Hydrological modeling of the Desna river basin using SWAT (Soil and Water Assessment Tool)

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Photography encouraged

Introduction

The Ukrainian Government started the process of EU water Directives implementation aimed at developing of the River Basin Management Plan for 9 main river catchments. The assessment of the impact of different factors on the formation of water runoff, including climate changes, flood forecasting and overflowing risk analysis, and the planned measures effectiveness analysis are entirely connected with distributed hydrological and water quality models.

For the East European Plain rivers, the accurate prediction of snow accumulation and subsequent snowmelt is an essential component of integrated hydrological and water quality models because snowmelt runoff is approximately 60-75% of the total surface runoff.

Therefore, **the main goal** of this article is to provide a SWAT guideline for a plain stream flow modeling of the rivers with a primary snowmelt supply.

Study area

The Desna is the main public water supply source in the capital of Ukraine, Kyiv. The Desna basin covering 88,800 km2 is located within the Russian Federation (RF) (68%) and Ukraine (32%). The Desna is a typical plain stream with a slight slope of 0.2-1 m/km. Therefore, the river channel is shaped and its width is ~150 m. The Desna basin is characterized by a good wetness. Annual values of precipitation are 650-700 mm. About 40% of the Desna basin is covered with soddy-podzolic soils. The major part of the basin is covered by agricultural lands (55%), forest (32%), and grasslands (10%).

Figure 1. The Desna watershed with SWAT-delineated subbasins, gauge's subwatersheds, digital elevation model, river network, and weather stations.

Table 1. Description and source of input data

Data type	Resolution	Source
DEM	25 m	Modified SRTMGL1
Soils	1 : 2500000	Merged Ukrainian and Russian atlases
Land use	25 m	Merged GlobeLand30 LULC and Global Forest Change, 2012 forest state
River network dataset	Fine; Variable[a]	OpenStreetMap, "waterway" layers
Climate (t_{max}, t_{min}, precipitation, humidity, wind, cloud coverage)	Observed 38 stations (daily)	rp5.ru (22 Russian & Belarus stations)
		Central Geophysical observatory (16 Ukrainian stations)
Snow cover	Observed 13 stations	European Climate Data Center (ECAD), **daily snow depth in cm**
		Central Geophysical observatory (7 Ukrainian stations), snow depth in **mm H_2O every 5 days**
River discharge	12 guages	Automatic Information System of National Monitoring of Water Bodies (7 RF gauges)
		Central Geophysical observatory (5 Ukrainian gauges)
Crops (planting, fertilizers, yield)	Wheat, rye, hay, barley, oats, corn, sunflower, sugarbeet, potato	Russian statistics services of Bryansk, Kaluga Oblast, Kursk Oblast, Oryol Oblast, Smolensk Oblast
		State statistics Service of Ukraine, statistics services of Chernihiv Oblast, Sumy Oblast

