REMOTE SENSING BASED WATER LEVEL MONITORING MODEL FOR SHALLOW GROUNDWATER IN ARID REGION OF NORTHWEST CHINA

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ABSTRACT: For the frangible ecological environment, it is very important to reasonably develop and utilize groundwater resources in Northwest China. Shallow groundwater level is an essential factor related to the eco-environmental problems such as oasis degeneration and land salinification. The lack of groundwater dynamic data is a critical concern for water resources management in the arid region. This paper aims at the development of groundwater level information model with remotely sensed data, combined with the well observations and field investigation. The method is based on the basic fact that the surface soil water moisture is observably related to the shallow groundwater level because of the very few precipitation in the lower plain of inner arid land basin. The analysis models for soil water content and radiation of remote sensing image are established, and then the remotely sensed data based groundwater level monitoring model is developed by using Landsat TM images. The models are demonstrated in the Shule River Basin which is located in Hexi Corridor, Gansu province of China. The research results could provide effective tools for the hydrology research, and support the sustainable water resources development and management in arid regions.

1 INTRODUCTION

Shule river basin is located in the west end of Hexi Corridor, Gansu province of China (see Figure 1). This is an extremely dry area with the mean annual precipitation is only about 40 mm in the lower plain while the potential evaporation reaches 2,500 mm. The annual river runoff, mainly formed in the mountainous area, is about 1.63 billion m^3. The whole basin is separates to several sub-basins by outcrops of bedrock. Three sub-basins, Yumen, Anxi and Huahai, with similar geological conditions are the larger irrigation commands which had developed by the implementing of Shule River Basin Agriculture Development and Resettlement Project, supported by the central government and the World Bank. Only Yumen basin, the largest sub-basin, is considered for discussion in details in this paper (see Fig.1). It was verified that the land and water resources are enough for the agriculture development, the major concern is that if the exploitation will cause negative impacts on the ecosystem in this region.

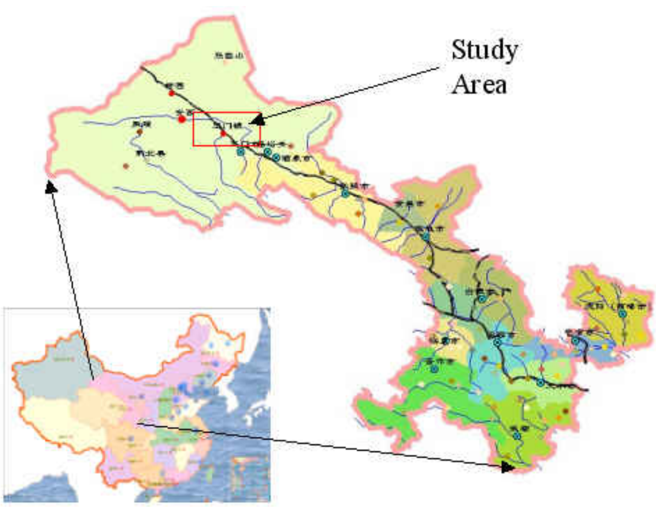

Fig.1 Location of Study Area

Shallow groundwater level is an essential factor related to the eco-environmental problems such as oasis degeneration caused by water level declining, and land salinification due to water level rising. The lack of groundwater dynamic data is a critical concern for water resources management in this region. Remote sensing technique may take an important role in obtaining dynamic information of water level in a large basin scale. This paper mainly discusses the development of groundwater level information model with remotely sensed data in arid areas.

2 GEOLOGICAL SETTING AND GROUNDWATER SYSTEM

Groundwater becomes one of the most critical and sensitive factors that affect the ecological environment, because of the dry climate in this region. Groundwater, relatively rich in alluvial and floodplain, is recharged by rivers in upper desert plain areas and discharged by springs and envp-transpiration in lower plain areas. In lower plain, formed by fine sand, silt and clay, the aquifer system can be schematically subdivided into two layers, i.e. the shallow water, the upper layer with depth of 30-50m, and the deep groundwater, the lower layer with depth of 60-120m. Groundwater is the only water source on which the oasis depends. The dynamic of shallow water influences the development of ecological system. The variations of groundwater level are directly related to the changes of inflow from upper areas and the evap-transpiration. In May and June, groundwater level is higher because of infiltration recharge of irrigation utilizing surface water, while from July to September, water level is much lower because of the large evap-transpiration. From November to March of next year, water level rises because of the inflow of upper areas (see Fig.2).

