APPLICATION OF SOIL AND WATER ASSESSMENT TOOL IN SUSTAINABLE WATER MANAGEMENT IN THE AZOV SEA BASIN

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Abstract

The Azov Sea Basin plays important role in the region providing local population and national economies with numerous water-related services. Unsustainable water and land use management practices considerably decreased the capacity of the Basin to maintain these services.

This study investigated the change of inflow into the Tsimlyansk reservoir, the largest freshwater body in the Azov Sea Basin, under different scenarios.

The Soil and Water Assessment tool (SWAT) has been used to model streamflow change. Four scenarios of potential regional development have been analyzed. It was found that the water inflow into the reservoir will be significantly reduced (from 28% to 36%), threatening sustainable water supply and numerous water-dependent activities in the region.

Keywords: SWAT, GIS, sustainable water management, environmental modeling, Azov Sea

Introduction

Shared by Russia and Ukraine the Azov Sea Basin (Figure 1) is a unique watershed providing regional population and national economies with numerous water-related services. However, due to unsustainable water and land management the capacity of the Azov ecosystem to maintain these services has been diminished significantly. The problem is exacerbated by a lack of regional cooperation in the area.[1]

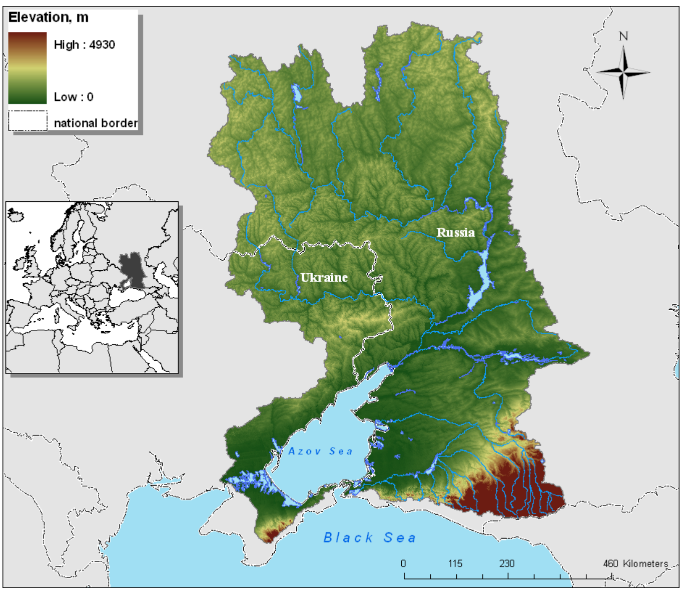

Figure 1. The Azov Sea Basin

A long-term regional development strategy should be elaborated to ensure sustainable water management. The assessment of potential changes in water supply under different scenarios is an essential part of this strategy.

A number of environmental modeling tools can be used for this purpose. The Soil and Water Assessment Tool (SWAT) is one of such tools, which allow assessment of water quantity and quality under different management scenarios[2]. SWAT is physically-based basin-scale continuous-time modeling tool capable to assess water budget within the spatially explicit watershed borders, which was successfully applied for numerous studies[3].

The main objective of the research was to investigate the change of inflow into the Tsimlyansk reservoir under different scenarios by the year 2050 using the SWAT model.

The Tsimlyansk reservoir, the largest freshwater body in the Azov Sea Basin, playing an important role in water distribution scheme in the region, has been chosen for the research. Different regional development projects, such as the construction of the new Volga-Don shipping canal or industrial water supply, are highly dependent on the reservoir water budget.

Material and Methods of Work

The ArcGIS-ArcView extension for SWAT ArcSWAT 2009.93.7b has been used to develop and run the model.[4] The Upper Don River catchment with the main outlet at the entrance into the Tsimlyansk reservoir has been delineated using ArcSWAT (Figure 2) according to elevation data derived from the global dataset Shuttle Radar Topography Mission (SRTM)[5].