Results

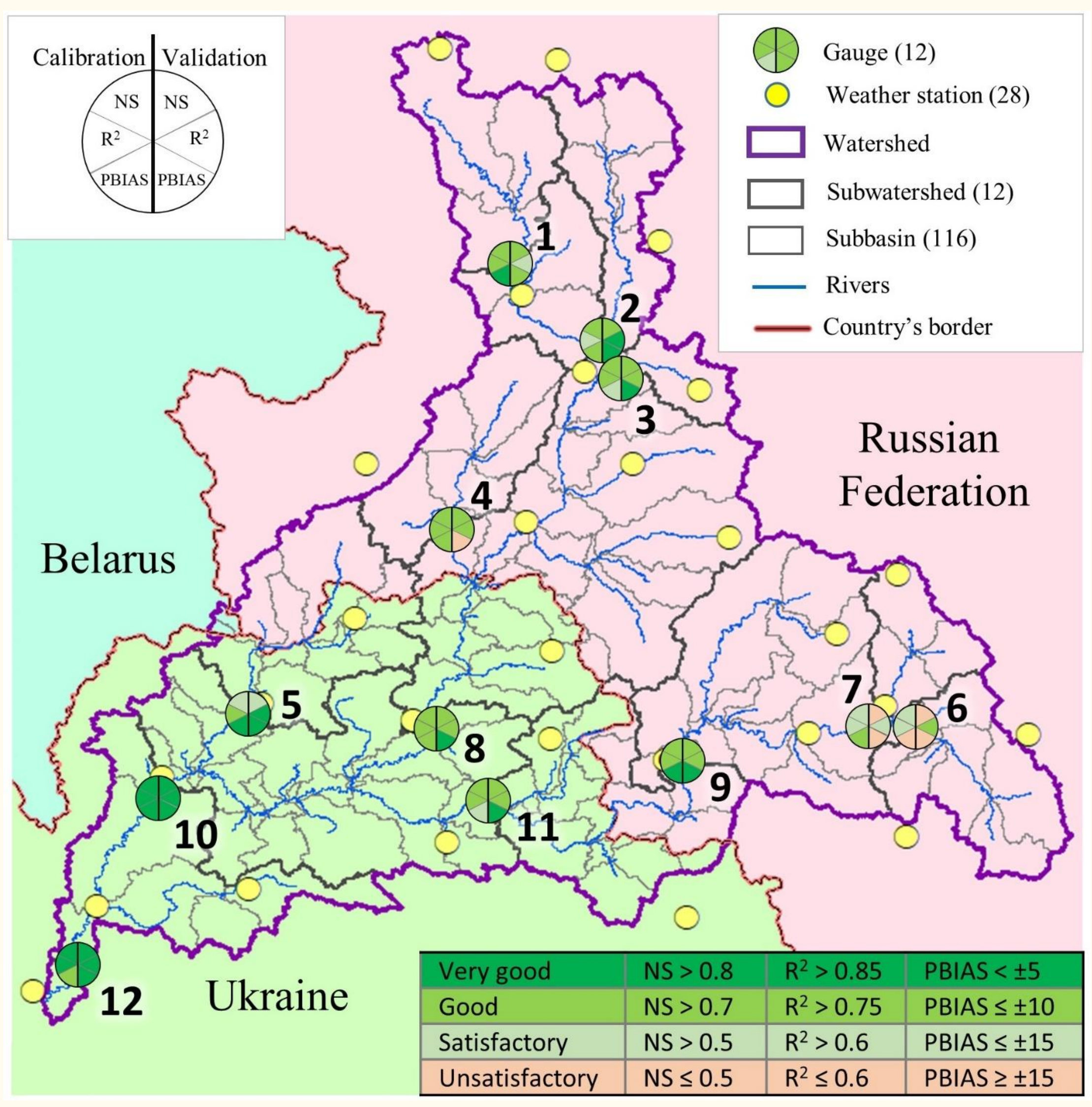