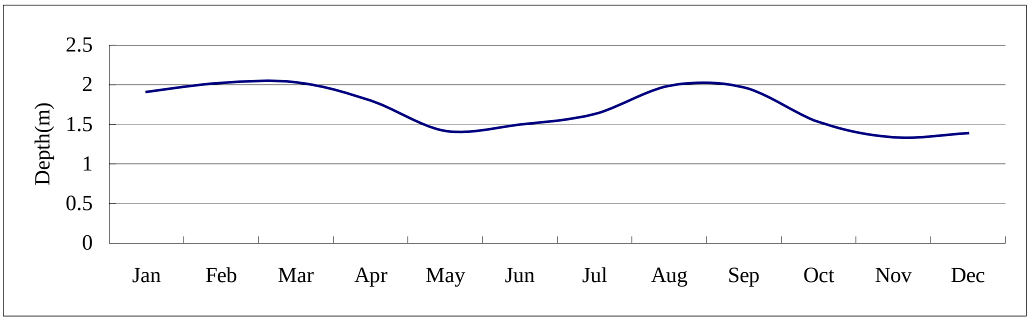

Fig.2 Shallow water level annual dynamic curve (observation well 4-4)

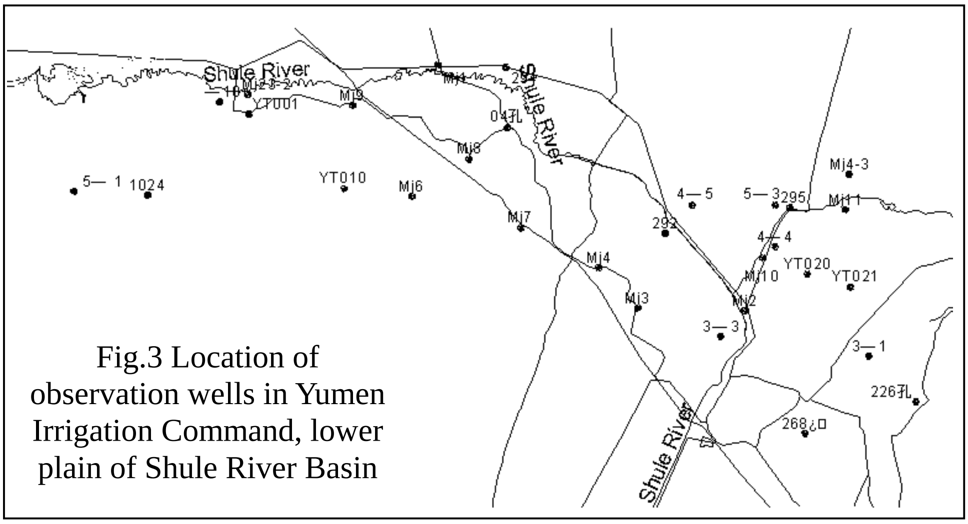

Fig.3 Location of observation wells in Yumen Irrigation Command, lower plain of Shule River Basin

3 DATA AND MODEL

Digital data of cloud free LandSat TM of Oct.2 of 2006 was used to detect the surface reflectance under the changes of shallow water level. The topographic maps with scale 1:50000 were used from the National Survey Bureau. Observation data of 17 wells were collected for the model development. The location of wells were located by GPS(see Fig.3).

The method is based on the basic fact that the surface soil water moisture is observably related to the shallow groundwater level because of the very less precipitation in the lower plain of inner arid land basin.

