JOURNAL OF FOREST SCIENCE, *63*, 2017 (11): 485–489

doi: 10.17221/71/2016-JFS

Remote cartographic assessment of the erosion condition of agrolandscapes

Aleksey Semenovich OVCHINNIKOV[1], *Evgeniy Aleksandrovich LITVINOV*[1], *Aleksandr Sergeevich RULEV*[2], *Sergey Denisovich FOMIN*[1]*, *Maksim Mikhaylovich KOCHKAR'*[2], *Olga Mikhaylovna VOROB'EVA*[1]

[1]*Department of Agroecology and Forest Melioration of Landscapes, Faculty of Agricultural Technology, Volgograd State Agrarian University, Volgograd, Russian Federation*

[2]*Federal Science Center of Agroecology, Russian Academy of Science, Volgograd, Russian Federation*

**Corresponding author: fsd_58@mail.ru*

Abstract

Ovchinnikov A.S., Litvinov E.A., Rulev A.S., Fomin S.D., Kochkar' M.M., Vorob'eva O.M. (2017): Remote cartographic assessment of the erosion condition of agrolandscapes. J. For. Sci., 63: 485–489.

The article provides an assessment methodology of the erosion condition of agricultural landscapes based on remote sensing data. The methodology is based on a multi-parametric cartographic analysis with the use of geoinformation technologies. Currently, only a cartographic image can give a holistic view of the landscape erosion and the processes occurring in them, and resorting to the modern geoinformation systems (GIS) for its obtaining and analysis is becoming a compulsory requirement of our time. The practical use of modern GIS technology in agroforestry practice allows automating the process of working with aero and space images and cartographic materials drawing up, which fully characterize the object of study. Remote cartographic studies have shown that the agricultural landscapes of the Dono-Chirskiy interfluve area need optimizing in land use and integrated agroforestry arrangement.

Keywords: geoinformation technologies; geoinformation systems; erosion-control agroforestry complex

To date, in the territory of the Dono-Chirskiy interfluve, there is almost no natural landscape with original biodiversity and high productivity of phytocoenoses. In the region, soil erosion is a predominant degradation process which became actively spread in the right bank of the Volga River and the Don River basin, which is due to the peculiarities of the relief of these territories.

The soil erosion control is becoming of particular relevance (Colborne, Staines 1985; Vittal et al. 1990; Klik, Eitzinger 2010). To identify erosion processes remote sensing has been increasingly used in recent years. Remote sensing systems receive comprehensive development: the characteristics of optical imagery systems are significantly improved, regular digital imagery with the use of high-resolution satellites IRS (India) with a spatial resolution of 6 m, Aster: 15–30 m, Spot: 6–10 m, QuickBird: 1.6–2.4 m, GeoEye: 0.6–1 m (USA) and others is now available. However, the space images with 15 m spatial resolution are not inferior in quality to aero images when used for solving management tasks. Great opportunities are offered for high-resolution data from QuickBird and GeoEye satellites, which are available for specific regions of Russia.

The practical use of modern geoinformation systems (GIS) technologies in agroforestry practice allows automating the process of working with the aero and space images and drawing up cartographic materials, which fully characterize the object of the study. GIS technologies are a means of spatially coordinated geographical information collection, storage, conversion, display and dissemination, and they also enable the integration of aerospace monitoring, mathematical modelling and computer cartographic methods into a single process that raises this research to a new level (Jarritt, Lawrence 2006; Efe et al. 2008; Alatorre, Begueria 2009; Kiesel et al. 2009; Kulik et al. 2013; Rulev et al. 2013).

The aim of the research was to conduct an agroecological assessment of the watersheds of the Dono-Chirskiy interfluve with a view to their rational forest-ameliorative arrangement on a landscape basis using remote sensing and cartographic methods.

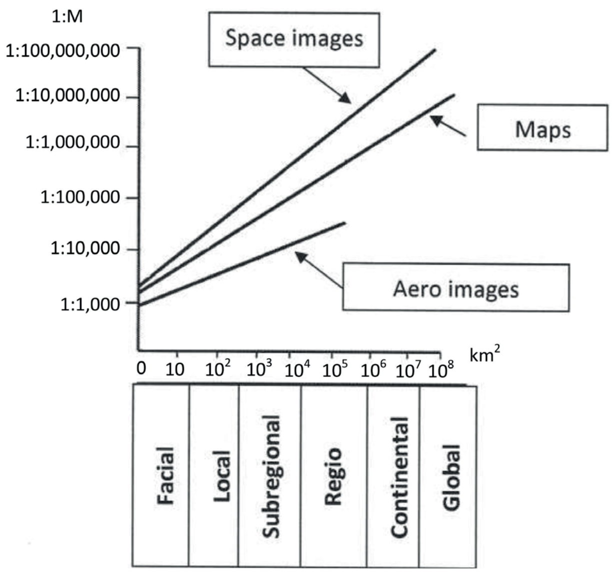

Fig. 1. The scale field of cartographic aerospace images

MATERIAL AND METHODS

In general, the methodology involves a desktop computer decryption of medium-scale aerospace images of natural areas (1:10,000–1:100,000) at a resolution of up to 30 m, a desktop and field classification of large-scale aerospace images of specific objects (up to 1:10,000) at a resolution of up to 10 m; aerospace field classification of high resolution images (up to 1 m) of small-sized objects (Fig. 1) (Berljant 1995; Chandra, Ghosh 2015).