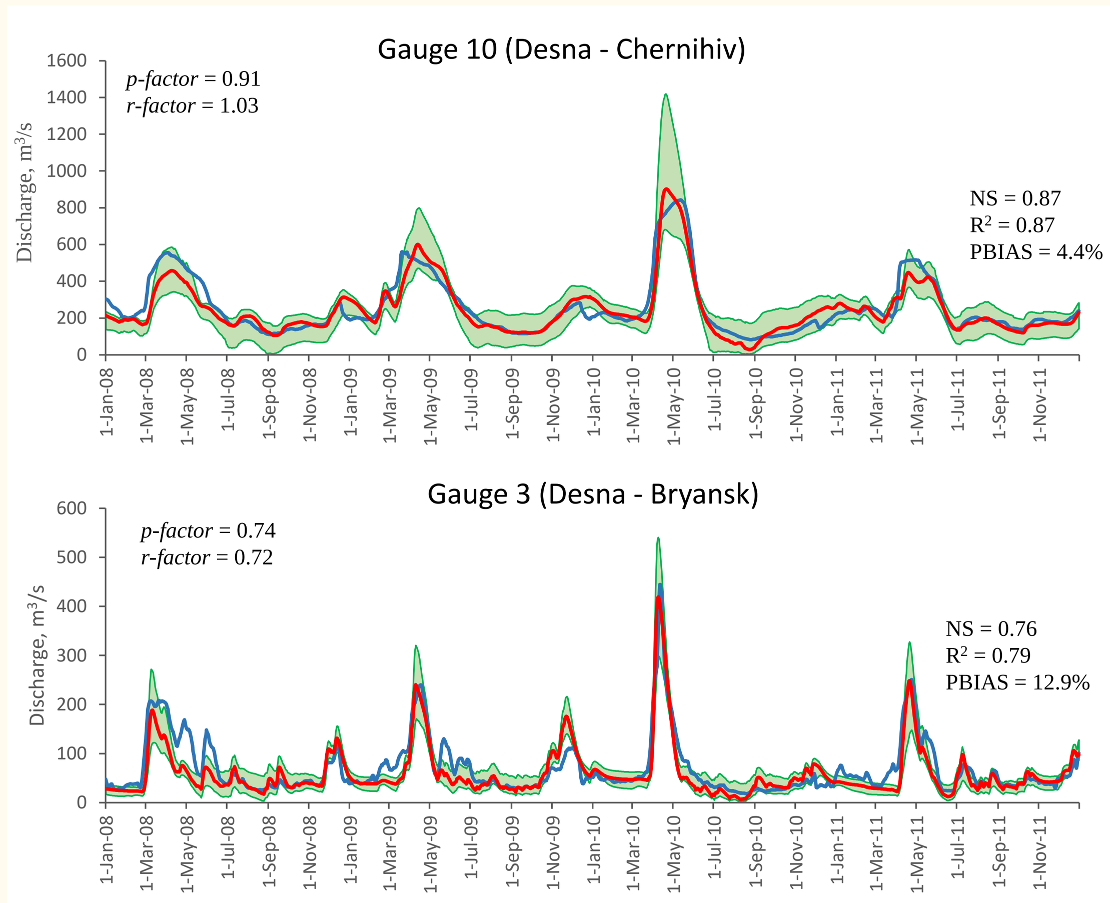