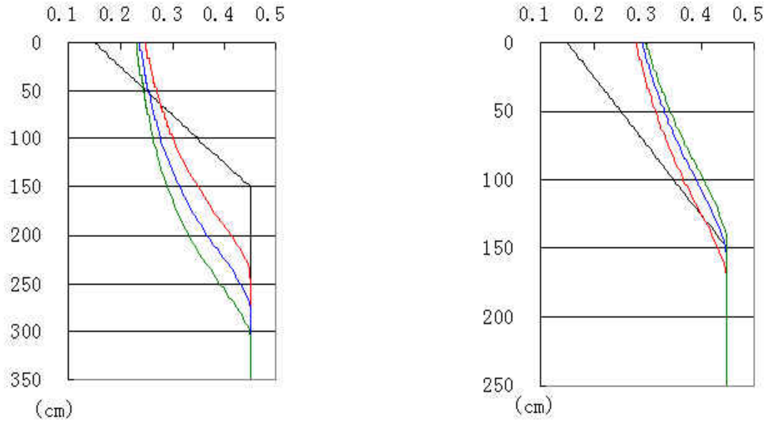

Fig.4 Relationship between water level depth and surface soil moisture

The higher the surface soil moisture, the higher shallow water level (see Fig.4). The surface reflectance which can be obtained from the image vary with the surface soil moisture. Therefore, the relationship between the reflectance and water level depth can be analyzed using the well observations of same time period. In this region, vegetation type and coverage are the main factors to water level variation because of the large amount water consumed by the vegetation. The NDVIs derived from image data were used to eliminate the influence of vegetations. The model is described as following.

$$Dw = a + b \times DN_i + e^{c \times NDVI}$$

where, *Dw* is the depth of water level in meters, *DNi* is the reflectance of different channels and is represented by the grayness of the pixel where the observation well located, *a*, *b* and *c* is the equation coefficients. To reduce the random, the DN values were smoothed with 3×3 window, i.e. the grayness of the interested pixel is smoothed together with the grayness of the 8 surrounding pixels.

4 MODEL RESULTS AND DISCUSSIONS

The models were tested by 6 bands with 30m spatial resolution (channel 1-5 and channel 7). Models using channel 7, 3 and 2 have satisfactory results with correlation coefficient (R^2) from 0.63 to 0.73 (see table 1), and channel 7 is the best one for modeling the depth of water level, with the correlation coefficient (R^2) 0.7266 (see Fig.5). The differences of between observed and calculated vary from –1.6m to 2m, but most observation wells, about 60% of total observations, the differences are between 0.03m and 0.5m, differences for about 23% of the total vary from 0.5m to 1.0m.

Table 1 Model parameters with different channels of Landsat TM

Channel	*a*	*B*	*c*	R^2
1	-6.675	0.165	20.43	0.6303
2	-4.713	0.142	20.43	0.6382
3	-3.502	0.102	20.43	0.6902
4	0.025	0.003	20.43	0.2314
5	-3.801	0.116	20.43	0.6208
7	-2.985	0.126	20.43	0.7266

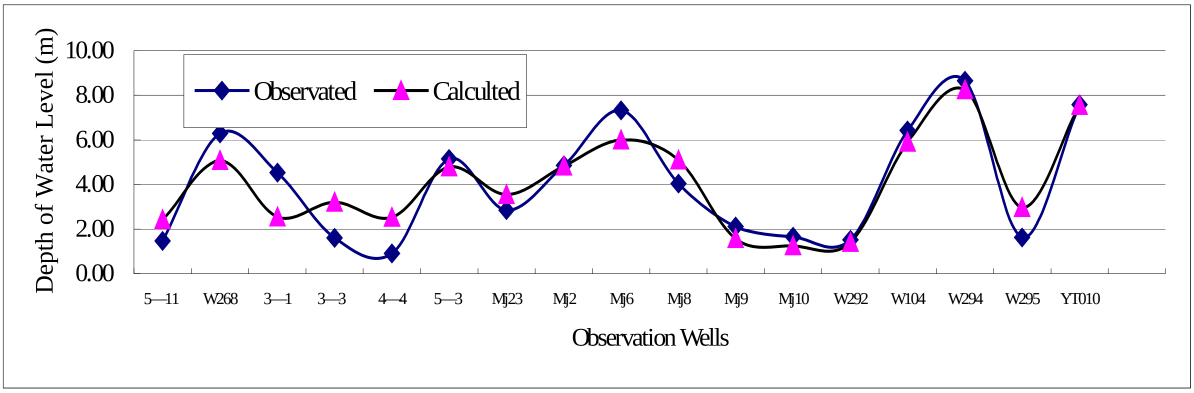

Fig.5 Fitting curves of observed data and calculated (channel 7) for 17 observation wells.

