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The possibilities of using remote sensing data when monitoring cross-border regions

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Abstract. The article shows the possibility of using the results of remote sensing data processing for the purpose of geo-information support for monitoring, evaluating, and forecasting the development of cross-border regions.

1. Introduction

For the near future, the dynamics of the spatial development of individual regions of the country is connected with the domestic and foreign practice of cross-border cooperation. The intensification of cross-border interaction affects not only the economic development of the region, but also the political trends of the state. The development of global geopolitical systems requires reliable information on the impact of cross-border formations on neighboring territories.

The components of a transboundary region are the same signs that are generally characteristic of the region, namely: economic entities, geodemographic and socio-territorial communities, ecosystems, settlements.

The cross-border areas of interaction can significantly change the economic and social structure of a territory, since they are often peripheral formations of neighboring states. Effective use of the modernization process requires adequate resources, and for the effective management of these resources, objective information about the state of the region is needed. The main resources for cross-border cooperation are economic feasibility and geographical location [1]. Russia's strategy in implementing transboundary capabilities should be based not only on resource, infrastructure and institutional capabilities, but also on innovative information projects.

The recently adopted *Digital Economy of the Russian Federation* program shows the need to create a domestic digital platform for collecting, processing, and distributing spatial data to solve various political and economic problems. [2]. In accordance with the above concept, the use of modern methods of quickly obtaining objective information can be very useful for the effective management of territories and ensuring their sustainable development.

2. Materials and Methods

The presence of transboundary situations stimulates a change in ground infrastructure, contributes to the emergence of traffic flows, new settlements, objects of economic activity, which entails a change in the natural situation in the region. The diversity of the observed processes makes it difficult to monitor and analyze the situation as a whole.



Contemporary means of remote sensing allow to obtain objective information regarding the dynamics of transboundary territories, and to carry out a comparative analysis of their development with almost any time interval and with a given accuracy of determining spatial coordinates. Images can be obtained in various fairly narrow areas of the electromagnetic spectrum with high spectral resolution and ultra-high spatial resolution. Pictures can differ in a different field of view, and in this area we can get pictures of both high detail and large coverage.

For example, Figure 1 shows pictures of one of the mineral deposits of the Trans-Baikal Region with an interval of four years (2012–2016).



Figure 1. Mineral deposits, Trans-Baikal Region, a four-year shooting interval [3].

Figure 2 shows images of the border area of the North-East of the People's Republic of China with a time interval of seven years (2011–2018).



Figure 2. Border area of the North-East of the People's Republic of China, Manchuria, a time interval of seven years [3].

The given images are geolocated, they visually observe a significant change in the state of the territory; however, it is difficult to identify small tumors in this way and the quantitative characteristics of the transformation of the plots cannot be given.

For processing multi-time snapshots, various methods of automated decryption are used to increase their informativeness [4]. For example, the identification of changes in the studied areas can be detected by comparing the original images and composite images, as well as using the images converted by the principal component method, etc. The choice of methods or their combination is determined by the task, as well as by the spatial, spectral, radiometric, or temporal resolution of the satellite images used.

To detect changes in territories using different-time images, both separate image processing and the use of source images for their subsequent comparison using Change Detection algorithms are used.

The method of differentiation of multi-time images (Image differencing) is based on the elementwise subtraction of the brightness of the original images. In unchanged areas, the difference in brightness values will be close to zero. At the same time, they will have positive or negative values in the changed areas (depending on the direction of change).

A comparison of multi-time snapshots after classification (post-classification comparison) can lead to serious difficulties in comparing the results of classification associated with a mismatch of both the number of classes and their correlation with objects. However, in many cases, the processing of generalized thematic rasters shows the highest reliability of the results at regional monitoring scales.

Detection of changes in multi-temporal images converted by the principal component analysis (PCA) is based on the elementwise subtraction of the brightness values of the corresponding pixels of the main components. However, there is another way in which multi-temporal images are combined into one file, which is converted using PCA, and those components with a lower correlation are analyzed. This approach consists in the joint processing of a set of images for different dates, which are combined into a single image and processed like a multizone image.