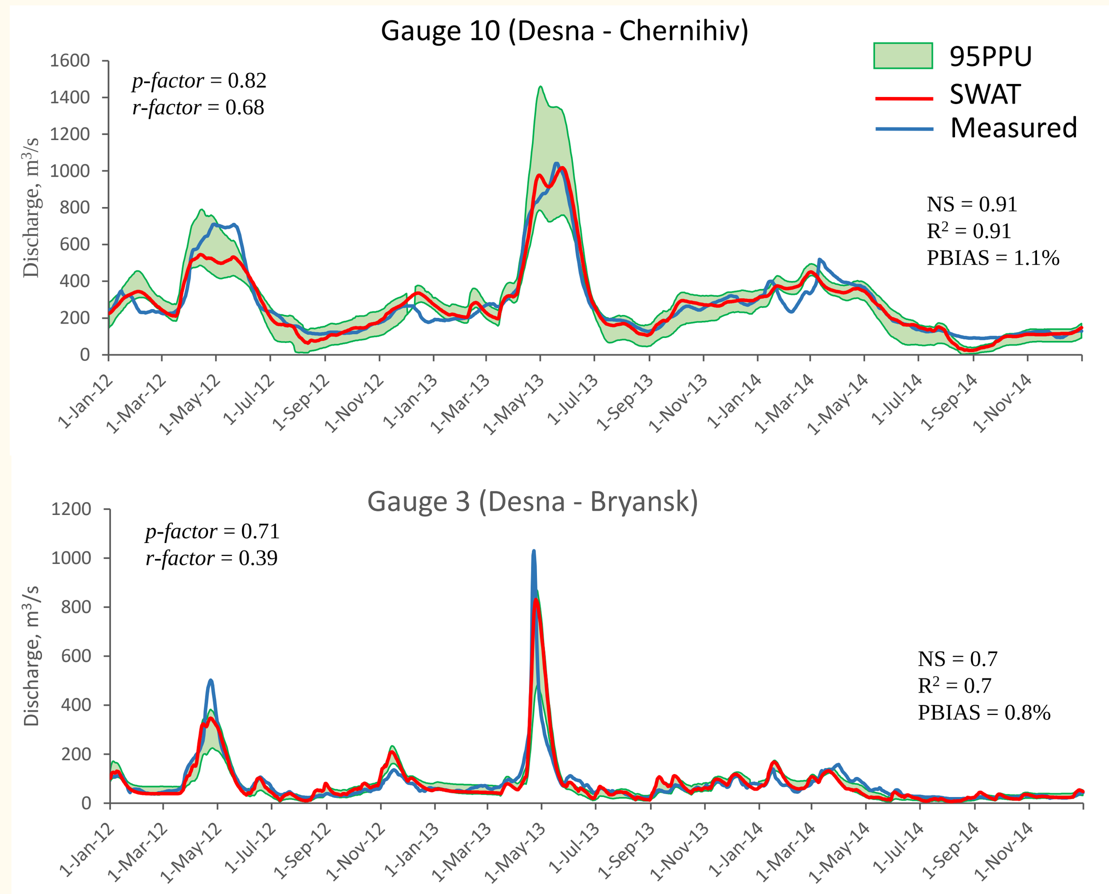
Figure 2. The calibration and validation results of streamflow at 12 gauges of the Desna basin. The performance evaluation criteria according to Moriasi et al., 2015

