Hydrological monitoring and modeling in the Western Dvina river catchment

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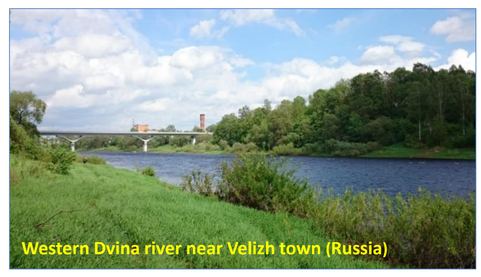


Background

MANTRA-Rivers project (Management of Transboundary Rivers) aims at a transnational system analysis of river basins within the IWRM framework (Integrated Water Resources Management) and a dialog between riparian countries. Transboundary rivers constitute an important bridge between countries. Joint monitoring efforts and data exchange are constantly required. The European Union, Ukraine and Russia share various river basins such as Western Bug, Desna and Western Dvina (Daugava), which are investigated in the project.

OBJECTIVES of the study

1) To develop catchment-based system of river fluxes monitoring
2) To provide a unified tool for water quality, quantity and sediment load modeling
3) To understand the influence of catchment processes on water resources

Western Dvina river catchment, the Russian part at the Velizh station outlet and the pilot study Velesa river small catchment in the Tver region in Russia

Water balance modeling using SWAT (Soil and Water Assessment Tool)

Open source input data

Weather data sources:

ECA&D

NOAA

CDIAC

ECMWF

Meteo.ru

Catchment data:

Relief: SRTM, ALOS

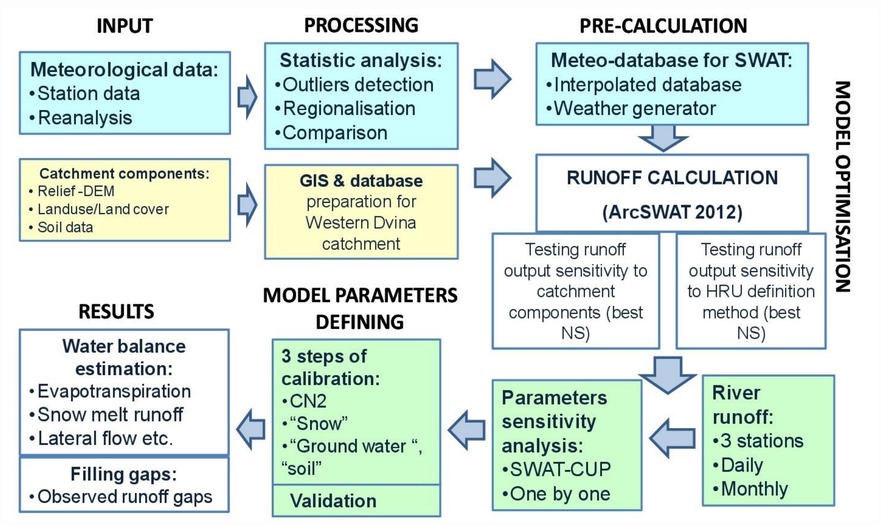
Land cover:

Globallandcover30,

CORINE LandCover

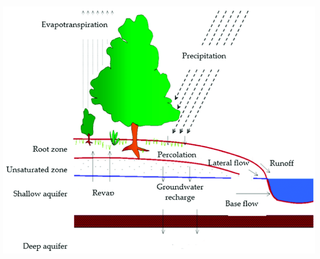
Soil: FAO-HWSD

Modeling approach



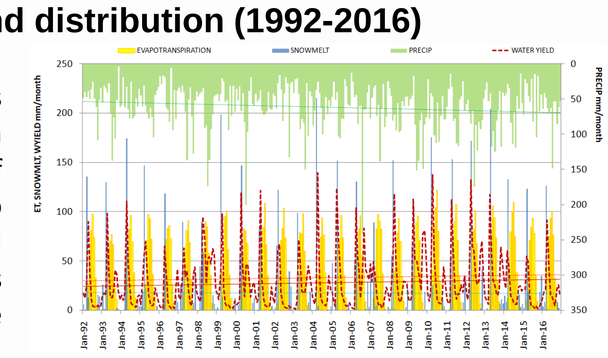
The catchment model was built with the ArcSWAT2012 GIS-interface. The modeling process of different types of fluxes (water, dissolved and suspended matter) is based on the calculations of river discharge and its parameterization. Period of model calibration (1992-1998) and validation (1999-2004) is chosen according to continuous hydrological observations inside the catchment.

Water balance structure and distribution (1992-2016)



River catchment water balance general scheme

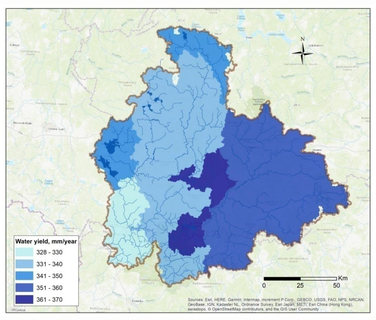
Model performance is good. Simulated mean annual river runoff corresponds to observed, actual evapotranspiration is almost the same estimated by MODIS.