Multi-parameter cartographic analysis makes it possible to synthesize information flows, allows analysing the most important processes, to examine the relationship and interdependence, and the dynamics of their development in time and space, determine the trend of development and future environmental condition forecast of the territory. Using advanced computer programs – ArcInfo (Version 10.0, 2010), MapInfo (Version 9.5, 2008), GeoGraf/GeoDraw (Version 2.0.8.192, 2008), WinGIS (Version 4.0, 2002) to perform the multi-parameter analysis allows generalizing a significant amount of information, speeding up and clarifying the necessary calculations, and developing space images (Kulik, Rulev 2000; Ivanov, Kulik 2006; Anopin, Rulev 2007).

The agrolandscape system assessment modelling is based on multiple information sources using namely satellite imagery of the territory, landscape map, topographic map for the same site of the surface, soil map, vegetation map, etc., as well as the model indicates GPS surveying data with their topographic coordinates and elevations clarifying.

Landscape planning of the erosion-control agroforestry complex includes remote cartographic assessment of erosion methods, as well as economic and environmental protection measures, which integrates the traditional and the latest technologies for the land rehabilitation and restoration.

Agrolandscape territorial structures of the Dono-Chirskiy interfluve area are the object of this study. The Dono-Chirskiy interfluve area is located in the western part of the Volgograd region. Northern and eastern borders of the region pass across the valley of the Don River, southern borders across the valley of the Chir river, western borders on the administrative border with the Rostov region. The territory of the region occupies the space of about 10,000 km^2 (Fig. 2). Key test areas are located in the territory of Kletsky and Surovikinsky district of the

Fig. 2. The Dono-Chirskiy interfluve area within the Volgograd region

Volgograd region. To determine the land erosion condition the mapping of watersheds was carried out at a scale 1:100,000.

The satellite imagery materials of the territory (satellite imagery at a scale 1:20,000 with high resolution) were used in the study. Field studies with inserting and construction of landscape profiles were performed in the key areas. The methodology which is conventional in agroforestry and landscape studies was used as the main technique (Kulik et al. 2003, 2007; Bouzekraoui et al. 2016).

RESULTS AND DISCUSSION

The main relief forms in the region were formed in the newest (Pleistocene-Neogene), young (Holocene), historical (Neolithic) and modern periods (Tsygankov 1962) of the evolution from the following geomorphological processes: erosion-accumulative, accumulative, denudation-accumulative and man-made.

The studies have shown that the higher erosion dissection is observed in the watersheds of the right bank of the Don River (1.6–1.8) – more than 2 $km \cdot km^{-2}$. Excess of the nearby watersheds over the local erosion bases ranges from 40 to 120 m or more, and the average length of the slopes from the upper tiers of the relief to the bottoms of the hydrographic network is 600–800 m with a range from 200 to 3,000 m. It should be noted that in the most dissected watersheds of the right bank of the Don River, the man-made forest cover does not exceed 3%, which has no significant effect on the stabilization of the ecological situation in agricultural landscapes.

The key area "Nizhneosinovsky" is the Osinovaya ravine watershed, which flows into the Chir River 2 km to the west from Surovikino. Numerous ravines of the second order flow into the Osinovaya ravine: Golaya, Peshechnaya, Gracheva, Beryozovaya and others. The total watershed area is 151.45 km^2, 53% of which is occupied by arable land (Table 1).

The chestnut soils of primarily heavy (medium and heavy loam) size distribution of varying erosion degrees dominate in this area.

Alluvial soils are spread on the bottoms and slopes of the ravines. Natural arboreal-shrub vegetation is represented by the remnants of ravine forests in the north of the key area. Artificial tree vegetation is represented by shelterbelts, ravine side, roadside and garden protective forest strips and pine massifs created on the sands in southeastern and northwestern part of the site.