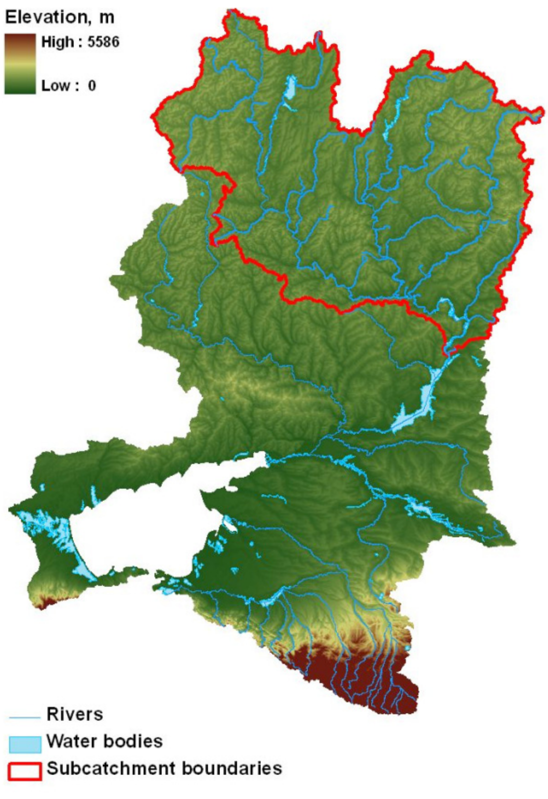

Figure 2. Upper Don River Catchment

The hydrologic response units (HRUs) have been defined based on land use categories, soil properties and slope characteristics derived from different datasets.

The period from 1st January 1998 to 31st December 2008 has been chosen for simulation, using the first two years as a warm-up period.

The SWAT model should be calibrated in order to adjust calculation results based on available observation data. Therefore, it is necessary to acquire the actual flow data of the drainage networks and compare it with the results of flow estimation, simulated by the SWAT model.

The SWAT-CUP application has been applied for model calibration and validation[6]. For this purpose observed monthly flow data from 2 hydrological gauges have been used. The SUFI2 method has been chosen for calibration. In SUFI-2, uncertainty of input parameters is depicted as uniform distributions, while model output uncertainty is quantified by the 95% prediction uncertainty (95PPU) calculated at the 2.5% and 97.5% levels of the cumulative distribution of output variables obtained through Latin hypercube sampling.

The model has been calibrated using historical hydrological records for 8 years (2001-2008). Satisfactory calibration results have been achieved for annual streamflow simulation.

The scenarios on land use and climate change in the year 2050 using data provided by EnviroGRIDS project have been analyzed within the developed model[7].

The land cover change scenarios, giving projections for the year 2050 have been used. These scenarios were developed with the Metronamica model, enabling the investigation of spatial development in the area of study depending on autonomous developments, external factors and policy measures[8].

As a result four land use scenarios were analyzed: BS HOT, BS ALONE, BS COOP and BS COOL. The storylines of these scenarios were based on emissions scenarios proposed by IPCC-SRES[9], representing different ways of the global socio-economic development. Additionally, different studies on global and European scenarios have been used. More information can be found in deliverables of the EnviroGRIDS project "D3.8 The EnviroGRIDS scenarios"[10].

BS HOT corresponds to the IPCC's A1FI scenarios (fossil intensive), when environmental issues are not the main concern. BS COOP refers to the B1 climate scenarios, with strong cooperation and high environmental concerns. The BS ALONE corresponds to A2 scenario with high economic growth and high environmental pressure, and BS COOL corresponds to B2 scenario with strengthening of the local bodies implementing strategies to promote local sustainable development.

To develop datasets on weather conditions, corresponding to land use change scenarios the stochastic weather generator Long Ashton Research Station Weather Generator (LARS-WG) has been used[11]. The generator simulates time-series of daily weather at a single station. The tool has been applied successfully for SWAT studies, showing satisfactory level of weather data simulation.

Table 1 shows the scenarios of climate change used for weather data generation according to land use change scenarios. Green areas indicate correspondence between land use scenarios proposed by EnviroGRIDS and emission scenarios used for generating weather time-series.

Table 1. Correspondence of climate scenarios to land use change scenarios

<table>
<tr><th bgcolor="yellow"></th><th bgcolor="yellow">BS HOT</th><th bgcolor="yellow">BS COOL</th><th bgcolor="yellow">BS COOP</th><th bgcolor="yellow">BS ALONE</th></tr>
<tr><td bgcolor="yellow">SRA1B</td><td bgcolor="green"></td><td></td><td></td><td></td></tr>
<tr><td bgcolor="yellow">SRA2</td><td></td><td></td><td></td><td bgcolor="green"></td></tr>
<tr><td bgcolor="yellow">SRB1</td><td></td><td bgcolor="green"></td><td bgcolor="green"></td><td></td></tr>
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Findings and Discussion

The analysis has shown that the water inflow from the Upper Don River catchment into the Tsimlyansk reservoir will significantly decrease by the year 2050. The following results have been found under different scenarios:

BS HOT. In this scenario the water yield will decrease almost by 22%, which is greater than under other scenarios, with the highest decrease of precipitation. The baseflow is found to be reduced as well, while evapotranspiration and potential evapotranspiration will increase by 4% and 6% correspondingly. As a result the average annual inflow into the Tsimlyansk reservoir will decrease by 30% in 2050.

