Cluster analysis of border areas in the southern part of Siberia

T M Oydup and S A Chupikova
Tuvinian Institute for Exploration of Natural Resources, SB RAS, Kyzyl, 667007 Russia

E-mail: tana_o@mail.ru

Abstract. The purpose of the work is to carry out a comparative analysis of the location of the regions, to determine the location and status of each border region, to identify the constituent entities of the Russian Federation with the similar position and problem situations. The present work solved the problem of multidimensional data classification using the grouping method and cluster analysis. We conducted a comparative analysis of the regions using three criteria: social, economic and territorial. The following indicators were used: for the social criterion – the ratio of average per capita income to the subsistence level; for economic – the level of real fiscal security; for territorial – population density (people/km²). The method of cluster analysis was applied, and a dendrogram was constructed for the border regions of Southern Siberia in order to present the data in a visual form. Determining the status of a region according to three criteria gives an advantage over the traditional types of ranking and groupings from viewpoint of the objectivity of determining the rating position of a region, analysis of current social-economic problems.

1. Introduction
The republics of Altai, Tyva, Buryatia and Zabaikalsky Krai are among the border regions of the South of Siberia. The total area is 1,044.7 thousand km², where 2,592.9 thousand people lived by end-year 2019. All the listed regions have significant social-economic differences from each other despite the presence of the unifying status of the border region. Nevertheless, a comparative analysis of the situation of the Russian regions can be made in order to identify the status, typical problems, and similarities of each border region.

2. Models and Methods
Scientific researches cover the issues of typology and characteristics of regions in many scientific areas from economic geography to political studies. All of these research studies characterize a region depending on the “status” that it occupies relatively to another region and according to some criteria, that’s why a region may have several “statuses” at the same time.

For example, the Republic of Tuva in terms of its administrative-territorial position has the following characteristics - it is a republic within the Siberian Federal District, belonging to the East Siberian economic region, as well as being a border region. In relation to existing problems, Tuva is a Depressed, subsidised region. So, one region can simultaneously possess several statuses that characterize it. However, the above “statuses”, in our view, give a one-sided characterisation of a region: they either relate the position of one region to another, or focus only on the problem of one group [1-2].
Therefore, in addition to the generalised characterisations listed above, another group of three factors can be identified:

- **social** – indicates the social, demographic, and socio-labour level of a region. The criteria for assessing social status are social indicators, as well as indicators of quality of life, migration and life expectancy;
- **economic** (level of economic development of a region, gross domestic product, etc.) – can be defined in the following categories: depressive or non-depressive; subsidized or non-subsidized; recipient or donor, etc.;
- **territorial** – (central, remote, border, median, etc. as well as the parameters of a region in relation to the area it occupies).

Each of the mentioned factors except the territorial one is characterized by many attributes that undoubtedly supplement each other and provide the most complete picture of the social-economic situation in a region. In our opinion, a large array of indicators does not make it possible to focus on a specific task, to reveal the main problems, so we chose one indicator for each factor.

In accordance with the objectives of our study, we suggest that the following indicators should be taken as characteristic ones:

- for social factor – the ratio of average per capita income to the subsistence minimum;
- for economic factor – the level of real budgetary security;
- for territorial factor – population density (people/km\(^2\)).

The regions were grouped according to each indicator. The **social** indicator covers the distribution of the constituent entities of the Russian Federation in terms of the ratio of average per capita income to the subsistence minimum. The **economic** indicator divides regions according to the level of real (before the distribution of subsidies) budgetary security. The **territorial** indicator considers the distribution of the constituent entities of the Russian Federation according to population density.

The border regions of Southern Siberia were singled out for further analysis from the whole set of constituent territories of the Russian Federation.

The method of cluster analysis was applied; a dendrogram was constructed for the border regions of Southern Siberia in order to present the data in a visual form. This method is used when it is necessary to combine the studied data into apparent structures and is widely used in scientific studies with a large array of indicators [3-5]. “In clustering the study objects are assigned to groups so that intra-group differences are minimal but inter-group differences are maximal. Cluster analysis is designed to split a set of objects into different groups (clusters or classes). In fact, it is a multidimensional data classification task” [6].

### 3. Results and Discussion

Below we consider how our proposed principle of three-dimensional regional status works using the example of Siberia’s border regions. A cluster analysis was carried out for the four regions bordering Mongolia using three indicators, which shows that the Republics of Altai, Buryatia and Zabaikalsky Krai are the closest in terms of their status. Only the Republic of Tuva is located far from all of them. Figure 1 shows the Euclidean distance from the Republic of Tuva to the second cluster of three regions is significantly greater than within the second cluster.

In the dendrogram the close relationship between Buryatia, Zabaikalsky Krai and the Altai Republic is stronger than with Tuva. Figure 2 demonstrates that the diverge between clusters occurs in all three indicators: “the ratio of average per capita income to the subsistence minimum”, “the level of real budgetary security” and “population density”.

It should be noted that the border regions of the southern part of Siberia have indicators significantly lower than the national average. The Republic of Tuva is in the group of the weakest regions where the ratio is less than 200% according to the ratio of average per capita income to the subsistence minimum. The Republics of Buryatia and Altai as well as Zabaikalsky Krai are in the middle group with indicators ranging from 200% to 300%.
In terms of fiscal capacity, the Republic of Tyva is in the fourth group with the lowest own budgetary revenues 19.3% (0.193). After the distribution of subsidies, considering the amendments, the total amount of Tuva Republic’s income is 18,625.8 million rubles. It increases the budgetary provision by 46% (0.46) and brings the estimated fiscal capacity to 0.653. But this indicates that 34.7% of revenues will not be covered by revenues. After the distribution of subsidies, the level of estimated fiscal capacity becomes approximately the same: in the Republic of Altai 69.1%, Buryatia - 67.1%, Zabaikalsky Krai 70.8%, and Tyva - 65.3%.

Thus, in all the analysed border regions there is no 100% coverage of expenditures, the level of estimated fiscal capacity is 65-70%. The share of subsidy part is approximately equal, except for the Tyva Republic, where own revenues are about 20%, which leads to an increase in subsidies from the federal centre to keep the republic at the average level for the macroregion.
The regions differ significantly in terms of population density. The lowest value is in Tuva, barely exceeding 2.0 people per 1 km². This indicator is ambiguous: on the one hand, it shows that the region has large free territories (an important resource). On the other hand, the low figure indicates that the territories are sparsely populated, and with the expansion of the production base, commissioning of new deposits, and industrial infrastructure facilities, they may experience labour shortages.

4. Conclusion
Thus, first, the border areas of Siberia lag behind other territories of the region in their social-economic situation; second, the border areas themselves heterogeneous – the Republic of Tyva is in the most underdeveloped position; third, with equal capacities of regional budgets, the level of social security of the regions varies markedly.

The ‘three-dimensional’ status of a constituent entity of the Russian Federation makes it possible to determine its position in the regional system, and evaluate the current state and development prospects. The proposed approach significantly deepens knowledge about the research object, it also allows identifying groups of regions with similar social-economic problems and growth indicators.

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