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Geoinformatics and cartographic analysis, based on modeling and mapping of the microclimate and groundwater flow

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Abstract

The study of the groundwater resources and their properties are very important due to the vast desert areas and arid conditions. Given the current situation in Iran, the water supply is one of the most important territorial and environmental problems. In this study, groundwater resources were surveyed and mapped in Yazd Province and their properties were modeled to determine their effectiveness for grazing and agricultural activities. The main objective of this study was to develop and establish groundwater geoinformatics and cartographic monitoring of the meteorological data and groundwater formation. Also, the climatic characteristics were evaluated as determinants parameters of groundwater flow to measure its parameters variations. The thematic charts and geoinformatics maps were provided. Profile software was used for modeling microclimate and groundwater flow's parameters, like groundwater level and moisture transfer for several decades. Priznak model was used for comparison and multi-parameter analysis of specified profiles and their classification. Finally, different regions of Yazd Province were mapped and classified with different degrees of possibility for grazing and agricultural activities. Results showed that groundwater levels in the study territory are at depths ranging from 40 to 145 m. According to the results, it was observed that the changes in groundwater level and microclimate can be used to evaluate the land capability for grazing and agricultural activities.

Keywords: Yazd; Profile Software; Priznak; Groundwater; Modeling

1. Introduction

Geoinformatics is aimed at the development and application of methods and concepts of computer science for the study of spatial objects and phenomena. Spatial relationships in geoinformatics are considered as binding elements. Development of geoinformatics is achieved using creation of geoinformation monitoring as a research tool (Kapralov *et al*., 2004). Micro-watershed level planning requires a host of interrelated information to be generated and studied in relation to each other (Narmada *et al*., 2015). Knowledge of groundwater conditions is a prerequisite for integrated land and water management (Batelaana *et al.*, 2003). By combining both land resources with water resources using the GIS techniques, a composite map on the Resource Potential Zones (RPZ) can be created (Magesh *et al*., 2012; Narmada *et al*., 2015). Groundwater prospect zones were delineated through the integration of the reclassified raster map layers of geomorphology, slope percent, drainage buffer, geology, landuse/land cover and soil texture using the weighted overlay analysis in ArcGIS (Dinesan *et al*., 2015). A key output of groundwater resources study is useful information in developing targeted management to reduce

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aquifer depletion and degradation (Switzman *et al*., 2015.).

Using GIS and RS can study relationships between groundwater and its related hydrological factors to mapping the regional groundwater potential (Oha *et al.*, 2011). By combination of water balance and flow models, catchment turnover times and produce related maps can be calculate based on the groundwater discharge rates and flow parameters (Pacheco, 2015).

Formation of groundwater resources in Yazd Province has to be studied in order to clarify the prospects of using groundwater resources in the region, which result in infrastructure development in plains and mountain areas. At the current time the water supply is the most important issue in Iran, as the significantly low amount of precipitations below the world average are observed in desert, hot and dry areas. Desert lands occupy more than 50% of Yazd Province, and the low amount of annual precipitations have been reported (Negaresh and Fallahian, 2010). Based on the general statistics reports of the country, Yazd is designated as a point of low precipitations. Currently, limited water resources, reduction of aquifer levels and drought are the main problems of natural resources management in Yazd. In semi-arid and arid areas, groundwater and agricultural water use are two critical and closely interrelated hydrological processes (Tian *et al.*, 2015). The object of this study is to characterize groundwater dynamics and the factors affecting groundwater flow. Improving irrigation efficiency can increase groundwater levels and thus will follow the development of the agricultural industry (Berim Nezad and Paykani, 2004). Relevance and the practical importance of the microclimate and groundwater flow modeling in Yazd Province determined by necessity: 1) Territorial separation with different provision groundwater and comparative evaluation of possibilities for the development of animal husbandry, 2) Assess the resource potential of bio-components of the landscape. Understanding the distribution of groundwater levels and quantifying the contribution of groundwater to be important for managing and protecting the surface water resources (Cartwright and Gilfedder, 2015; Zarutsky and Krasilnikova, 1989). Variations in groundwater inflows are related to geology and topography. Hydrogeological mapping of groundwater resources is one of the main tools for the controlled development of groundwater resources. Remote sensing data with their synoptic view and repetitive coverage provide more meaningful information on terrain parameters such as geology, landforms, land use and soil condition and other physical parameters of the study area. Integrated remote sensing and GIS are widely used in groundwater mapping. Remotely sensed surface indicators of groundwater provide useful data where practical classical alternatives are not available (Fathy, 2012; Nobre *et al*., 2007). The nature of remote sensing-based groundwater exploration is to delineate all possible features connected with localization of groundwater (García-Gil *et al*., 2015; Vershinin *et al*., 2005). The produced groundwater maps can serve in land and groundwater development planning (Ozdemir, 2011).