Table 1. Explication of the lands in the key area "Nizhneosinovsky"

Agricultural land	Area	
	(km^2)	(% of the total area)
Arable land	80.0	52.8
Pasture	39.5	26.1
Gully and ravine network	14.7	9.7
Treeless areas	12.4	8.2
Forested	2.3	1.5
Protective forest plantations	0.15	0.1
Shelterbelts	0.06	0.04
Ravine side	0.05	0.03
Others (roadside, protected garden)	0.04	0.03
Forest plantations (pine)	4.8	3.2
Sand massifs	3.7	2.4
Gardens	0.7	0.5
Settlements	5.2	3.4
Road and path network	2.7	1.8
Total	151.45	100

The analysis of the landscape profile extending from the south-west to the north-east through the watershed area of the Osinovaya ravine to a distance of 6 km showed that all the uplands and most slopes are ploughed. There are pastures with poor scattered vegetation on the unploughed slopes to the ravines.

The principles of landscape planning of the antierosion agroforestry complex are implemented in the landscape plan of agroforestry arrangement of the watershed of Melokletskaya gully and ravine system (Fig. 3). The imposition of the contour straight erosion-control forest strips in the watershed area was designed by Kochetov et al. 1999.

The Melokletskaya gully and ravine system is characterized by erosion and denudation-sloping and accumulative terraced river types of relief. Specific forms are the leading for each type: slightly convex upland and watershed side slopes, structural erosion-denudation, ledges and terraces, avalanchine and colluvial, alluvial river terraces. On the basis of field studies the soil-erosion map has been set. In the spatial structure of the watershed the facies with dark brown soils of varying thickness, varying erosion degrees, salinity and alkalinity are presented.

The use of remote sensing data revealed that degradation processes in the Dono-Chirskiy interfluve area are related to a high degree of relief dissection, as well as a low share of protective forest plantations, and the absence of landscape arrangement of the land use territory.

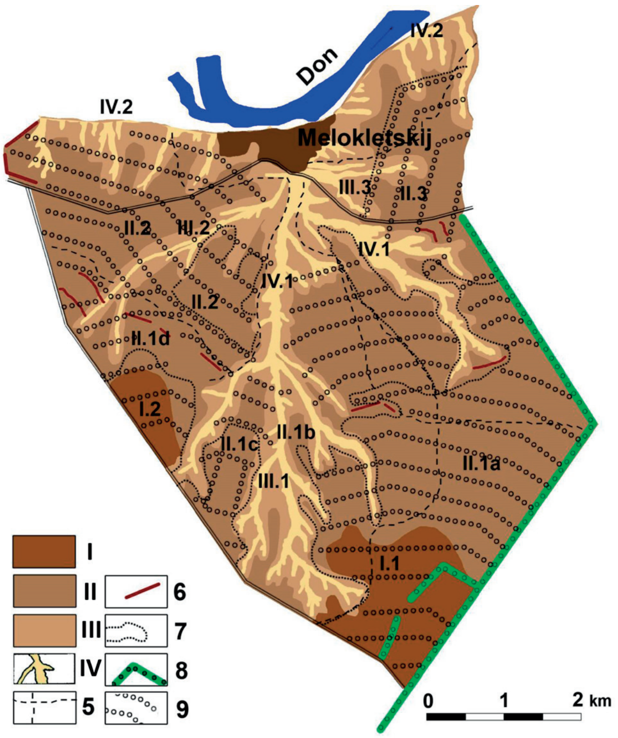

Fig. 3. Landscape plan of agroforestry arrangement of the watershed of Melokletskaya gully and ravine system

I – watershed landscape strip (I.1, I.2), II – watershed side (II.1a, II.1b, II.1c, II.1d, II.2, II.3), III – net side (III.1, III.2, III.3), IV – hydrographic dry (IV.1, IV.2), 5 – facies borders of erosion and accumulation stages, 6 – water shutoff shafts, 7 – arable land borders, 8 – existing shelterbelt, 9 – projected shelterbelt

CONCLUSIONS

In the transition of agriculture on the landscape base the rational arrangement of the land use territory with the maximum adaptation of the used techniques and technologies to environmental, soil and climatic, geomorphological, and other characteristics of the region becomes a priority object (Ivanov et al. 2009). The results of studies on remote cartographic and agro-ecological assessment of the watersheds of the Dono-Chirskiy interfluve showed that intensive farming resulted in partial destruction of natural and anthropogenic landscapes and intensification of degradation processes, which resulted in a decrease in their productivity and sustainability.

As a result of the implementation of a complex of agroforestry measures carried out taking into account the landscape features of the territory, it is possible to optimize the share of arable land, increase the protective forest cover of arable land to 5–7%, and protect the territory with forest plantations by more than 80%.

Arable lands located within the marginal landscape strip (on steep slopes) and subjected to active erosion processes must be taken for permanent maintenance with perennial grasses, especially on the slopes of light exposures.

The use of space images in agroforestry improvement makes it possible to reduce the monetary costs by 1.9 times (by 47.4%) compared to similar works carried out only by land methods.

