PRELIMINARY LONG-TERM PREDICTIVE MODELLING RESERVES OF GROUNDWATER RESOURCES IN VIEW OF CLIMATE CHANGE – A CASE STUDY FROM EASTERN POLAND

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Introduction

The presented research goal was a multi-scenario predictive modelling of groundwater reserves in the area analysed, under projected warming climate conditions for the years 2080 to 2100, and using the assumed method of modelling the predicted groundwater reserves. The novelty of this preliminary research is carrying out of prognostic modeling of reserves of groundwater resources in the distant future, based on available IPCC emission scenarios of CO_2 (SRES) and regional climate models (RCM) for the study area, taking into account forecasted water demand in the future (estimated) and the need to preserve the environmental flow of the river draining the catchment, determined for hydrological conditions from the reference period 1971–1990.

Samples and methods

The study area is a lowland part of the Lower Wieprz river catchment, and is located in the Central Vistula river basin in eastern Poland. The area (3899.8 km^2) mostly comprises an agricultural plain and forests. The groundwater has an unconfined character and the depth to the groundwater table is 15 to 50 m.

The predictive modelling of reserves of groundwater resources in the study area was made on the basis of climate change forecasts in the last decades of the 21st century. The forecast relied on predicted precipitation and air temperature data obtained with two sets of SRES, joined by various RCMs. The first set was for three SRES: A1B, B1 and A2 jointed with RCM averaged from two GCMs (ECHAM-5 and HadCM3). The second set was for four variants uniting SRES A2 and B2 with two RCMs, i.e. HIRHAM and RCAO.

The reference renewable groundwater resources in the catchment ware determined by the Kille hydraulic method, i.e. the average groundwater outflow to the river was defined as a median with minimum monthly stream flows in the period 1971–1990. For needs of herein presented preliminary long-term predictive modelling, the environmental flow in the river in the reference period was estimated by hydraulic method in simplified way as a median of the minimal annual stream flows. It was assumed that the environmental flow of a river in the last decades of the 21st century would remain the same as in the reference period.

The predicted groundwater reserves in the analysed catchment were calculated on the basis of the water management balance:

$$B_{A(pr)} = A_{r(pr)} - F_{env} - U_{(pr)}$$

where $B_{A(pr)}$ is the predicted reserve of groundwater resources, $A_{r(pr)}$ are the predicted renewable groundwater resources, F_{env} is the environmental flow of a river and $U_{(pr)}$ is the predicted groundwater abstraction.

Results

Obtained the spatial distributions of predicted average annual groundwater recharge in the study area at the end of the 21st century, based on assumed ensembles SRES with RCMs, are illustrated in Fig. 1.

The predicted in this preliminary modelling groundwater reserves values in the last decades of the 21st century for the analysed climate warming scenarios have been presented in Tab. 1. In each of the analysed scenarios, the forecast reserves may diminished when compared to the reserves of the reference period. The biggest drop of the predictively modelled resources, consequently leading to a deficiency of resources in the predicted groundwater abstraction conditions, may be observed for SRES A2 joined with RCMs RCAO and HIRHAM. The average decrease of predicted groundwater reserves in the study area defined with all models, may constitutes 67% of the reserves available in years 1971-1990. The average predicted in this preliminary modelling reserve of groundwater resources may be approximately 1.3 m^3s^{-1}.