The main aims of this study were to develop and establish groundwater geoinformatics, to characterize the factors affecting groundwater flow and modeling groundwater flow; and to evaluate the different water resources management via the modeling (Tian *et al.*, 2015).

2. Materials and Methods

2.1. The study area

The study area is the western half of Yazd Province in center of Iran, that is located in 29˚40'-33˚40' north latitude and 52˚52'-57˚50' east longitude (Fig. 1). Yazd is located in a belt of arid and semi-arid areas in the northern Hemisphere. The power of wind erosion is one of the most important factors changing the landforms of area. Yazd is one of the provinces with the lowest precipitation in Iran, since the average annual amount of precipitations is only 61.02 mm (Omidvar, 2006). Temperature seasonal and diurnal fluctuations are very high. The maximum temperature of Yazd province has been recorded in July about 45°C and the minimum temperature has been recorded in January about -20°C (Omidvar, 2006). Low amount of precipitations, high temperature variations, high evaporation rates and deep groundwater level define the unfavorable climatic conditions for plants communities' biomass. Most lands in the province are not suitable for agricultural activities due to the excessive amount of salt and alkaline minerals in area. Surface horizons of soils are salt and gypsum deposits. Based on the above factors the climate of the region is classified as arid and semi-arid area.

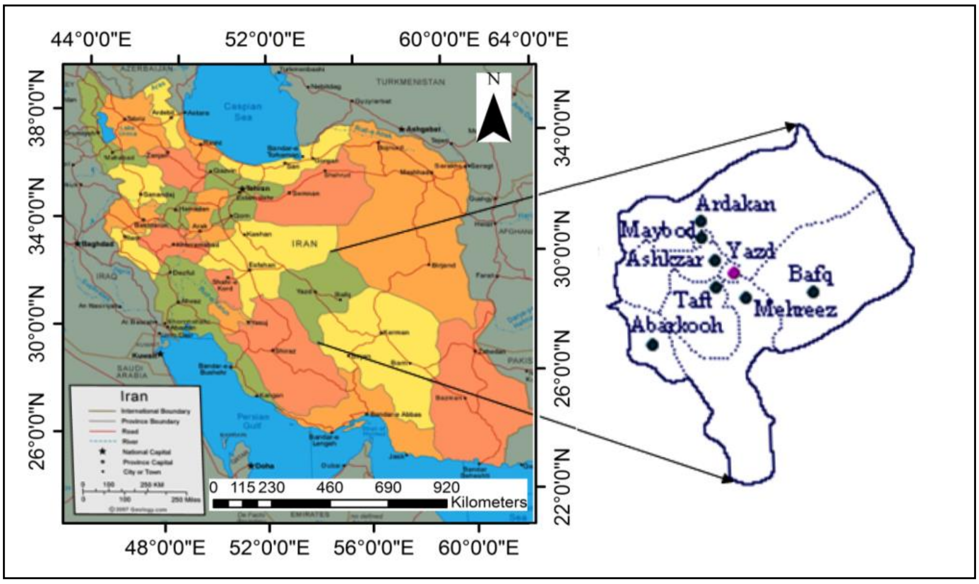

Fig.1. Location of Yazd province in Iran

2.2. Methodology

A topographic map of Iran with scale 1: 500,000 was used as a cartographic basis. After scanning topographic map, cartographic base and thematic layers were created in ArcGIS program. The required images were created using trapeziums H-39-A, H-39-B, H-40-A and H-40-B (Fig. 2).