References

Alatorre L.C., Begueria S. (2009): Identification eroded areas using remote sensing in a badlands landscape on marls in the central Spanish Pyrenees. Catena, 76: 182–190.

Anopin V.N., Rulev A.S. (2007): Kartografirovanie degradirovannyh landshaftov Nizhnego Povolzh’ja. Volgograd, Volgograd State University of Architecture and Civil Engineering: 168. (in Russian)

Berljant A. M. (1995): Geoikonika. Moscow, Astreja: 219. (in Russian)

Bouzekraoui H., El Khalki Y., Mouaddine A., Lhissou R., El Youssi M., Barakat A. (2016): Characterization and dynamics of agroforestry landscape using geospatial techniques and field survey: A case study in central High-Atlas (Morocco). Agroforestry Systems, 90: 965–978.

Chandra A.M., Ghosh S.K. (2015): Remote Sensing and Geographical Information System. 2nd Ed. New Delhi, Narosa Publishing House: 310.

Colborne G.J.N., Staines S.J. (1985): Soil erosion in south Somerset. The Journal of Agricultural Science, 104: 107–112.

Efe R., Ekinci D., Curebal I. (2008): Erosion analysis of Şahin Creek watershed (NW of Turkey) using GIS based on RUSLE (3D) method. Journal of Applied Sciences, 8: 49–58.

Ivanov A.L., Kulik K.N. (2006): Agrolesomelioracija. Volgograd, All-Russian Scientific Research Institute of Agroforestry: 746. (in Russian)

Ivanov A.L., Svincov I.P., Ovchinnikov A.S. et al. (2009): Sistema adaptivno-landshaftnogo zemledelija Volgogradskoj oblasti na period do 2015 goda. Volgograd, Volgograd State Agricultural Academy: 304. (in Russian)

Jarritt N.P., Lawrence D.S.L. (2006): Simulation fine sediment delivery in lowland catchments: Model development and application of INCA-Sed. In: Owens P.N., Collins A.J. (eds): Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modelling and Management. Wallingford, CABI: 207–216.

Kiesel J., Schmalz B., Fohrer N. (2009): SEPAL – a simple GIS-based tool to estimate sediment pathways in lowland catchments. Advances in Geosciences, 21: 25–32.

Klik A., Eitzinger J. (2010): Impact of climate change on soil erosion and the efficiency of soil conservation practices in Austria. The Journal of Agricultural Science, 148: 529–541.

Kochetov I.S., Barabanov A.T., Garshinev E.A., Zykov I.G. (1999): Agrolesomeliorativnoe adaptivno-landshaftnoe obustrojstvo vodosborov. Volgograd, All-Russian Scientific Research Institute of Agroforestry: 84. (in Russian)

Kulik K.N., Rulev A.S. (2000): Geoinformacionnoe kartografirovanie v agrolesomelioracii. Doklady RASHN, 1: 42–43. (in Russian)

Kulik K.N., Rulev A.S., Yuferev V.G. (2003): Primenenie informacionnyh tehnologij v agrolesomeliorativnom kartografirovanii: metod. posobie. Moscow, Russian Academy of Agricultural Sciences: 48. (in Russian)

Kulik K.N., Rulev A.S., Yuferev V.G. (2013): Geoinformation analysis of desertification hotspots in Astrakhan oblast. Arid Ecosystems, 3: 184–190.

Kulik K.N., Pavlovsky E.S., Rulev A.S., Yuferev V.G., Bakurova K.B., Dorokhina Z.P., Tubalov A.A., Koshelev A.V., Berezovikova O.Y., Dzugaev A.A. (2007): Metodicheskie ukazanija po landshaftno-jekologicheskomu profilirovaniju pri agrolesomeliorativnom kartografirovanii. Moscow, Russian Academy of Agricultural Sciences: 41. (in Russian)

Rulev A.S., Juferev V.G., Juferev M.V. (2013): Geoinformacionnye issledovanija jerozionnoj degradacii v agrolandshaftah. Izvestija Nizhnevolzhskogo agrouniversitetskogo kompleksa:nauka i vysshee professional'noe obrazovanie, 2: 84–88. (in Russian)

Tsygankov A.V. (ed.) (1962): Osnovnye cherty morfostruktury Nizhnego Povolzh'ja. In: Geologicheskoye stroyeniye i neftegazonosnost' Volgogradskoy oblasti. Moscow, Volgograd Oil and Gas Industry Research Institute: 141–178. (in Russian)

Vittal K.P.R., Vijayalakshmi K., Rao U.M.B. (1990): The effect of cumulative erosion and rainfall on sorghum, pearl millet and castor bean yields under dry farming conditions in Andhra Pradesh, India. Experimental Agriculture, 26: 429–439.

Received for publication June 10, 2016
Accepted after corrections August 30, 2017
Published online October 19, 2017