Calibration (2008-2011)



Component	Average annual	Min - max
Precipitation, mm	**589**	**435 – 655**
Evapotranspiration, mm	**445**	**424 – 470**
Percolation (from soil profile), mm	**96**	**51 – 156**
Return from shallow aquifer, mm	**49**	**-**
Water yield, mm	**115 (100%)**	**92 – 161**
Surface flow, mm	**26 (23%)**	**9 – 54**
Lateral flow (interflow), mm	**31 (27%)**	**20 – 40**
Groundwater flow, mm	**58 (50%)**	**52 – 67**

Validation (2012-2014)



p-factor is the fraction of measured data (plus its error) bracketed by the 95PPU band (acceptable - *p-factor* < 0.7).

r-factor is the ratio of the average width of the 95PPU band and the standard deviation of the measured variable (acceptable - *r-factor* < 1.5).

Since 1989, the January-April mean temperature has increased inducing greater infiltration, therefore, increasing groundwater recharge by 10% average. High amount of lateral flow is caused by soddy-podzolic soils which have illuvial horizon with very low saturated conductivity. This factor leads to the formation of impermeable layer during high infiltration periods like snowmelt.

Water balance

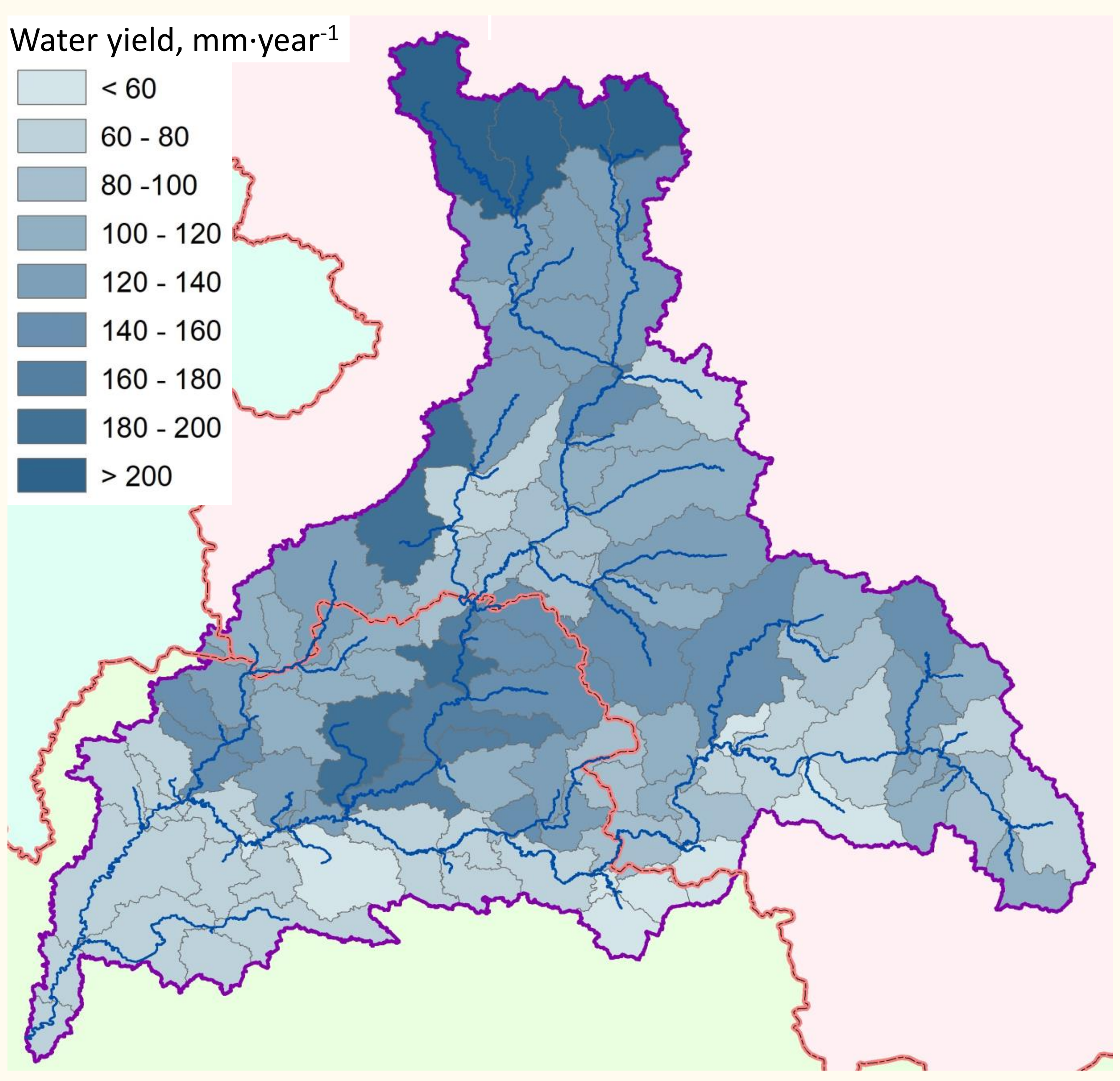


Figure 3. Blue water resources across the Desna river basin (2008 – 2014)

