Method and Tool for Monitoring and Mapping of Snow Cover Formation and Snowmelt

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***Abstract* - The article describes the method and tools developed for monitoring and mapping of snow cover, as well as results obtained with their application for the Kasakh River basin. The method uses integrated satellite and ground-based data. The presented study is considered as the first step of a more general perspective study for snow accumulation and melt process GIS modeling and development of a multifactorial prediction method for seasonal and annual water availability assessment. The presented method using available satellite and ground observation data allows us to calculate the area of snow cover and to develop a time series of maps that record its change. Using the results of this study, it is possible to obtain data on the area of the snow cover with the necessary accuracy, temporal frequency, and spatial resolution without additional costs.**

***Keywords*—satellite imagery, spatial data analysis.**

The surface water resources of Armenia are formed by mountainous rivers which are mainly snowmelt-fed. Therefore, the efficient monitoring of snow cover formation and melt is an important component of the water resources management planning of the country.

To study the changes in snow cover, a method and tool for spatial and temporal monitoring of those processes has been developed that integrates a Sentinel-2 satellite data, digital elevation model, and ground-based hydrological and meteorological observations.

Kasakh River basin was chosen for this study taking into account that it is one of the 14 largest river basins of the Republic of Armenia and specifics of its geomorphometric features, the homogeneity of the lithology of bedrocks, the presence of the Aparan reservoir, which is of great national economic importance [1].

Sentinel-2 satellite data, data from meteorological stations and hydrological observation points of the Kasakh River basin provided by the "Hydrometeorology and Monitoring Center" SNCO of the Ministry of Environment, as well as the SRTM digital elevation model with a resolution of 30m were used for the study.

The Normalized Difference Snow Index (NDSI) was used for mapping the snow cover. NDSI is an index that is related to the presence of snow in a pixel. It is a measure of the relative magnitude of the reflectance difference between visible (green) and shortwave infrared (SWIR):

$$NDSI = (Green-SWIR) / (Green+SWIR)[2]$$

The theoretical range of NDSI values varies from -1 to +1. The review of long-term experience presented in multiple publications shows that the index value of 0.4 is considered to be the threshold for the presence of snow [3].

An application has been developed by the authors of this thesis that simplifies the satellite images preprocessing and NDSI index calculation (Figure 1). The application is developed in Python and can be integrated with the ArcGIS or QGIS packages. In the application window, a user only needs to select a satellite data source (Sentinel or Landsat), specify the folder or .zip file where the satellite images are placed and choose the index to be calculated. The application automatically selects the bands that are needed for a specific index, calculates the index and outputs the result as a TIFF file.

Currently, the application calculates NDVI, SAVI, NDWI, and NDMI indices which are also important for the current research, but also can be applied for other environmental and economic studies (forest management, land use and land cover mapping, agriculture, etc.).

To test the satellite data-based method application for snow cover changes in Kasakh River basin, time series of maps of snow cover were compiled based on the values of the NDSI index. After that, the accuracy of snow cover

Figure 1. Index Calculator (developed by the authors of the thesis)

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contours derived from the satellite images through NDSI index were compared to the same-day snow observations in the monitoring stations of the study area. The comparison shows that in 94.6% of cases the area with snow cover identified using NDSI index corresponds to a ground-based monitoring data.

Using the results of this study, it will be possible to obtain the area of snow cover with the acceptable accuracy, time frequency, and spatial resolution. Currently, this research is being expanded aimed at the development of methods for identification of snow layer height and snow water equivalent together with HMC specialists This data is crucial for calculating accumulated snow reserves and predicting the volume of snowmelt-runoff, which would assist to a better planning of water resources management planning in a river basin level.

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