The thematic map was derived from the image (channel 7) using the relationship model to show the distribution of shallow water level in the lower plain (see Fig.6). The large depths of water table, varied from 5m to 7m, are mainly distributed along the ecotone between the oasis and the desert. Along the Shule river, the depths of water level are also larger, about 5m-8m, because of the deeply cutting of the river. The depths of water table in the inner basin vary mainly from 0.5m to 3m. The results are consistent with the actual situation in the Yumen basin.

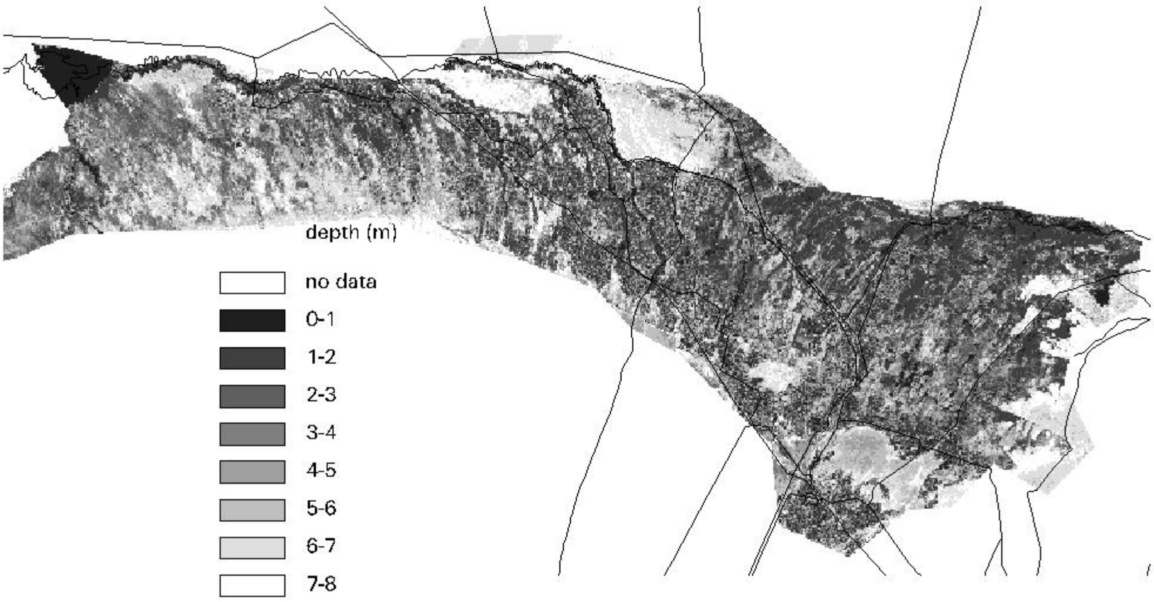

Fig.6 Distribution of shallow water level depth in Yumen Basin of Shule River

5 CONCLUSIONS AND FUTURE DIRECTIONS

Remote sensing images, for their high cost-effectiveness, could be the available information for the shallow groundwater dynamic monitoring. This research suggested the channel 7 of Landsat TM is the most suitable band to establish the relationship between water level depth and the reflectance of image. The model should be verified using multi-temporal images and long series of well observations. The precision of the analysis model needs to be further improved, in order to consider the factors such as soil characteristic, vegetation types, as well as irrigation activities. In future research, models with consideration of these factors could be developed for analysis of the groundwater dynamic, and other remote sensing data with a higher temporal resolution, like MODIS, could be applied for the dynamic monitoring purposes in the arid areas.

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