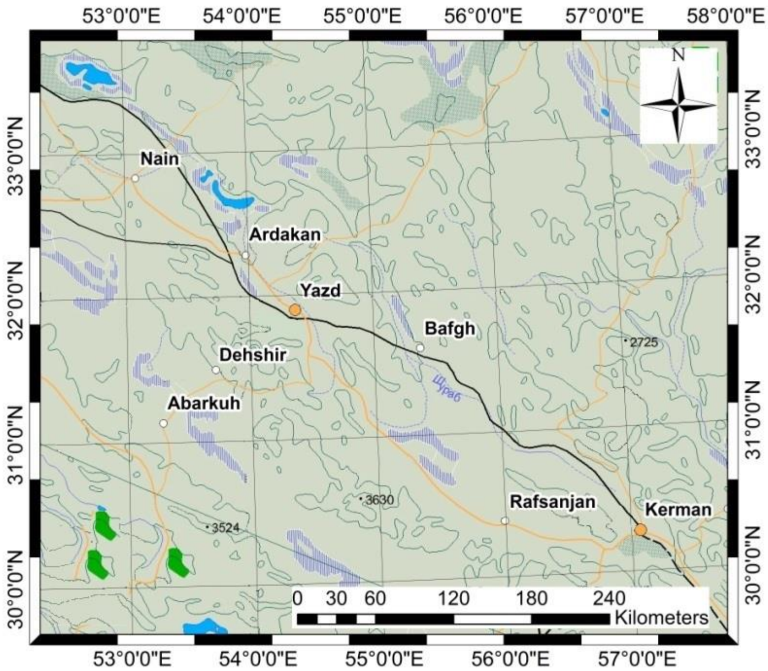

Fig. 2. Cartographic basis of modeled territory

In this study, monitoring of meteorological data and the groundwater formation were performed using a supported GIS. Meteorological database of observation stations in western half of Yazd Province was created, then thematic layers, including the characteristic profiles of groundwater flow models were performed in the ArcGIS environment. Data of the Yazd, Meybod, Ardakan, Mehriz, Ashkezar, Nadushan, Khezrabad, Chahafzal and Ebrahimabad meteorological stations were used to create a meteorological database. Necessary profiles for groundwater flow modeling were selected in the western half of Yazd Province, with mountainous, grazing and agricultural areas (Fig. 3) (Anderson *et al*., 2002).

