Assessment of agricultural land distribution within the Middle Amur Lowland based on remote sensing data and the DEM

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Abstract. The agricultural development of the Middle Amur lowland was assessed based on the analysis of Earth remote sensing data. On average, the level of modern land use for agriculture is 5.5%, varying from 0-0.5% within peripheral foothills and island ranges to 6.4% on low-lying alluvial plains. The developed map of terrain types of the territory allowed considering the spatial features of the distribution of agricultural land depending on the genetic type of terrain. It is shown that the morphometric characteristics of the earth's surface (slope, elevation difference within a radius of 500 meters, surface vector curvature) are determined by the different genesis of the terrain area. These values are important in the redistribution and accumulation of moisture, which determines the possibility of agricultural land use. The study results suggest that the possibilities of extensive agricultural production expansion within the Middle Amur lowland are largely exhausted.

1. Introduction

The implementation of state programs aimed at enhancing the economic development of the Far East requires compliance with environmental restrictions on economic development. Criteria for ensuring environmental balance should be reflected in the development strategies of the regions through which the state environmental policy is implemented. Scientific substantiation of the characteristics that respect the ecological balance is impossible without efficient and relevant inventory information reflecting the resource capabilities and the current state of geosystems, which is hindered by an extremely low level of knowledge of the Far East and the Amur region. Map materials of a large scale 1:2,500,000-1:1,000,000 currently available are sufficient for the development of socio-economic development strategies and territorial planning schemes at the level of the Russian Federation's constituent entities. However, they poorly reflect the spatial organization and specifics of geosystems when moving to a more detailed scale required when developing strategies and schemes at the municipal level. Besides, all materials reflect the situation of at least 10 to 30 years ago, which indicates the need to update them and, in conditions of the high cost of cartographic work, maximize the use of Earth remote sensing data (ERSD).

The territory of the Middle Amur lowland is part of the transboundary Sungari-Central Amur physical and geographical province. It is part of the Amur industrial and agricultural area and, according to the strategy of socio-economic development of the Far East [1], plays an important role in ensuring food security in the region. With the full implementation of the territory's development goals, the gross regional product of agriculture in the Far East should increase by 10 times, which
implies a significant intensification of economic activity and an increase in the load on the host geosystems. The above makes it relevant to assess their ecological status and the extent of the modern use of the territory.

For the territory of the Middle Amur lowland, the dominant factors of land use are residential and industrial development, agricultural land use, and pyrogenic transformation of natural complexes associated with human activity. In this work, the main focus is on agricultural land use.

2. Results and Discussion

The assessment of the current agricultural use of the territory was based on automatic and expert ERSD classification from Landsat 7-8 satellites (cloudless coverage of 14 scenes for the summer period of 2017, resolution 30 m/pix) and Aster (42 scenes, 2013-17, 15 m/pix) (accessed via the EarthExplorer site (http://earthexplorer.usgs.gov)) in the ArcGIS 10.5 software environment. The local size of the transformed territories determined the need for high spatial resolution images of free GeoEye access (resolution 0.5 m/pix) via the ArcGIS WorldImagery service, as well as images of the Canopus-B satellite (resolution 2.15 m/pix). As a result, the boundaries of agricultural land and reclamation systems that are not currently used were allocated for the research area. During the expedition work in 2016-2019, the materials were field verified.

Within the Middle Amur lowland, agricultural land occupies 234.7 thousand hectares or 3.6% of its area, and reclamation systems that are not currently used for agriculture have an area of 120.6 thousand hectares (1.9%). Analysis of the spatial distribution of agricultural land revealed their high inhomogeneity, which is determined by the nature and history of the development of the territory, its transport accessibility: the position in the Trans-Siberian (Birobidzhan-Khabarovsk-Vladivostok) and Amur development areas (along the Amur River and the Khabarovsk-Komsomolsk-on-Amur railway). The agricultural development vector determined the distribution of transformed land depending on the geomorphological characteristics of the territory, which determine the presence of fertile soils.

The need for a more detailed analysis of the farmland distribution depending on the morphometric characteristics of the terrain determined the need to develop a map of the genetic types of the area terrain. Geomorphological maps 1:2,500,000, 1:1,500,000, 1:1,000,000, currently existing for the territory of the Khabarovsk Territory [2, 3] have a low level of detail. In addition, the capabilities of modern GIS technologies make it possible, along with topographic and geological maps, to actively use digital terrain models obtained from SRTM 4.1 data (http://dwtkns.com/srtm30m/) both in the original form, reflecting the elevation matrix of the territory, and their derivatives. Based on their processing in the Spatial Analyst module of ArcMap 10.5, the following SRTM derived layers were obtained: surface slopes, elevation classes, and the depth (intensity) of vertical terrain dissection within a radius of 0.5, 1, and 2 km (“terrain energy” maps).

