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Forecasting Net Groundwater Depletion in Well Irrigation Areas with Long Short-term Memory Networks

Li Yuheng and Tang Lihua
Tsinghua University, Institute of Hydrology and Water Resources, Department of Hydraulic Engineering, China (729611768@qq.com)

Due to the scarcity of available surface water, many irrigated areas in North China Plain (NCP) heavily rely on groundwater, which has resulted in groundwater overexploitation and massive environmental impacts, such as groundwater depression core and land subsidence. The net groundwater depletion, one of the groundwater indicators, means the actual groundwater consumption for human impact. This indicator is quite essential for the evaluation of the effects of agricultural activities in well irrigation areas. However, net depletion forecasts, which can help inform the management of well irrigation areas, are generally unavailable with easy methods. Therefore, this study explored machine learning models, Long Short-term Memory (LSTM) networks, to forecast net groundwater depletion in well irrigation counties, Hebei Province. Firstly, Luancheng county was selected to construct the forecasting model. The training dataset was prepared by collecting the measured precipitation, remote sensing evaporation and groundwater table from 2006-2017. Besides, an agro-hydrological model (Soil-Water-Atmosphere-Plant, SWAP) with an optimization tool (Parameter ESTimation, PEST) was used to calculate the net depletion, and an unsaturated-saturated zone water balance conceptual hydrological model was constructed to calculate the net groundwater use. Secondly, to determine the effect of training data type on model accuracy, freshwater budget (evaporation minus precipitation), change of groundwater table and net groundwater use were chosen as training inputs by analyzing related temporal variable characteristics of net groundwater depletion. The response time of training inputs with net groundwater depletion were also approximated with highest cross-correlation value (CCF). Then, by circular bootstrapping methods to enlarge the Luancheng datasets from 2006-2016, the annual and monthly model for forecasting the net depletion were respectively trained with enlarged Luancheng datasets. Additionally, to test the model's ability to predict the net groundwater depletion in other well irrigation areas with the similar rule of groundwater depletion, the annual and monthly forecasting scenarios were also carried out in the adjacent county, Zhaoxian. The results showed that both of the monthly and annual models estimating the groundwater net depletion had good performance in Zhaoxian from 2006-2017, with NSE of 0.91 and 0.81, respectively. According to the modelling results, further analysis showed that groundwater depletion in research counties mainly occurred in spring (March to May) and winter (December to February). In addition, the major factor leading to groundwater depletion in spring and winter was freshwater budget; while in summer and autumn, soil moisture determined the depletion activity. These results demonstrate the feasible use of LSTM networks to create annual

and monthly forecasts of net groundwater depletion in well irrigation areas with similar depletion rule, which can provide valuable suggestion to well irrigation management in NCP within a challenging environment.

Keywords: net groundwater depletion; long short-term memory; well irrigation areas