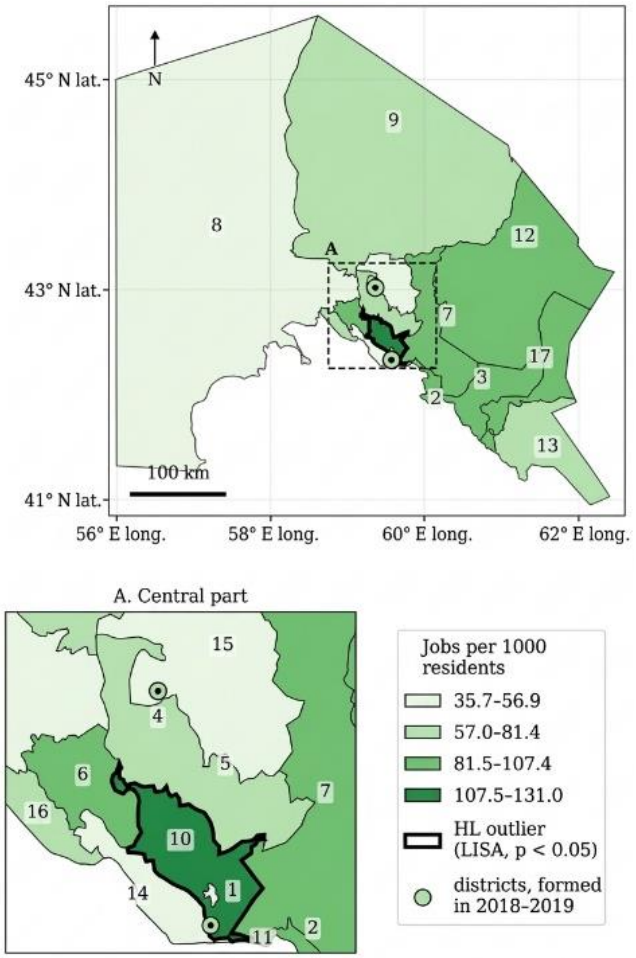


Figure 3. *Job creation intensity in the Republic of Karakalpakstan in 2024 (map, Jenks classes) and LISA result.*

District numbers correspond to Table 2: 1 - Nukus city; 2 - Amudarya; 3 - Beruni; 4 - Bozatau; 5 - Kegeyli; 6 - Kanlykul; 7 - Karauzyak; 8 - Kungrad; 9 - Muynak; 10 - Nukus; 11 - Takhiatash; 12 - Takhtakupyr; 13 - Turtkul; 14 - Khojeyli; 15 - Chimbay; 16 - Shumanay; 17 - Ellikkala. Compiled by the author; district boundaries - geoBoundaries.

4. Discussion

The absence of stable autocorrelation is in itself a meaningful result. If new jobs were created as a result of business activity spreading from growth centers, neighboring areas would have a similar intensity and the Moran index would be consistently positive. The observed picture is different: values are close to spatially random, and differences between areas are decreasing. The explanation is a comparison of the plan and the fact. The correlation coefficient between planned and actual intensity was 0.96-0.998 in all years except 2022 (0.646), and the plan's fulfillment in 2024 lies within a narrow range of 100.6-111.3%. This means that the territorial distribution of jobs is primarily determined by planned assignments to districts, rather than by the neighborly interaction of economies. 2022 also stands out in this regard: nine out of 17 districts failed to meet the plan (from 46.1% in the Takhiatash district), which coincides with a change in the composition of the indicator.

For cartography, a practical conclusion follows from this. A map where areas are "grouped" by color can give the reader a false impression of the existence of zones, especially on a quantile scale. Checking with the Moran index and LISA before drawing up a map allows for a reasonable decision as to whether areas and clusters should be shown on it, or whether it is sufficient to highlight individual anomalous units. In this case, it is cartographically justified to highlight one area-the Nukus district-and the contrast "capital - suburban district," rather than constructing zones.

The contrast between the city of Nukus and the Nukus district also requires careful interpretation. Part of the residents of the suburban district work in the capital, and the jobs created at the enterprises registered in the district partially serve the city's labor market. This is a typical manifestation of the variable area unit (MAUP) problem [8]: the result depends on how administrative boundaries are drawn. The unification of the city and district into a single agglomeration unit would yield approximately 49 jobs per 1,000 residents (19.2 thousand per 393.1 thousand residents), which is lower than the national average.

The limitations of the study are related to the small number of units (n = 15-17), which reduces the power of the tests: moderate autocorrelation at such a n may go unnoticed. Neighborhood was determined by the coordinates of district centers rather than by general boundaries, as the available set of vector boundaries does not reflect the formation of the Bozatau and Takhiatash districts; meanwhile, stability testing revealed that individual results are sensitive to the choice of the weight matrix. The transition to a contiguity matrix based on actual borders and to more fractional units (mahallas, rural assemblies) is the next step. Finally, the indicator reflects reporting data on job creation rather than net employment growth, and its comparability was disrupted by a change in methodology in 2022.

5. Conclusion

1) Spatial statistics methods - the global Moran index, LISA, Getis-Ord Gi*, and GVF classification assessment - form a sequential procedure that is advisable to perform before designing a thematic map: first, the presence of a spatial pattern is verified, then the scale and imaging method are selected.
2) For the Republic of Karakalpakstan in 2017-2024, the intensity of job creation per 1,000 residents does not form stable spatial clusters (I from -0.219 to 0.183): individual significant values are not reproduced when the weight matrix is changed, and since 2023, the Moran index has been negative. At the same time, inter-district differentiation decreased: the variation coefficient decreased from 58.9% to 28.5%.

3) The close relationship between planned and actual values (r = 0.96–0.998) indicates the administrative nature of the territorial distribution of jobs. The only sustainable local emission is the Nukus district, in contrast to the city of Nukus, where the intensity is minimal (35.7 per 1,000 residents in 2024).
4) To map this indicator, the Jenks natural boundary scale (GVF = 0.927) is the best; the quantile scale (GVF = 0.846) exaggerates the differences. The proposed sequence of calculations can be transferred to the GIS environment and applied to other socio-economic indicators of the regions of Uzbekistan.
5) The practical significance of the results is as follows: they can be used in compiling thematic maps for the programs of socio-economic development of the Republic of Karakalpakstan, as well as in distributing planned tasks for job creation between districts-taking into account the population size, as in the current distribution, Nukus, where 16.9% of the republic's population resides, receives only 8.2% of new jobs.

Author Contributions

Reymov Polat Rasbergenovich: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Matjanova Shinar Kadirbaevna: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Reymov Polat Rasbergenovich is a Doctor of Geographical Sciences and Professor at Karakalpak State University named after Berdakh, Nukus, Uzbekistan. He is the Head of the Geoinformatics Laboratory and conducts research in geoinformatics, cartography, geoecology, and environmental monitoring. His scientific interests include the application of GIS and remote sensing technologies, landscape mapping, assessment of desertification processes, and the monitoring and management of natural resources in the Aral Sea region. His research also focuses on geospatial analysis and the ecological transformation of the landscapes of the Southern Aral Sea region.



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Reymov Polat Rasbergenovich: Geoinformatics, Geographic Information Systems (GIS), Remote Sensing, Cartography, Geoecology, Landscape Mapping, Environmental Monitoring, Desertification, Natural Resource Management, and Aral Sea Region Studies

Matjanova Shinar Kadirbaevna: Economic Geography, Social Geography, Regional Development, Population Geography, Agricultural Geography, Territorial Planning, and Socio-Economic Development of Karakalpakstan