Method to localize snowmelt runoff pollutant sources of surface water bodies by paired geoinformation and hydrological analyses

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Abstract. The quality of melt runoff from agricultural fields significantly affects the quality of surface water bodies and their ecosystem services. Currently, methods based on geographic information systems (GIS) are used with aim to reduce the risk of pollution of surface water bodies. Thus do make possible a localization of pollutants sources at rural areas and their transport routes to the water bodies. This paper presents the results of geoinformation analysis of the results of melt runoff sampling as well as cartographic modeling of melt runoff on the territory of the summer field dacha (SFD) of the RSAU-MTA.

In early April 2018 a specially designed fields monitoring was accomplished. Twenty water samples were taken at the locations of ten catchment’s outlets located within the SFD territory. Chemical analyzes identified 5 inorganic chemical components with high concentration values. Digital elevation model (DEM) of the plot area was generated from UAV data for the analysis of the territory’s topography. Spatial analysis of samples in combination with hydrological analysis of DTM showed differentiation in pollution of snowmelt runoff by catchments. This enabled to identify some catchments as providers of the biggest negative contribution to the quality of melt runoff

Keywords: Geographic information systems, melt runoff, pollutants, surface water bodies cartographic modeling

1. Introduction
Surface runoff entering surface and ground water bodies from agricultural lands is the main supplier of substances of chemical and biological origin, creating pollution risks for water users, and risks of loss of biological diversity for aquatic ecosystems. In order to control these risks, different methods and technologies are used to manage surface runoff and soil & ground water flows in order to increase not only the protection of the water bodies themselves, but also to reduce the level of environmental threat from production activities carried out on agricultural territories.

One of the issues that arise when assessing the quality of surface runoff generated by rain and snow melt runoff from agricultural lands is the spatial variation of the corresponding polluters. For this purpose, in practice, cartographic resources are used to assess the characteristics of the land surface, soil and vegetation cover, as well as surface and ground water bodies. In recent years, such resources in
digital formats have been obtained using geographic information technology (GIS) based remote sensing data (RS).

In the last two decades, data from space radar sensing, aerial lidar scanning, as well as stereo imagery from unmanned aerial vehicles (UAVs) have been used for these purposes. The resulting cartographic resources, as a rule, have a high degree of reliability due to their relevance, as well as the required spatial resolution. A significant factor affecting the adequacy of cartographic modelling of runoff, which is the main trigger for the pollutant transport & entering into water bodies, is the spatial data adequacy of the corresponding layers of the applied models.

The sets of the indicated digital resources, formed into the corresponding spatial layers for GIS based models make possible to carry out cartographic modelling of the surface runoff\[1\] The cartographic modelling allow to identify the potential sources of pollutants and their transport routes. As a result, this make possible to develop measures aimed at minimizing the risks of pollution of water bodies [2], as well as to carry out verification of this measures.

Ultimately, the described methodology should potentially allow in practice to make reliably grounded decisions that meet the requirements of problems related to the management of melt runoff to prevent pollutants from entering water bodies [3]. However, the currently existing relevant methods are mainly created to solve this kind of problems at the regional level. To verify the methodology for building cartographic models aimed at assessing the quality of surface runoff at the local level, in April 2018, the chemical composition of melt water was monitored on the territory of the summer field dacha (SFD) of the Russian State Agricultural University – Moscow Agricultural Academy named after K.A. Timiryazeva (RSAU-MTA), as well as the geospatial analysis of its results using geodata sets obtained using UAV stereo imagery.

2. Material and methods
Monitoring of melt runoff quality was done at the territory of the experimental SFD, where scientific research as well as educational and industrial practices of students are carried out. At this SFD a variety of experimental field & crops are carried, in particular, with the use of new precise farming technologies, soil cultivation, fertilization, as well as chemical protection of agricultural crops.

The land surface of the SFD is organized in the form of alternation of regular and small plots with shapes close to rectangular. These plots are predominantly elongated in the west-east direction. On the territory of the SFD country roads are used for the transportation as well as the movement of pedestrians. The main road dividing SFD into two parts, is elongated in the southeast - northwest direction. According to the scheme of organization and complexity of the experiments carried out in these fields, their territory is a convenient object for research for the purpose of cartographic modeling of surface runoff and transport of pollutants to water bodies.