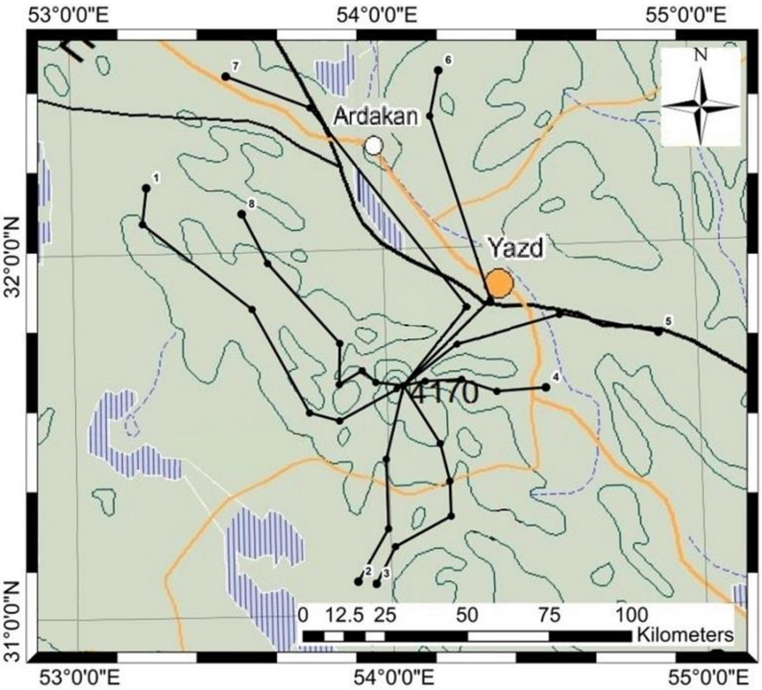

Fig. 3. Profiles of groundwater flow

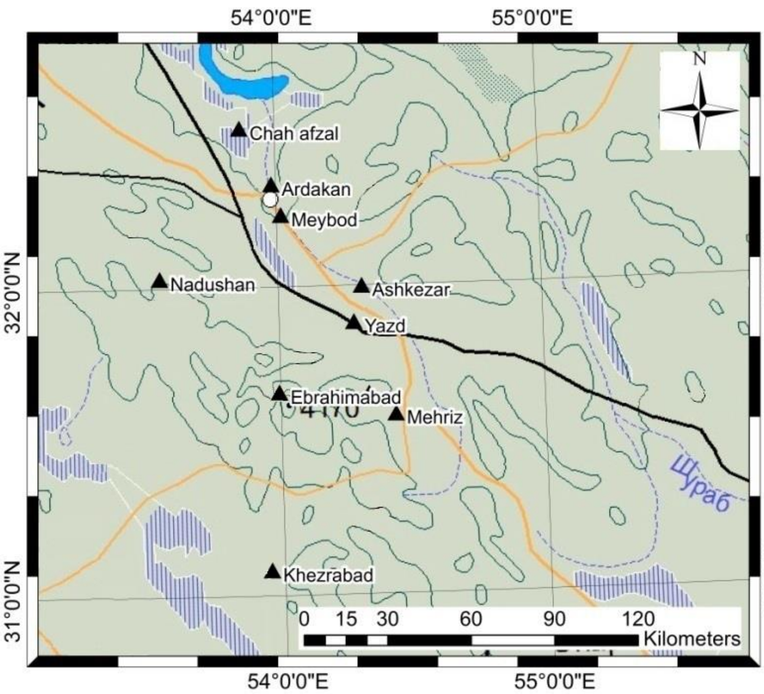

Fig. 4. Meteorological stations used in this study

As the surface flows are defined by topographical characteristics; therefore they have been used to select the profiles of groundwater flow. Also, remote sensing data including raster images resulting from infrared radiometry, NDVI and LST indices have been used (Kapralov and Konovalova, 1997; Kapralov *et al*., 2004). For this study, the eight profiles were selected in four directions (north, south, east and west) of study area, next to the existing meteorological stations (table 1). Profiles were different in moisture, evaporation, type of vegetation and land surface temperature.

Table 1. Profiles of groundwater flow

Number and length of profile	Number and length of section
1 (121.1 km)	1 (22.2 km)
	2 (94.3 km)
	3 (11.1 km)
	4 (36.0 km)
	5 (42.2 km)
2 (62.8 km)	1 (23.0 km)
	2 (21.2 km)
	3 (18.6 km)
3 (75.4 km)	1 (20.9 km)
	2 (11.8 km)
	3 (10.7 km)
	4 (19.3 km)
	5 (12.7 km)
4 (44.2 km)	1 (67.1 km)
	2 (11.2 km)
	3 (11.4 km)
	4 (15.0 km)
5 (83.8 km)	1 (20.6 km)
	2 (32.5 km)
	3 (30.7 km)
6 (11.0 km)	1 (37.2 km)
	2 (58.9 km)
	3 (14.1 km)
7 (135.3 km)	1 (30.8 km)
	2 (77.2 km)
	3 (27.3 km)
8 (84.4 km)	1 (8.5 km)
	2 (5.5 km)
	3 (8.2 km)
	4 (12.5 km)
	5 (32.8 km)
	6 (16.9 km)

Priznak software was used for statistical classification of area. This software was produced by specialists of Cartography and Geoinformatics Department of Saint Petersburg State University. Many parameters are inputs of Priznak software, such as soil moisture, NDVI, surface temperature, and solar radiation. Area classification is performed based on the mentioned parameters and their correlation analysis. Profile and Priznak models respectively were used for modeling of the microclimate and groundwater flow and comparison study on the hydrodynamic parameters of each profile. The profiles were investigated using four indicators of groundwater flow. The moisture storage values, ground water level, evaporation, and average surface temperature parameters in the second decade of July were compared together in initial and final sections of each profile. These parameters also have been used to establish similarity relations between the profiles, combine them into groups and rank these groups by moisture storage value and ground water level. The database tables created by the Profile software for each profile were used to sample data and create specific classification. This procedure was performed by transferring data from xls-tables into the Priznak model.