In addition to the above, we used the vector curvature of the VRM surface (Vector Ruggedness Measure), proposed and implemented in the script for ArcMap 10.5 by Shappington [4] based on the method developed by Hobson [5]. According to the data obtained by the authors when studying the terrain of Sikhote-Alin, this indicator effectively reflects two closely-related parameters of slope steepness and exposure, not replacing them, but supplementing them [6]. Another important advantage is the ability to calculate the indicator with different generalization steps (3×3, 5×5, etc.), while the formulas for calculating surface curvature indicators implemented in ArcGIS are applicable for calculating morphometric indicators only at the local level. For the territory of the middle Amur lowland, the VRM indicator was calculated with several levels of detail: 200×200, 500×500, 1,000×1,000, 2,000×2,000 m.

The classification used in the geomorphological map of the USSR at the scale of 1:2,500,000 is taken as the basis for the landform selection [2]. Geological maps of the territory at a scale of 1:200,000, geomorphological maps: 1:1,000 000, topographic maps: 1:50,000, 1:100,000, DEM data based on SRTM 4.1 (http://dwtkns.com/srtm30m/) that have undergone hydrological correction and their derivatives were used as the initial data. Within the study area, 9 genetic types of terrain are identified (figure 1, table 1), belonging to 4 high-altitude levels (terrain classes): valley, plain, foothill, low-
mountain with different characteristics of dissection.

![Figure 1. Transformed Lands of the Middle Amur Lowland (1:1,800,000).

Within the Middle Amur lowland, the maximum distribution was obtained by low-lying (up to 200 m) accumulative and accumulative-denudation plains (68.9% of the territory area) of alluvial (51%), alluvial-proluvial (6.1%), diluvial-proluvial (10.7%) and volcanic (1.1%) genesis (table 1). Accumulative floodplains are the second most common, occupying 21.7% of the area. Of these, 9.5% fall on the floodplain of the Amur River and its largest tributaries. Using the functions of zonal statistics and distribution histograms in the Spatial Analyst module of the ArcMap 10.5 software, it was possible to calculate the main morphometric characteristics of the genetic types of the relief of the middle Amur lowland, such as the average and prevailing surface slopes, the height difference in cells of various dimensions, the height histogram, and the average vector surface curvature. The same indicators were calculated for agricultural land within different types of terrain (table 2).

The maximum distribution of agricultural land within the Middle Amur lowland was obtained within the lowland plains (92.4% of the area of agricultural land and 97.18% of the area of reclamation systems) of alluvial (78.09%) and diluvial-proluvial (11.65%) genesis. In addition to flat areas, the agriculture of the Jewish Autonomous Region and Khabarovsk Territory actively uses natural complexes of accumulative floodplains of small and medium-sized rivers (5.89%). Drainage systems have a predominant distribution in the borders of low-lying alluvial (92.52%) and alluvial-proluvial (3.02%) plains.

From the obtained materials, it can be seen that the genesis of the area terrain largely determines its morphometric characteristics – the average slope and depth of vertical dissection, as well as indicators of the vector surface curvature. These parameters have a predominant value in the redistribution and accumulation of moisture, which largely determines the possibility of using soils for agriculture.
Table 1. Morphometric characteristics of agricultural land areas, drainage systems and relief types of the Middle Amur Lowland

