Review on the Groundwater Potential Evaluation Based on Remote Sensing Technology

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Abstract. Groundwater is an important water resource, and plays an important role in people’s life and production. The evaluation of groundwater potential is the prerequisite and basis of groundwater development and utilization. Compared to geophysical prospecting, drilling and other traditional groundwater evaluation method, remote sensing technology is an advanced monitoring method with time-saving, economize labour and highly efficient. Remote sensing technology can obtain the related information about groundwater potential with wide range, rapid and objective characteristic, and is an improvement and effective complement of the traditional methods. Based on the analysis of the current research status of remote sensing technology, this paper summarizes the method of groundwater potential evaluation by remote sensing technology, and analyses the advantages and disadvantages of various methods, and points out the research topic and development direction of the method.

1. Introduction
Groundwater is a very valuable natural resource as well as an important strategic material. It plays a very important role in ensuring the living of urban and rural residents, supporting the sustainable economic and social development and maintaining the ecological balance [1]. Especially in which lacks surface water resources, groundwater has irreplaceable effect and enhancing the evaluation of groundwater potential is of great significance.

The evaluation of the groundwater potential is the key to develop groundwater resources. Compared to traditional drilling and geophysical prospecting methods in evaluating groundwater potential, remote sensing technology has the advantages of macroscopical, fast, real-time, low cost and less man-made interference [2]. Therefore, remote sensing technology in evaluating groundwater potential makes up the shortage of traditional methods, larger manpower, higher economic costs and less investigation scope, and has attracted widespread attention, research and application.

2. Research status
Remote sensing technology as an emerging comprehensive detection technology developed in the 1960s. It concludes the latest achievements in such disciplines as space, electronics, optics, computer communications and geosciences. It is widely used in military, marine, meteorological, Earth resources census, environmental monitoring and other fields, and become an important part of contemporary technology [3]. Many scholars have done a great deal of research on the application of
remote sensing technology to the evaluation of groundwater potential, and have made a lot of achievements to promote the application of remote sensing technology.

In 1961, scientists extracted the topographic information from aerial photographic and built a simple water cycle model to estimate the existence of groundwater, and made a pre-judgment of the outflow zones and the sources of recharge by indicative vegetation. In 1980s, with the development of multi-temporal, multi-band, multi-angle, hyper-spectral and microwave remote sensing technology, the multi-source remote sensing is widely used in the interpretation of geological conditions about groundwater [4]. Some environmental factors, like lithology, rock formation, vegetation and hydrology, can be extracted from RS image. Compared with drilling and geophysical prospecting, remote sensing technology is more economical for groundwater resource assessment [5]. S W Finch et al. [6] focused on the study of groundwater recharge condition, and located groundwater enrichment area by vegetation, hydrology and temperature. Li Tingqi et al. [7] attempted to determine the lithology, regional topographic features and surface water recharge source of aquifer by MSS images to figure out groundwater volume, water quality and burial depth in Tarim Basin. Groundwater is classified according to mineralized degree, and the distribution of groundwater and groundwater level is qualitatively described. Wang Feiyue et al. [8] aimed to the relationship between vegetation and groundwater in arid area, and inferred shallow groundwater potential through analyzing the remote sense data of vegetation. By the end of the last century, RS (Remote Sensing) technology is combined with GIS (Geographic Information System) and GPS (Global Positioning System) to form 3S method [9, 10]. By fitting the multi-source remote sensing data with the hydrological, geological and geophysical data, the Groundwater analysis and evaluation model, which is composed of geological, geomorphic and hydrological linear feature maps, DEM and measured data, is established in GIS to infer the groundwater potential. Tashpolat et al. [11] take the evaluation of the groundwater in the oasis-desert ecotone of arid area by remote sensing data as a main goal. GLDRS model for evaluating the distribution of groundwater with Landsat7-ETM images is established by using the method of RS-mathematical modeling fusion.

3. Review
The evaluation of groundwater potential in remote sensing is based on the correlation of groundwater with surface water, vegetation, soil moisture, and surface temperature. By analyzing the surface information on remote sensing images, we can estimate the status of groundwater. Currently, the method for assessing the evaluation of groundwater potential in remote sensing has mainly a single factor model evaluation and multi-source hydrological geological analysis method assessment.

3.1. Single factor evaluation model

3.1.1. Surface soil moisture evaluation. Soil moisture is controlled by groundwater. When groundwater is highly enriched or the depth of groundwater is shallow, capillary water supplies top-soil to maintain high soil moisture. As the depth of groundwater deepens, or groundwater enrichment decreases, soil moisture content decreases with the supply of capillary water decreases, so that the soil moisture cannot feed the plant and form a soil drought. In a certain degree, soil moisture reflects groundwater potential. Therefore, soil moisture can be used as an indicator of groundwater potential. At present, the methods and theories of using remote sensing technology to obtain soil moisture have been very mature, and many researches have been done. However, these soil moisture inversion models are rarely applied to groundwater evaluation and achievements are relatively few. Li Jufang et al. [12] extracted soil moisture of hills in Lingyuan, Liaoning from Landsat image. Combined with other data, the relative enrichment area of shallow groundwater in the study area has been delineated. Li Wei et al. [13] used MODIS data to obtain the data of soil moisture in Maowusu Desert, and established a remote sensing information evaluation model of groundwater potential. The correlation coefficient of the prediction model is 0.78.
The evaluation of groundwater potential, based on soil moisture that interpreted by remote sensing technology, has better effect in arid areas. Because of the less rechargement, the lower air humidity, the larger evaporation, and the more ideal cross-section of groundwater in arid areas, the correlation between soil moisture and groundwater potential is obvious.