3. Results

The Profile model has been used to compare the groundwater level and moisture storage values of different profiles in July. It is observed that the southeastern parts of the studied area (profiles 2-4) are the less favorable areas for agricultural and grazing activities (Fig. 5 - 8; Table 2 and 3). Also, this condition is observed in salty lands of profile 7. The most suitable areas for grazing and agricultural activities are the northern and western parts of the study area (profiles 5, 6, 1 and 8). The obtained results of groundwater level modeling have been shown in figure 5 and 6.

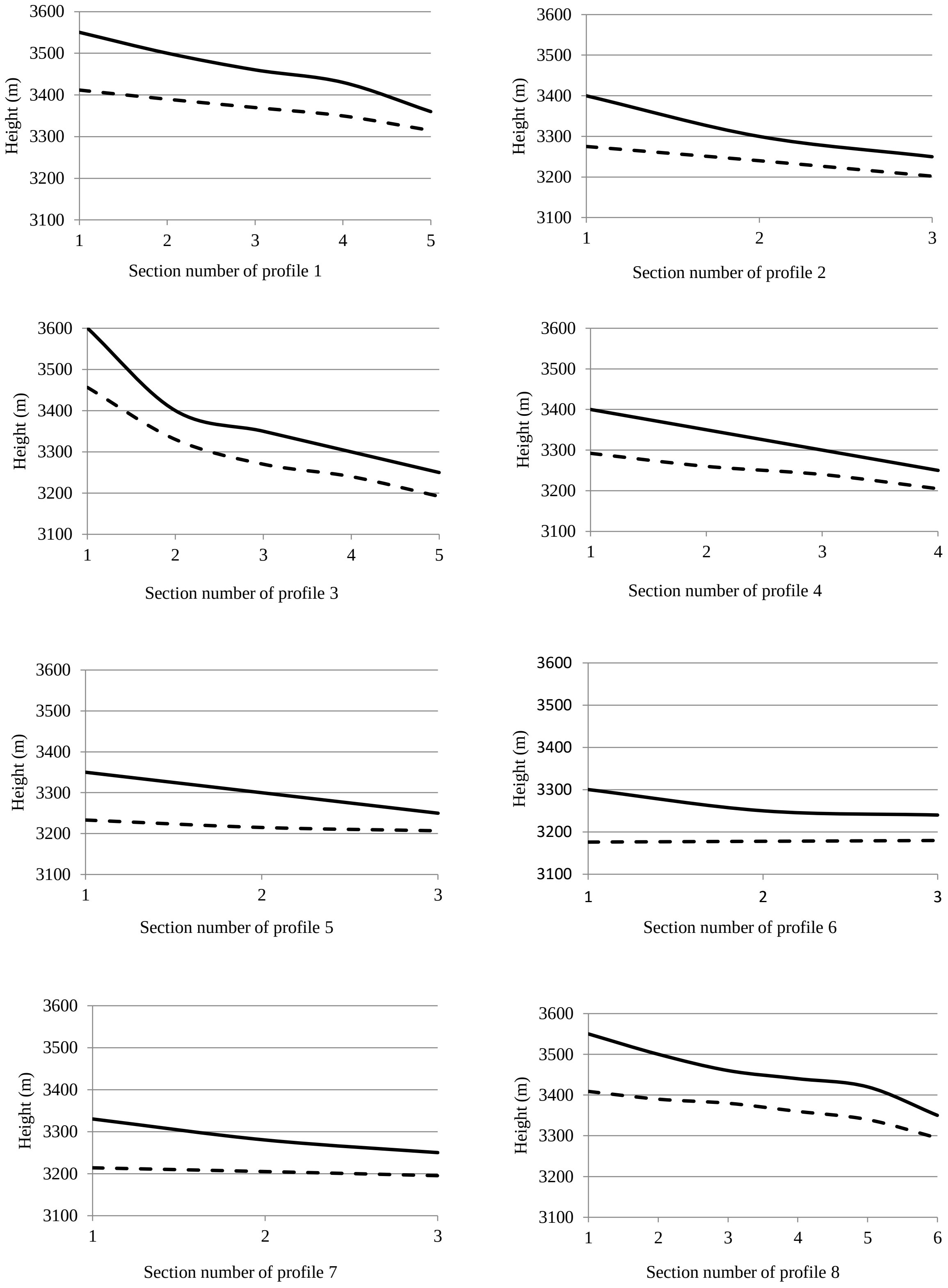

Fig. 5. Land surface and groundwater level of the profiles (——— Land surface (m), – – – Groundwater level (m))