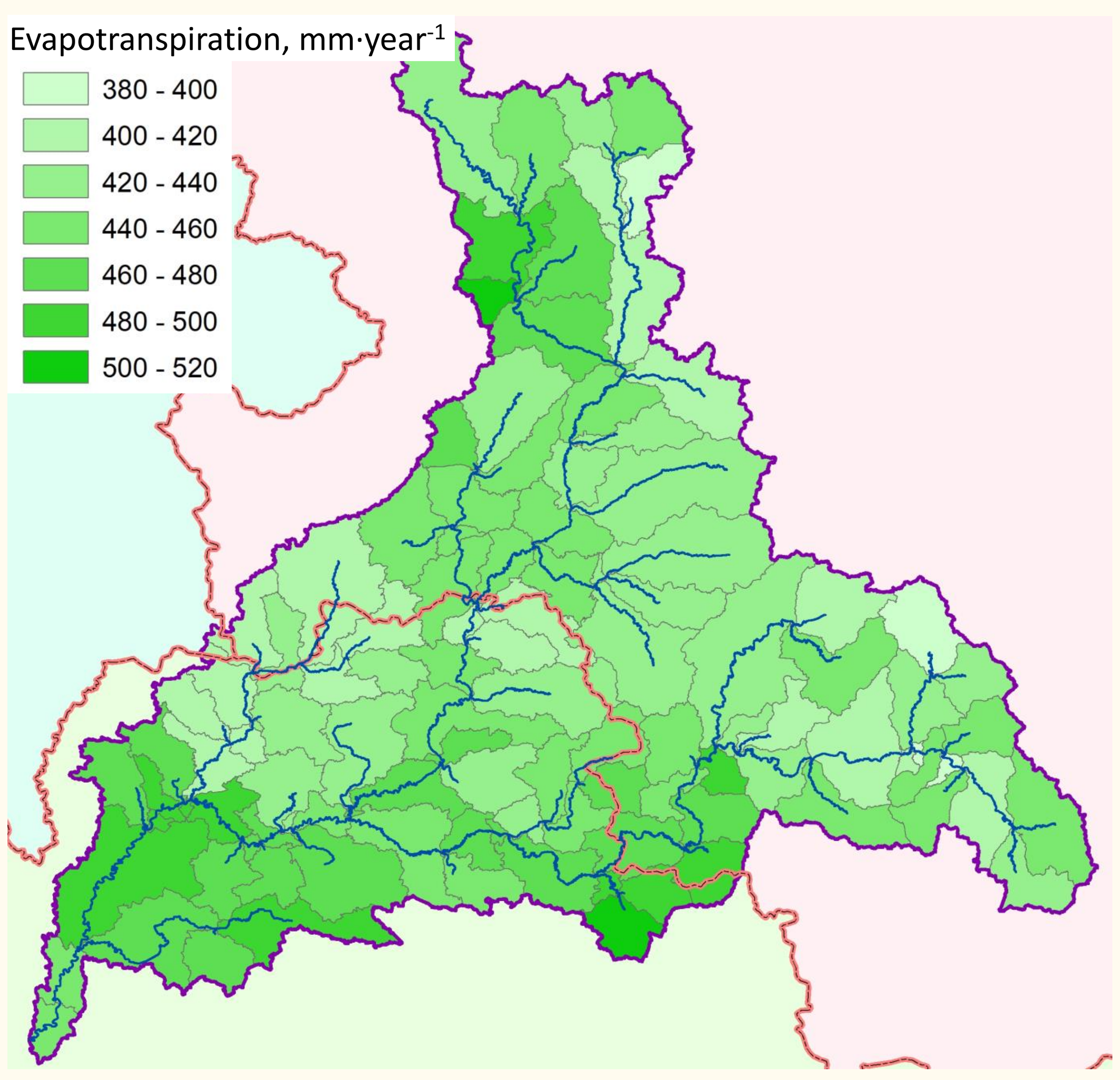


Figure 4. Green water flow (evapotranspiration) across the Desna basin (2008 – 2014)