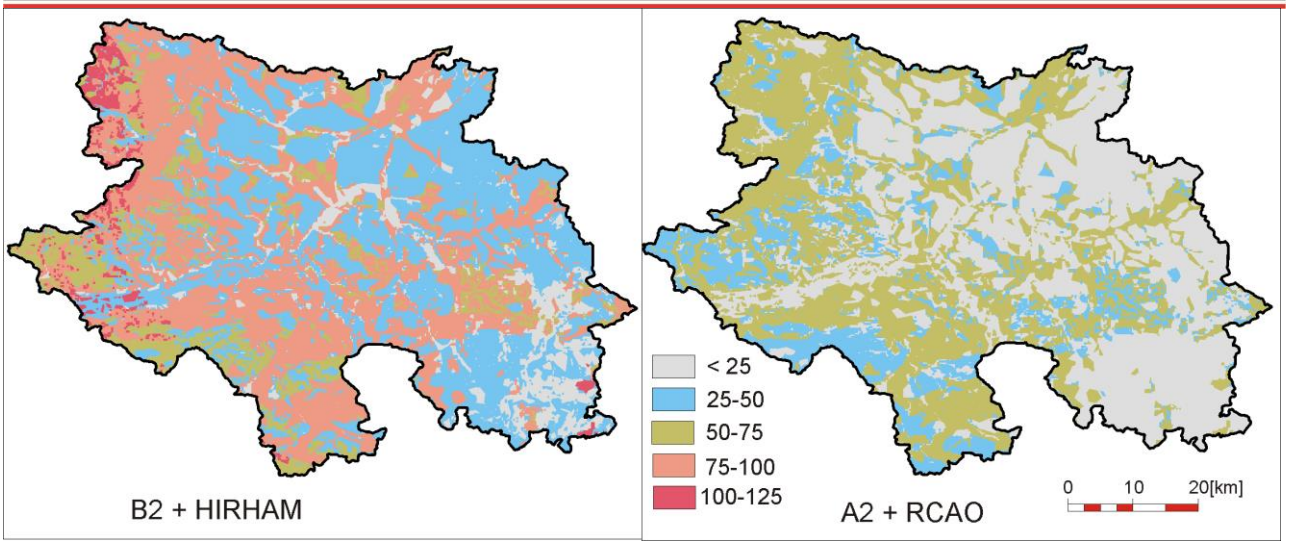

***Figure 1**. Predicted average annual groundwater recharge in the study area (mm) for 2071-2100. Explanations: B2, A2 – SRES; HIRHAM, RCAO – regional climate model (RCM).*

***Table 1.** Predictions for the last decades of the 21st century in the analysed catchment and decreasing reserves of groundwater resources in relation to the years 1971–1990.*

Emission scenario ensemble with RCM		$A_{r(pr)}$	F_{env}	$A_{(pr)}$	$U_{(pr)}$	$B_{A(pr)}$	B_A 1971-1990	Decrease of reserves
		m^3s^{-1}						%
A1B	RCM averaged from ECHAM5 and HadCM3	8.5	4.6	3.9	1.1	2.8	3.9	28
B1		8.3		3.7		2.6		33
A2		8.3		3.7		2.6		33
B2 + HIRHAM		7.6	4.6	3.0	1.1	1.9	3.9	51
A2 + HIRHAM		5.3		0.7		- 0.4 (deficiency)		110
B2 + RCAO		6.0		1.4		0.3		92
A2 + RCAO		4.7		0.1		- 1.0 (deficiency)		126

$A_{r(pr)}$ - renewable groundwater resources, F_{env} - environmental flow in the river, $A_{(pr)}$ - groundwater resources, $U_{(pr)}$ – groundwater abstraction, $B_{A(pr)}$ - reserves of groundwater resources, B_A - reserves for the years 1971–1990

Conclusions

This preliminary long-term predictive modelling, however burdened with some uncertainty, revealed that the groundwater resources reserves in the study area at the end of the 21st century may decrease due to climate change, compared to the reference period 1971–1990. The amount of the predicted groundwater reserve resulting from this preliminary modeling importantly depends on the assumed forecasted climate model, based on particular ensembles of SRES with given RCMs, and other adopted assumptions.

In further modeling of this type, it is necessary to assumption models of future climate changes that are more accurate than SRES, i.e. models based on representative concentration pathways (RCPs) of greenhouse gases. Furthermore, more detailed water demand scenarios should be devised for the last decades of the 21st century (and for even longer time perspectives), as they provide the basis for more reliable predictions of the effects of climate change on groundwater resources reserves in the future.