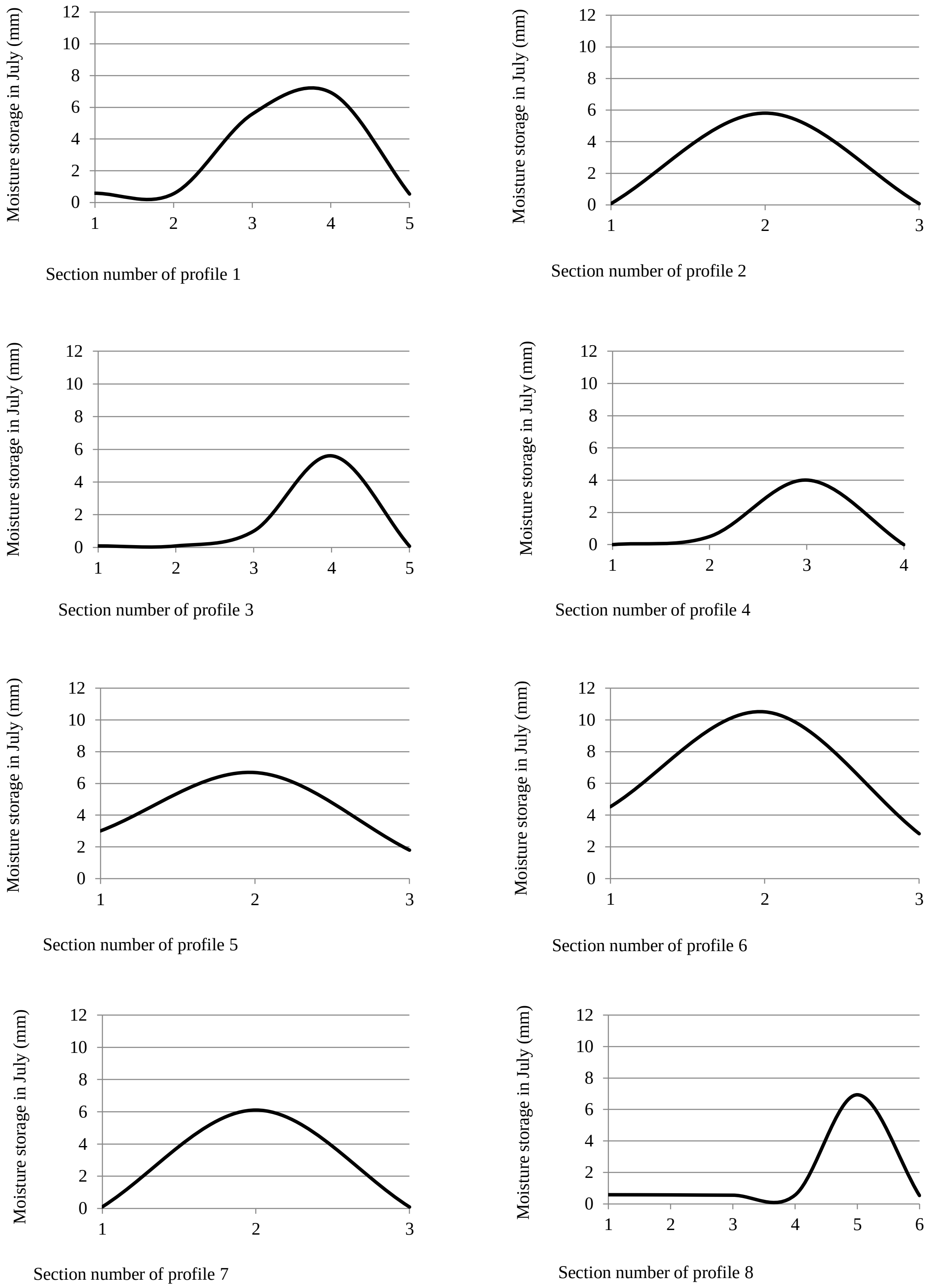

Fig. 6. Moisture storage values of the profiles (——— Moisture storage in July (mm))

Lands with higher moisture storage values and less depth of ground water level have a higher resource potential for grazing and agricultural activities. For obtaining the results of multi-comparison of the mapping objects, usually require additional analysis. In frequent cases separate class can be presented by a single object. Often two or more objects constitute a separate class and object classes intersect this means that the detected objects as belonging to one and to the other class (there is a transition class). In such cases, the mapping objects are ranked according to the most important sign.