BS COOL. Under this scenario the water yield will be reduced by 20%, however baseflow will not decrease as much as under other scenarios. Surface runoff will decrease by 13%, less than in BS HOT that can be explained by the increase in forests and shrublands area according to the land use change scenario. Nevertheless, higher ET rates and relatively low precipitation rates will result in the decrease of the average annual inflow into the reservoir by 36% in the year 2050.

BS ALONE. Under this scenario runoff will decrease less than under other scenarios (12%). It can be explained not only by relatively high precipitation rates, but also by the increase of barren and sparse vegetation according to the land use change scenario. As a result the average annual inflow into the reservoir will decrease by 28% in the year 2050, causing lowest change in the inflow among all scenarios.

BS COOP. Under this scenario runoff will increase which can be explained by the increase of barren and sparse vegetation. However, the baseflow will decrease less than under other scenarios and that can be explained by the expansion of forests and shrublands in the year 2050 according to the land use change scenario. In this case water content in soil may increase, while surface runoff will be reduced (14%). As a result the average annual inflow into the Tsimlyansk reservoir will decrease by 36% in the year 2050.

Ultimately, it was found under different scenarios that the water inflow into the Tsimlyansk reservoir is going to be reduced by up to 36%.

The model and datasets developed for the study area may serve as a foundation for developing effective basin-scale reporting and decision support tool. It might create incentives for the regional transboundary cooperation and ensure sustainable water resources management in the area.

However, it should be emphasized that the model has several limitations and assumptions that should be considered for the enhancement of the assessment results. All environmental models, including SWAT, are simplified representations of the reality with the level of uncertainty defined by available data sets and their relevance.

References

1. Lagutov, V. and Lagutov, V. (2010). The Azov ecosystem: resources and threats In V. Lagutov, ed, Environmental security in watersheds: The Sea of Azov, Springer, 3-62, Dordecht.
2. Arnold, J. G. and Fohrer, N. 2005. SWAT2000: current capabilities and research opportunities in applied watershed modeling, Hydrological Processes, 19, 3, 563-572.
3. Gassman, P. W., Reyes, M. R., Green, C. H. and Arnold, J. G. (2007). The soil and water assessment tool: historical development, applications, and future research directions, Transactions of the ASABE, 50, 4, 1211-1250.
4. Winchell, M., Srinivasan, R., Di Luzio, M. and Arnold, J. (2010). ArcSWAT Interface for SWAT 2009. Users'guide. Temple, U.S.A. Blackland Research Center, Texas Agricultural Experiment Station and Grassland, Soil and Water Research Laboratory, USDA Agricultural Research Service
5. Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D. and Alsdorf, D. 2007. The Shuttle Radar Topography Mission. *Reviews of geophysics* 45 (2): 934–948
6. Abbaspour, K. C. 2011. SWAT-CUP4: SWAT Calibration and Uncertainty Programs - A User Manual. Eawag Swiss Federal Institute of Aquatic Science and Technology. www.neprashtechnology.ca/Downloads/SwatCup/Manual/Usermanual_Swat_Cup.pdf [consulted 7 March 2013]
7. EnviroGRIDS. 2012. Building Capacity for a Black Sea Catchment Observation and Assessment System supporting Sustainable Development. Official web-site. http://envirogrids.net/ [consulted 1 June 2012]
8. Research Institute for Knowledge Systems (RIKS). 2005. The Metronamica modelling framework: model descriptions. Model documentation. Maastricht: RIKS.
9. Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T. Y. and Kram, T., La Rovere, E., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H.H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooyen, S., Victor, N. and Dadi, Z. 2000. Special Report on emissions scenarios. Cambridge: Cambridge University Press.
10. Mancosu, E., Gago da Silva, A. and De Bono, A. 2012. D3.7. Proposed land use scenario analysis, model input parameters and allocation rules. http://www.envirogrids.net [consulted 10 January 2013]
11. Semenov, M. A. and Stratonovitch, P. 2010. The use of multi-model ensembles from global climate models for impact assessments of climate change. Climate Research 41: 1-14