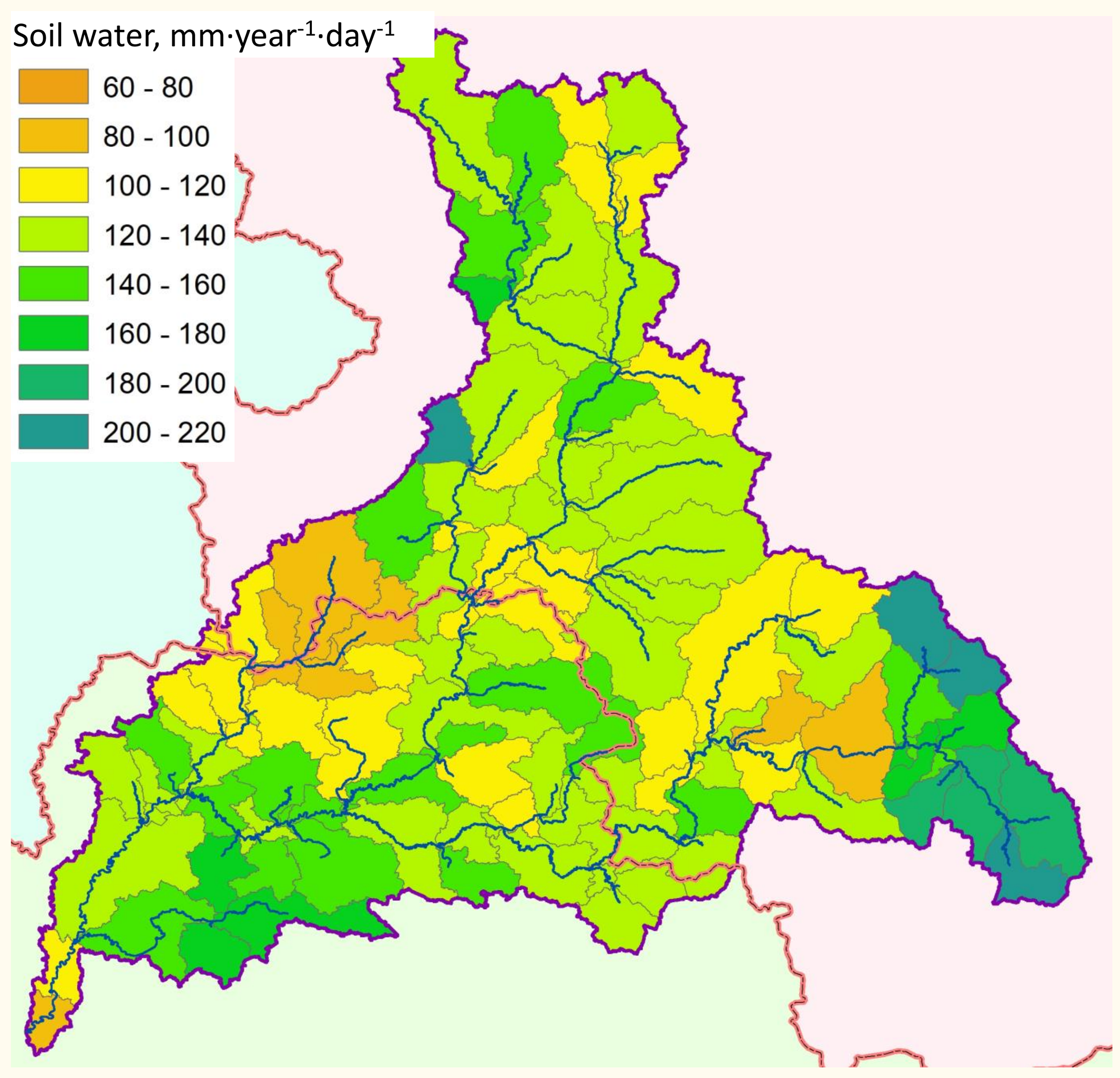


Figure 5. Green water storage (soil water) across the Desna river basin (2008 – 2014)

Discussion

When modeling small subbasins, the 95PPU captures less observations (lower *p-factor*), which is explained by the low special coverage of precipitation inputs. Accordingly, some of the precipitation is missed, and the part, on the contrary, doesn't fall in reality. With the increase in the number of weather stations, the likelihood of overestimating or underestimating of precipitations is minimized, since one station compensates the other. Therefore, the *p-factor* and the evaluation criteria are higher for the downstream gauges. Deeper analysis showed that a climate data can cause significant runoff difference during snowmelt period and unsatisfactory calibration results (Osypov et al., 2018).

Conclusions

The approach proposed in this study using SWAT model provides significant insight into calibration process of a plain snowmelt-driven watershed with a daily time step.

The SWAT model for the Desna watershed could be used to calculate cross-boundary water transfers, perform flood risk assessment, and conduct climate change studies. As a first step, water resources were spatially calculated for the catchment. Primarily, the blue water flow amount correlates with the amount of precipitations (R = 0.78). Evapotranspiration is higher in warmer regions and regions with greater soil water content as well as parts of the basin with more precipitation.

Acknowledgements

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References

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