To select objects of certain classes (vegetation, water objects, soil, anthropogenic formations, etc.), index images can be formed from multi-zone images. Obtaining index images is based on the choosing spectral channels for which the images of a given object have maximum differences in brightness. The following indexes are built on this principle: NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), GEMI (Global Environmental Monitoring Index), etc. [5].

3. Results

Figure 3 shows results of the comparison of the multi-temporal images presented above in order to identify changes in the state of the territories, performed by the method of differentiating multi-temporal images (image differencing).

The resulting thematic image masks superimposed on images for earlier dates, contains information on the difference in brightness of pixels having the same geographical coordinates. The magnitude of these changes can be expressed both in absolute values of brightness and in percentage. In each case, this parameter is determined experimentally and depends on the materials used and the objects under study.

In accordance with the legend in Figure 3, the changes are of a different nature, from “a significant increase” to “a significant decrease.” They correspond to the appearance or disappearance of an object. In most cases, the “slight increase / decrease” of brightness values are caused by differences in shooting conditions, season, light level, etc., and they are not included in the resulting mask. The number of pixels of the image areas corresponding to the identified changes is also given in the legend. Based on this characteristic, we can determine the area of the territory that has been transformed.

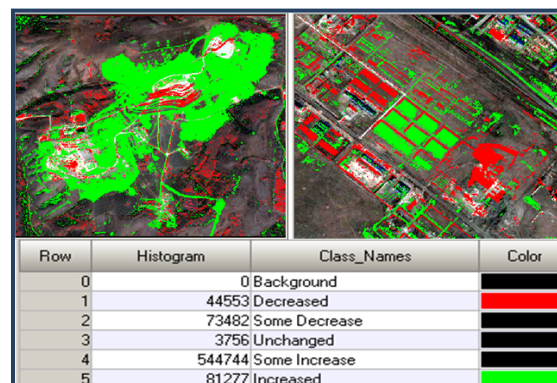


Figure 3. The results of the identification of changes in the state of the territories by different time shots.

The results show significant modifications in the studied objects, their nature of vegetation, the emergence of many buildings and structures, a new network of roads and communications, etc. Moreover, they are equally observed both in the territory of Russia and in the neighboring state.

Based on the information obtained from the processing of remote sensing data, we can assess trends in the development of natural and anthropogenic systems, the focus of economic activity in the region, compare changes in the Russian and adjacent territories, namely:

1. The increase in areas of residential neighborhoods in cities indicates an influx of population in the studied areas and a general economic rise.
2. Significant expansions of industrial and commercial areas indicate an increase in trade in cross-border areas.
3. Monitoring the position of communications allows one to track the disappearance or occurrence of roads, including those being not officially registered, which can reveal the illegality of certain actions.
4. Assessment of the state of forests allows to identify illegal logging and risk areas associated with the forest fires and epidemics.
5. Conducting operational monitoring of emergency situations, exciting the territory of neighboring states, ensures the effectiveness of rescue operations.

Thus, the obtained results show the possibility of operational control over the state and development of cross-border regions.

4. Discussion

The considered examples of detecting changes of a different nature have shown the possibility of on-line monitoring of territories and local objects by remote sensing methods, provided that the optimal method for decryption is chosen [6], [7], [8].

- The quality and reliability of the interpretation results is determined by the parameters of the source materials and the target task of the study.
- It is shown that the multi-temporal images obtained from space allow not only to confidently record the changes, but also their character.
- The information obtained allows us to identify the dynamics of not only the territories, but also to assess the social and economic trends associated with these changes.

The use of remote sensing data corresponds to the direction of the state policy in the field of ensuring the sustainable development of cross-border regions [2].

5. Conclusion

The conducted studies show the effectiveness of using the whole array of methods of automated processing of remote sensing data for monitoring the dynamics of the development of regions, including cross-border regions. And these studies provide the efficiency and informative assessment of not only the geophysical but also socio-economic processes occurring in these territories.

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