| Subclasses and types of relief | Area | % of the total | % of the type of relief | Average surface slope, degrees | Height difference within a radius of 1000 m | The average VRM of the surface in cells radius 500 m |
|-------------------------------|------|---------------|-------------------------|-------------------------------|------------------------------------------|--------------------------------------------------|
|                               | km²  | % of the type of relief |  |
| I. Plains low (up to 200 m) accumulative and accumulative –denudation | | | | | | |
| 1. Alluvial                   | 31094.9 | 53.83 | 0.28 | 7.8 | 2 | 0.000041 |
| Agricultural lands           | 1992.3 | 3.45 | 6.41 | 0.32 | 8.8 | 2 | 0.000057 |
| Drainage systems             | 1117.2 | 1.93 | 3.59 | 0.17 | 5.9 | 2 | 0.000037 |
| 2. Alluvial - proluvial      | 3701.3 | 6.41 | 0.73 | 20.5 | 5 | 0.000057 |
| Agricultural lands           | 39.1 | 0.07 | 1.06 | 0.91 | 24.0 | 18 | 0.000077 |
| Drainage systems             | 30.9 | 0.05 | 0.83 | 0.24 | 6.6 | 4 | 0.000036 |
| 3. Deluvial- proluvial       | 6533.0 | 11.31 | 2.45 | 54.56 | 20 | 0.000343 |
| Agricultural lands           | 185.5 | 0.32 | 2.84 | 2.47 | 46.7 | 19 | 0.000181 |
| Drainage systems             | 3.8 | 0.01 | 0.06 | 1.42 | 41.4 | 29 | 0.000118 |
| 4. Volcanogenic               | 688.4 | 1.19 | 2.35 | 45.9 | 35 | 0.000245 |
| Agricultural lands           | 16.3 | 0.03 | 2.37 | 1.31 | 29.8 | 27 | 0.000149 |
| Drainage systems             | 5.2 | 0.01 | 0.76 | 0.96 | 21.5 | 23 | 0.000085 |
| uplifted (200-500 m) denudation and denudation – erosion | | | | | | |
| 5. Deluvial- proluvial       | 881.3 | 1.53 | 6.41 | 129.6 | 101 | 0.001679 |
| II. Piedmont high (elevation of 500 – 1000 m) denudation –tectonic | | | | | | |
| 6. Fold-block                | 163.7 | 0.28 | 10.32 | 201.1 | 133 | 0.003898 |
| III. Low mountains (elevation of 500 - 1000 m) denudation and denudation - erosion | | | | | | |
| 7. Folded and fold-block     | 1367.7 | 2.37 | 10.8 | 228.0 | 144 | 0.003370 |
| IV. River floodplains        | | | | | | |
| 8. Accumulative floodplains of small and medium-size rivers | 7530.8 | 13.04 | 0.44 | 10.8 | 3 | 0.000085 |
| Agricultural lands           | 118.5 | 0.21 | 1.57 | 0.12 | 5.0 | 3 | 0.000068 |
| Drainage systems             | 22.0 | 0.04 | 0.29 | 0.11 | 4.8 | 3 | 0.000042 |
| 9. Accumulative floodplains of big rivers (Amur, Ussuri) | 5801.2 | 10.04 | 0.49 | 7.1 | 3 | 0.000056 |
| Agricultural lands           | 34.1 | 0.06 | 0.59 | 0.14 | 4.5 | 3 | 0.000034 |
| Drainage systems             | 17.3 | 0.03 | 0.30 | 0.18 | 5.2 | 3 | 0.000042 |
Table 2. The area of the transformed lands of the Middle Amur Lowland in different types of relief, % of the area of the transformation type

| Type of terrain | Agricultural lands | Drainage systems | Type of terrain | Agricultural lands | Drainage systems |
|-----------------|--------------------|------------------|-----------------|--------------------|------------------|
| 1               | 78.09              | 92.52            | 4               | 0.50               | 0.40             |
| 2               | 2.16               | 3.02             | 8               | 5.89               | 2.38             |
| 3               | 11.65              | 1.24             | 9               | 1.46               | 0.42             |

The analysis shows that there are two multidirectional trends in the distribution of agricultural land due to the nature of moisture redistribution in different genetic types of terrain. Within the low-lying accumulative plains of alluvial and alluvial-proluminal genesis, the main limiting factor for the use of the territory is its excessive moisture associated with the obstructed flow. As a result, the most developed areas are those with a more pronounced slope and elevation difference. For example, the average slope of agricultural land within the alluvial plains is 0.32°, while this characteristic for the type of terrain as a whole is 0.28°, the height difference within a radius of 1,000 meters is 8.7 m, compared to 7.7 m, and the vector curvature of the surface is 0.000057, compared to 0.000041. The spread of reclamation systems within this type of terrain is observed in the least divided areas (angle – 0.17°, difference – 5.9).

Other types of terrain in the Middle Amur lowland are characterized by high rates of dissection, and, as a result, more intensive surface runoff. As a result, agricultural land within their boundaries is confined to the more gently sloping and less dissected areas.

When assessing the prospects for involving new lands in the turnover, it should be noted that the morphometric parameters of the development of low-lying accumulative plains are largely limited. Figure 2 shows the characteristic of the vector area surface curvature of the Middle Amur lowland, where it can be seen that the most divided territories of the low-lying plains have already been developed, and the rest require large investments.

Figure 2. Vector Ruggedness Measure of the Middle Amur Lowland (1:2,500,000).
3. Conclusion
Thus, the analysis of ERSD allowed assessing the degree of agricultural development of the territory of the Middle Amur lowland. On average, the level of modern land use for agriculture is 5.5%, varying from 0-0.5% within the peripheral foothills and island ranges to 6.4% on low-lying alluvial plains. The obtained materials prove that the relief genesis plays a significant role in the distribution of agricultural land within the Middle Amur lowland. It determines the values of morphometric characteristics of various genetic types of terrain (surface slope, elevation difference within a radius of 500, 2,000 meters, vector surface curvature). This is important in the redistribution and accumulation of moisture and, as a result, determines the possibility of agricultural land use. The study results suggest that the possibilities of extensive agricultural production expansion within the Middle Amur lowland are largely exhausted.

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