Data obtained by the Profile software for each profile, created specific classification and transferring data from xls-tables into the Priznak model used for multi criteria analysis have been described in tables 2 and 3.These data were transferred to the final tables in ArcGIS to build the respective layers of maps.

Table 2. Data of initial sections for comparative analysis of profiles

Profile number	Moisture storage (mm)	Bedding depth of ground waters (m)	Pasture and agricultural conditions
6	2.82	60	Most favorable
5	1.80	43	
1	0.54	45	Slightly favorable
8	0.54	55	
7	0.09	55	Not favorable
2	0.08	48	
3	0.07	58	
4	0	45	

Table 3. Data of final sections for comparative analysis of profiles

Profile number	Moisture storage (mm)	Bedding depth of ground waters (m)	Pasture and agricultural conditions
6	4.52	124	Most favorable
5	3.01	117	Favorable
1	0.59	138	Slightly favorable
8	0.59	141	
7	0.1	116	Not favorable
2	0.09	125	
3	0.09	144	
4	0	108	

The similarities of initial sections in each profile were analyzed to classify them into 2 groups:

Group 1: profiles 5 and 6, group 2: profiles 1, 2, 3, 4, 7 and 8. The second group, isolated on the 4 indicators includes initial sections of the profiles 1 and 8, which are substantially differed with initial sections of the profiles 7, 2, 3 and 4 by moisture storage. Based on the moisture storage values the second group were divided into two subgroups comprising respectively initial sections of the profiles 1, 8 and 7, 2, 3, 4 (Fig. 7).

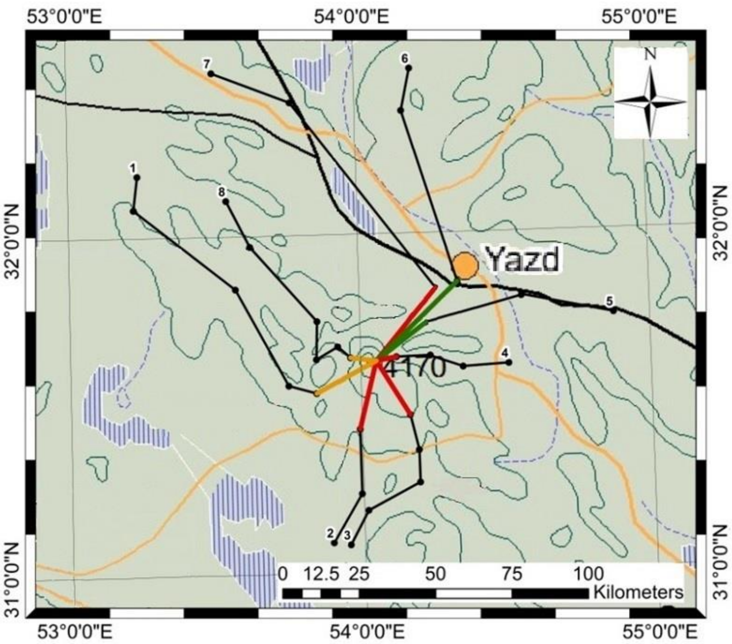

Fig. 7. Classification of initial sections of profiles

Colors reflected pasture and agricultural conditions: green - the most favorable, light orange - slightly favorable, red not favorable (Fig. 7). The final sections of each profile were analyzed based on their similarities to classify them into 5 groups including group 1: profile 6, group 2: profile 5, group 3 (intermediate): profiles 1 and 8, group 4: profiles 7 and 3, group 5: profiles 2 and 4. The final sections of the profiles 7, 2, 3 and 4 have moisture storage values close to zero; therefore, they were combined into a single group.