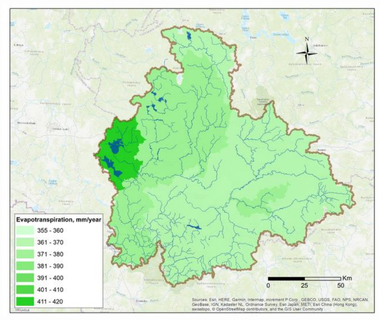
Filling gaps in the data and water balance temporal variation

Water balance component	Annual value mm
Precipitation	731
Snow melt in the watershed	133
Potential evapotranspiration	468
Actual evapotranspiration	364
Soil water content	188
Surface runoff	51.8
Groundwater flow	239
Water yield	296

Simulated mean water balance components



Annual water yield (blue water flow)



Annual evapotranspiration (green water flow)

Pilot study – sediment fingerprinting

Reliable quantitative information on fine-grained sediment sources in river basins is required for resolving numerous environmental and engineering tasks such as new construction, defense from bank erosion and water supply.

Sediment Fingerprinting – versatile approach for establishing sediment sources, pathways and sinks within a catchment.

Pilot study representative catchment – Velesa river. Main river length 114 km, basin area 1420 km^2, average annual discharge at mouth 13.4 m^3 s^{-1}

The following potential sediment sources considered:

1) channel bank erosion

2) tributary channel bed incision

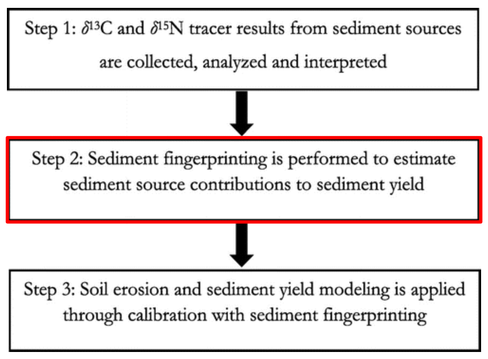
3) small tributary gullies

4) active timber harvesting territories

5) unpaved road erosion

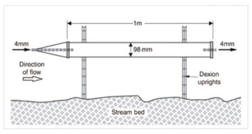
6) cultivated areas)

Sediment yield modeling and partitioning



Sampling :

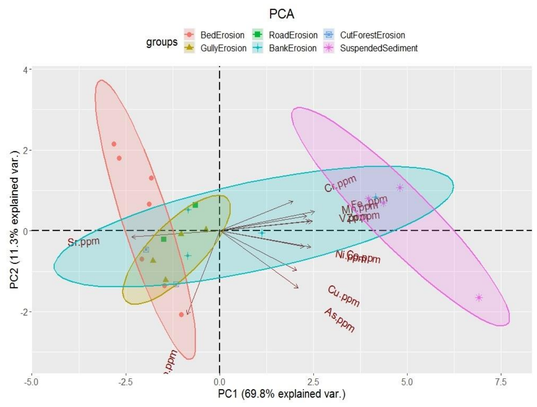
1) surface sources or fresh sediments
2) eroded banks
3) suspended sediment



Time-integrated suspended sediment sampling- device

Tracer properties analyzed

1) Mobile forms of selected elements by atomic-absorption spectrometry;
2) Total concentration of selected elements by X-ray fluorescence;
3) ^{137}Cs activity by gamma-ray spectrometry

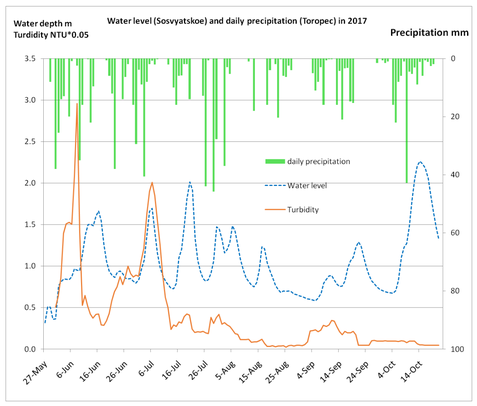


Total elements in suspended sediments divided by sources (example)

Principle component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observation of possibly correlated variables into a set of values of linearly uncorrelated variables called principle components. It is used to determine the sources of material in suspended sediments and accumulated clay matter on river banks and floodplain.

High frequency turbidity and water level monitoring

Observations are executed to support the interpretation of sampling results. Two autonomous sensors, a water level and temperature logger (Solinst Levelogger) and a turbidity logger (RBR Solo), were installed in the representative outlet of the Velesa catchment at Sosvyatskoe village.



Water level reflects cumulative effect of precipitation. It strongly depends on continuous precipitation during few days. Turbidity has it's maximum just before the spring level peak caused by melting snow. The second peak of turbidity was caused by long rainy period with heavy daily rainfalls.

Conclusions

The sparse gauging network and the amount of data gaps in some regions (e.g. Russian part of Western Dvina) impede a thorough understanding of hydrological processes, which is needed to manage sustainably the water resources. The high variability of natural flow generation and its distribution requires an adequate monitoring and modeling tools comparable to other countries. The study provides detailed information about the water balance components based on freely available data and a worldwide accepted model. Spatial distribution of water balance components represents the structure of flow generation drivers inside the catchment. It strongly depends on land cover and soil types. High evapotranspiration rates are linked to sub basins with lakes and wetlands predomination in the western part of the catchment. Higher snowmelt is linked to higher precipitation in the eastern part. Higher soil water and lower lateral and groundwater flow are linked to gleyic soils and histosols, which are dominant under wetlands. The pilot study program of suspended sediment fingerprinting within the Velesa River basin provides valuable information on spatial and even temporal variability of contribution of different sources using total content of selected elements and ^{137}Cs radioactive isotope. PCA analysis supported sediment sources partitioning.

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