Monitoring of the melt runoff pollutant in the territory of the SFD was carried out during the spring snowmelt in 2018 year. For this purpose, on April 5, 9 and 10, surface runoff was sampled at the predefined locations of the points of runoff concentration at perimeter of SFD. The identification of these locations was realized with hydrological tool of the ArcGIS family using digital elevation model (DEM) build with photogrammetric processing of stereo survey data done with UAVs in 2017 year. For this task a previously developed computer code was used [1], which automates the process of hydrological analysis, as well as the calculation of the corresponding hydrographic and morphometric characteristics (Figure 1). Based on the results of these calculations, it was decided to conduct studies of 11 catchments, shown in Figure 1b.
The field work verification was carried out in the warm season of 2017 year in order to increase the reliability of the identification of runoff concentration points. The resulting point data layer was published in the ArcGIS Online cloud service for field work management and editing the coordinates of spatial objects using the Collector application for mobile devices.

During the field verification of the points of melt runoff concentration, it was shown that, basically, the theoretically calculated coordinates corresponding to them corresponded to the real points of the rain runoff concentration. In some cases, minor discrepancies were found which were used for remote editing of the corresponding coordinates, as well as to refine the results of hydrological analysis. Obviously, the revealed minor discrepancies were associated with changes that occurred in the period between stereo survey and field verification, as a result of cultural and technical work.

3. Results
During the time of intense snow melting 2018 year at the identified sampling points, three times (April 5, 9 and 10), samples were taken out. The chemical analysis of these samples were carried out by a certified hydrochemical laboratory of the Federal State Institution "Centerregionvodkhoz". This analysis included the measurement of the concentrations of 8 inorganic chemicals according to the accepted standardized methods: 1) Suspended solids; 2) Chloride ion; 3) Sulphate ion; 4) Nitrate ion; 5) Phosphate ion; 6) Total iron; 7) Manganese; 8) Zinc. Comparison of the corresponding values of these chemicals obtained on adjacent monitoring dates indicate the stability of their concentrations over the studied time period.

To rank obtained results according to its negative impact on the quality of water bodies, their maximum permissible concentrations (MPC) in surface water bodies were used with the exception of suspended solids the maximum permissible concentration of which has not been set. In accordance with the corresponding MPC values of treated chemicals, normalized values of the measured concentrations were calculated for each sample. After these values, the chloride ion and sulphate ion, the concentrations of which did not exceed the MPC, were excluded from further analysis. Graphical presentation of the series of other five chemicals, the values of which exceeded the MPC shown at Figure 3.

Figure 1. Cartograms of the SFD territory: a) ortophotoplan; b) identified watersheds; c) points of the melt runoff sampling
Figure 2. Sampling points ranged by their maximum permissible concentration for surface water bodies.

The results of pollutant’s concentrations in samples were used to compile cartograms in accordance with the boundaries of the previously identified catchments. For this, the relative value concentrations normalized to the corresponding values of MPC were used. At Figure 3 the cartograms of the distribution of phosphate ion, total iron and manganese over the catchments at the SFD.

Figure 3. Cartograms of the distribution of the chemical concentrations of melt runoff on April 9 and 10, 2018, respectively: a) and d) phosphate ion; b) and e) total iron; c) and f) manganese.

The analysis of the measured values of the concentrations of chemical substances in the melt runoff showed that they basically correspond to, and in some cases exceed the corresponding values published in a number of sources [4–11].

4. Conclusion
Studies of the content of chemical substances in samples of melt runoff done in April 2018 on the territory of the SFD of the RSAU-MTA testify to the excess in many time the corresponding values of maximum permissible concentrations in cases of Total iron, Phosphate ion, Manganese and Zinc.

The presence of spatial variability of the concentrations of 4 pollutants within the catchments on the territory of the SFD was revealed, which, most likely, is associated with the difference in the morphological characteristics of the day surface of the studied catchments, as well as the farming technologies used there.

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