3.1.2. Thermal infrared evaluation. The thermal infrared remote sensing monitoring method can use the thermal infrared band (10.4 μm–12.5 μm) to infer groundwater potential, because the surface temperature is abnormal due to the occurrence of groundwater. In arid and semi-arid areas, as the thermal inertia of water is large, the temperature difference in a day or a year is smaller in area of shallow groundwater. Therefore, the groundwater potential can be traced by the temperature abnormal changes in arid and semi-arid areas. Many scholars have used this method to study groundwater potential. Many scholars have used this method to study groundwater potential. Fu Bihong et al. [14] quantitatively retrieved the surface temperature of Shiyang River Basin by using Landsat-TM thermal infrared remote sensing data. The zone of abnormal surface temperature shows the enrichment area of groundwater, and the temperature of the abnormal zone is lower than that of normal ground 7K. Based on it, thermal infrared remote sensing technology can be used to effectively detect information of groundwater potential in arid area. However, the surface temperature can be influenced by various factors, such as the difference of emissivity, topography, wind speed, atmosphere and local climate conditions. So, the inversion of surface temperature is a difficult problem in the field of remote sensing. But, with the success of remote sensing inversion of sea surface temperature, the inversion of land surface temperature has also gained great momentum. And other scholars have retrieved the surface temperature with high precision used the multi-channel method, which provides a more dynamic technique for the monitoring of groundwater by thermal infrared remote sensing.

3.1.3. Vegetation evaluation. Some scholars have focused on the relationship between vegetation and groundwater. On the basis of a large amount of observation data, Maitre et al. [15] researched the influence of the change of surface vegetation cover on the groundwater recharge. In the study of Yinchuan basin, Jin Xiamen et al. [16] proposed the concept of conditional vegetation coverage. By combining remote sensing technology data of groundwater, they studied the appropriate groundwater depth for vegetation growth. The results show that the conditional vegetation coverages have good correlation with the groundwater depths when they are in 2~8m. Sun Xianchun et al. [17] studied the relationship between the mixed distribution function and data histogram in Yinchuan basin, and used the new method of estimating parameters with the least square method to quantitatively analyze the buried depth of groundwater and the growth of vegetation by combining the NDVI index. It is considered that the influence of groundwater depth on vegetation is normal distribution.

Groundwater has a strong effect on vegetation, and groundwater potential is reflected by vegetation. The change of groundwater information can be indirectly inferred by the analysis of vegetation changes by remote sensing. There are also some shortages in using vegetation information to obtain groundwater potential. Firstly the method only can be applied in vegetation covered areas, which limits its application. Secondly, vegetation development is also disturbed by many other factors, just like the salinity, topography, elevation and climate.

Thirdly, different vegetation responses to the groundwater level differently, so this method only can be used in areas with fewer vegetation types.

3.2. Multi hydrogeological factor evaluation method

Although groundwater has control and influence on the surface humidity, temperature and vegetation, it also be controlled by the groundwater flow system. The effects which artificial or natural factors has on the rechargement and excretion of groundwater can be transmitted to the entire hydrological cycle through the groundwater flow system, and affect the groundwater. Thompson et al. [18] extracted topographic data from DEM model and in the study of the groundwater in a small mountain basin found that the groundwater depth is closely related to the water collector area of a unit length contour.
line and the slope. The mountain basin is recharged by atmospheric precipitation. The terrain controls the recharging, and the correlation between the topographic factors and the groundwater shows the result of the control. The more obvious the control is, the closer the correlation is.

With the development of remote sensing technology and the abundance of remote sensing data, the research on the application of multi-source remote sensing data to the assessment of groundwater potential has attracted more attention. Gumma et al. [19] have evaluated the groundwater potential in Garner by seven indexes, such as precipitation, confluence intensity and land use, and trust that RS and GIS technology can carry out the national evaluation of groundwater potential well. M Vasanthavigar et al. [20] have accessed the data of terrain, landforms, water network density and fracture density through RS technology, and evaluate the structural fissures groundwater in basin. The results suggest that the intersection of fissures is the area of groundwater potential, which is consistent with the actual experience of tracing groundwater. D Machiwal et al. [21] gain ten indexes related to groundwater through RS technology, and pick up seven indexes by principal component analysis to assess the groundwater potential in arid areas. The evaluation is in general agreement with the field verification, and it is also indicated that the distribution of groundwater isn’t correlated to annual precipitation and altitude. Wan Zheng [22] established the remote sensing monitoring model of groundwater distribution in Horqin grassland-dessert ecotone in Tong Liao, Inner Mongolia through Landsat images and hydrogeological factors, and it has been verified in field with good results.

However, these models aim at specific landform types and areas, and lack comprehensiveness and universality as the indicators in the models need to be restricted under certain conditions to be applied. Secondly, the models are only for a single phase, and the extracted remote sensing data has no way of contributing to the effects of meteorological and hydrological conditions at the time. They aren’t stable enough to reflect the groundwater potential. Thirdly, the models divide the evaluation index from continuous distribution to a few discrete levels. But, due to the relativity and fuzziness of the groundwater potential, the quantitative method is difficult to accurately describe the degree of groundwater potential. Each index of the evaluation model is only a simple parallel relationship. The interpretation of the influence of each index is not clear. It is difficult to accurately quantify the impact of each index on the evaluation results when there are many indicators.

4. Conclusion

Remote sensing technology is a new comprehensive detection technology. It has become an important technology for monitoring and assessing groundwater potential. Many scholars have carried out researches on the evaluation of groundwater potential, and acquired great achievements which have greatly improved the efficiency and effectiveness of the technology. But, because remote sensing technology cannot observe underground directly, the accuracy of evaluating groundwater potential with remote sensing technology remains to be improved. Improving the accuracy of data, building a more reasonable evaluation model, lifting the inversion accuracy and multi method fusion will be the main research direction in the future.

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