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Editorial

Remote Sensing and Geoscience Information Systems Applied to Groundwater Research

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As computer and space technologies have developed, geoscience information systems (GIS) and remote sensing (RS) techniques have also been rapidly growing. Recently, the importance of groundwater has grown across the world. The integration of RS and GIS techniques with knowledge of geology has effectively been used to assess groundwater potential and the groundwater pollution problem. We do not doubt that the use of RS and GIS techniques is a powerful tool to study groundwater resources and design suitable exploration plans. This Special Issue aims to create a multidisciplinary forum of discussion for recent advances in the RS and GIS fields for their groundwater applications. Topics of this Special Issue include:

- Application of RS and GIS techniques in groundwater research
- Spatial analysis and geocomputation in groundwater research
- Spatial prediction using machine learning techniques in groundwater potential research
- Geospatial big data processing and artificial intelligence for groundwater research
- Geospatial research for groundwater potential and pollution
- Case studies of groundwater potential and pollution using GIS and RS.

In this Special Issue, twenty papers were submitted, and seven highly qualified papers were published. In the papers, the study areas were Iran [1–3], South Korea [4,5], Mexico [6] and the United Arab Emirates [7]. The machine learning techniques were used in the five papers [1,2,4,5,7]. Six of the seven papers presented potential mapping results using RS and GIS techniques. The following summarizes the contents of the papers published in this Special Issue.

Arabameri et al. [1] created a groundwater potentiality (GWP) map over the Damghan sedimentary plain area, which is located in the region of a semi-arid climate of Iran. For this, they used the random forest (RF), binary logistic regression (BLR), a technique for order preference by similarity to ideal solution (TOPSIS), weight-of-evidence (WoE), and support vector machine models (SVM). Ground water parameters were collected from 80 wells, and the data from 56 (70%) wells were used for the training data while the data from 24 (30%) were used for the test data. The performance between the models was estimated by using the area under the curve of the receiver operating characteristic (AUROC). The best performance was calculated from the BLR model, while the worst performance was from the SVM model.

Arabameri et al. [2] presented a novel ensemble approach through integration of the Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR), frequency ratio (FR) and random forest (RF) models to produce a GWP map in the Bastam watershed, Iran. The proposed methods were composed of six main steps: (1) data preparation, (2) data assessment, (3) relative importance calculation using groundwater conditioning factors,

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(4) decision matrix calculation, (5) ground water map generation using the proposed ensemble approach, and (6) performance validation. To evaluate the accuracy of the produced GWP map, the success rate curve (SRC) and prediction rate curve (PRC) were calculated, and the values of SRC and PRC were about 0.925 and 0.934, respectively. This result shows the proposed approach can be used for (1) the management of groundwater resources and (2) the decision-making in groundwater-investment planning to achieve sustainability.

Rahmati et al. [3] (1) developed an automated GIS tool to select absence samples, (2) applied the selected absence samples to the machine learning models including RF and multivariate adaptive regression splines (MARS) to create a groundwater potential map, (3) evaluated the model performance by using the receiver operating characteristic (ROC) curve, and (4) compared between the two model results. The ROC was about 0.931, and the result indicates that the proposed tool can be used to generate an improved groundwater potential map.

Kim et al. [4] created a groundwater productivity potential (GPP) map over Okcheon city, South Korea using the boosted regression tree (BRT), RF, and logistic regression (LR) models. They exploited the relation between the groundwater-productivity such as specific capacity (SPC) and transmissivity (T) and the land-cover map, topographic map, lineament map, geology, etc. The land-cover map and topographic map were created from satellite images. They collected groundwater productivity data from 86 wells. The 50% productivity data were used as the training data, and the other 50% of the data were used as the test data. The model parameters of BRT, RF and LR were estimated by using the training data. The existence of GPP was determined by T or SPC. The input neurons in the models were composed of 18 hydrogeology-related factors. They created three GPP maps from the T value by using the three models and produced three GPP maps from the SPC value by using the models. Then, they evaluated the model performance of the GPP maps. When the T value was used for the models, the model accuracy was about 81.7%, 80.2%, 85.0% in BRT, RF and LR, respectively, while the model accuracy was approximately 81.5%, 78.6% and 82.22% in BRT, RF and LR, respectively, when the SPC value was used. In the GPP map creation in Okcheon city, Korea, the LR model was best, and the model parameter estimation from the T value was better than the SPC value.

Fadhillah et al. [5] created and analyzed a GPP map over Gangneung-si, South Korea using a support vector regression (SVR) model from the hydraulic dataset of transmissivity. They collected the transmissivity data from the 285 wells, and then the 285 data were divided into training and test data at a ratio of 70% vs. 30%. The models used for this study were SVR, SVR with grey wolf optimization (GWO), and SVR with particle swarm optimization (PSO). The area under curve (AUC) value was used to evaluate the model performance. The AUC values estimated from SVR, SVR with GWO, SVR with PSO were about 0.803, 0.878 and 0.814, respectively. The created GPP maps were used for the groundwater development and management in Gangneung-si, South Korea.

Moreno-Gómez et al. [6] proposed a new method for dolines mapping, and they evaluate the performance of the proposed method in the study area, which is located in the Yucatan Peninsula. The Yucatan Peninsula is an interesting karst region having unique features such as "Cenotes", which is an open doline exposing water, and a semicircular doline alignment. The proposed method is a semiautomatic multi-depth threshold approach (MDTA). They mapped a total of 665 dolines using the proposed method and the detection accuracy and precision of the proposed method were about 85% and 71%, respectively.

Elmahdy et al. [7] mapped and monitored the land use/land cover (LULC) changes over the Northern United Arab Emirates (NUAE) to spatially analyze the level and quality of the groundwater. The LULC change maps with the accuracy of more than 0.9 were created by using the SVM machine learning model. They created four enhanced LULC maps from the periods of 1990–2000, 2000–2010, 2010–2018, and 1990–2018. In the study area, the built-up area increased approximately from 227 km^2 to 870 km^2, while the vegetation area increased approximately from 77 km^2 to 291 km^2. The observed LULC changes are closely related to the groundwater level and quality in the NUAE.

We hope that the research topics of the seven published papers will help and be widely used in the ground applications based on the RS and GIS techniques.

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