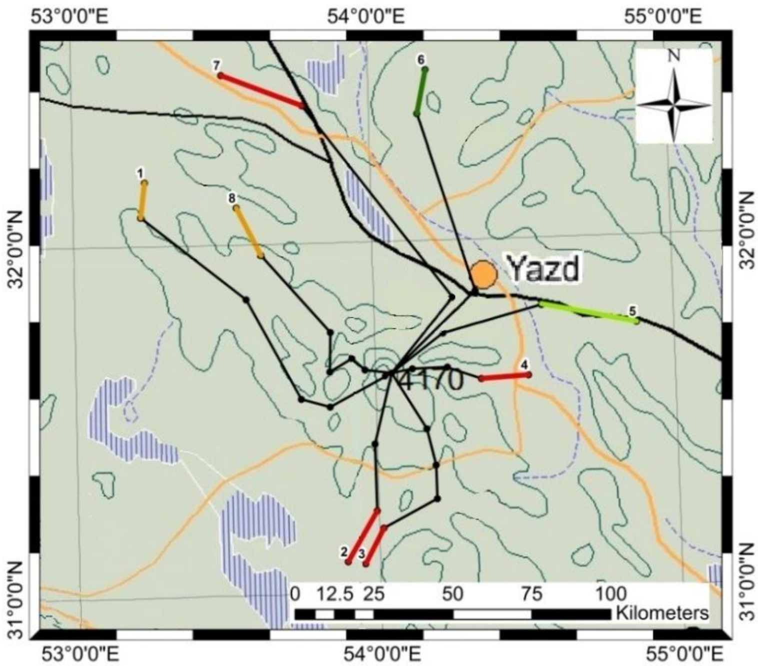

Fig. 8. The final sections of profiles

Colors reflected pasture and agricultural conditions: green - the most favorable, lime green - favorable, light orange - slightly favorable, red not favorable (Fig. 8).

4. Discussion and Conclusions

The occurrence and movement of groundwater in an area is largely controlled by rainfall, and the characteristics of the terrain features like landforms, geology, soil, drainage, topography, landuse/ land cover, etc (Narmada, 2015). The study demonstrated the utility of RS and GIS technique in modeling and mapping of the microclimate and groundwater flow prospect zones for a geographical area of non-uniform terrain features (Dinesan et al., 2015; Fathy, 2012; Ozdemir, 2011). Lands with higher moisture storage values and less depth of groundwater level have a higher resource potential for grazing and agricultural activities. The results showed that southeastern parts of the studied area are the less favorable areas for agricultural and grazing activities, which can be due to salty land. The northern and western parts of the study area are the most suitable areas for agricultural activities that this is the result of more dense vegetation and more balanced temperature of these borders. The study results help managers to design regional stability system. Study of the effect of improving the irrigation efficiency on the increasing groundwater level in the agricultural sector by Berim Nejad and Paykani (2004) represents the effect of applying the system of irrigation engineering on the groundwater situation. This study demonstrated the applicability of the new model to the water resources management in arid and semi-arid areas. Groundwater resources management and assessment of agricultural potential in the region were evaluated via the modeling, as also were performed in other studies and similar results were obtained (Tian *et al.*, 2015). The results show that extremist use and without management of groundwater recourses, would lead to acceleration of the groundwater depletion, and therefore introduce ecological problems in the region.

According to the results, it was observed that study of the groundwater flow and microclimate changes is necessary to evaluate lands for grazing and agricultural activities in different conditions, especially in arid and semi-arid areas. Study and management of groundwater can also improve irrigation efficiency, because can increase the groundwater level in a long time and thus will follow the development of the agricultural industry. According to the results, localization of groundwater and modeling their levels are important for managing the surface water resources. Mapping of groundwater resources is one of the main tools for the controlled development of groundwater resources.

Based on the analysis of initial data, which were used to solve the problems of modeling and interpretation in this study, it was considered that Profile and Priznak models are suitable to study the microclimate and groundwater flow, mapping agricultural potential areas. Fresh water was not observed in the mapping territory, except temporary streams formed during rain floods. Also, iced water was not observed in the surface horizons of soils, while they are frozen due to negative night temperatures in winter. Groundwater levels were observed at depths ranging from 40 to 145 m in the study territory, and it can significantly reduce access to fresh water, even by constructing aqueduct. Based on the results, the studied area is generally not favorable for grazing and agricultural activities and seems to be unpromising.

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