Estimation of Carbon Emissions from Groundwater Variation: Machine Learning/Deep Learning Approaches

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Recent reports show that groundwater plays an important role in the carbon cycle and cannot be underestimated. Rather than controlling direct carbon exchange, groundwater is thought to take part in indirect carbon emissions at the secondary and tertiary levels. Especially, carbon emissions due to the depletion of groundwater as a result of overexploitation can be significant. Therefore, it is crucial to understand the groundwater variation in space and time for the accurate estimation of carbon emissions. The availability of Gravity Recovery and Climate Experiment (GRACE) and GRACE-Follow On (GRACE-FO) satellite data since 2002 has made it possible to monitor groundwater storage variations on a global scale. To supplement the low resolution of GRACE, multiple satellite data or machine learning/deep learning models can be used together. In this study, machine learning (Xgboost) and deep learning (Convolutional Neural Network-Long Short Term Model; CNN-LSTM) models were developed to predict groundwater storage anomalies in South Korea. Meteorological and hydrological satellite data (terrestrial water storage, precipitation, soil moisture content, temperature, normalized difference vegetation index, and modified normalized difference water index) were used. Hyperparameters in Xgboost and CNN-LSTM were tuned by grid search and Bayesian optimization, respectively. The lag time was set from 1 to 12 months. The time series of input and output data were divided into training (80%) and test sets (20%). The predicted groundwater storage anomalies (GWSA) were analyzed to identify watersheds with decreasing trends for the period of January 2003–December 2019. The bicarbonate (HCO3-) concentration data from National Groundwater Monitoring Network of South Korea was used to calculate the carbon emissions from the identified watersheds. The method proposed here can help control carbon emissions from future groundwater use, which will be an important contribution to carbon neutrality. Continued research is needed to understand the interrelationship among climate change, groundwater storage and groundwater use.

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