Assessment of groundwater levels and mineralization in irrigated areas using geographic information systems (a case study of Buvayda district)

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Abstract. Today, there is an increase in the level of underground water and an increase in mineralization in irrigated areas. These situations have a negative impact on the agro-economic development of countries engaged in irrigated agriculture. The increase in the level of underground water and the increase in mineralization cause the acceleration of the salinization process in the irrigated areas. This, in turn, leads to the loss of soil fertility and the problem of food shortage. During the 12 months of 2023, changes in the level and mineralization of underground water in irrigated fields of Buvayda district of Fergana region were evaluated. Traditional methods and GIS technologies were used to analyze the obtained results. The results of the study show that the average monthly values of the groundwater level in the district are 2.05 m and 2.27 m in April and July, respectively, and 2.38 m in October. The mineralization level of the groundwater changed during the months as follows: it showed 2.06 g/l in April, 2.10 g/l in July and 2.18 g/l in October.

1 Introduction

Maintaining the level and level of mineralization of underground water in the full implementation of irrigated agriculture is important to ensure the correct water and salt balance in the plant root zone. Otherwise, salts, which are one of the main factors limiting agricultural production, lead to a limitation of water absorption by plants and a proportional increase of sodium ion compared to other cations. Thus, it leads to the deterioration of soil physical properties, low hydraulic conductivity, and a decrease in infiltration rate due to the breakdown of clay colloids. As a result, the groundwater in the soil increases, where the conductivity decreases and the risk of salinization increases [1]. About 50 percent (954 million ha) of irrigated agriculture in arid and semi-arid regions have experienced varying degrees of salinity problems [2].

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The increase in irrigated land areas and their dependence on groundwater causes severe stress on groundwater resources, which leads to a decrease in groundwater levels [3], [4], [5]. Developing a strategy for sustainable management of underground water resources is one of the most pressing issues today. At this point, it is important to understand the changes in the groundwater level in connection with natural or artificial groundwater recharge, separation in space and time. Spatial and temporal changes in groundwater levels have been studied by many researchers. Scientists such as Finke, Ahmadi, and Sedghamiz used the Kriging interpolation method to map groundwater levels to identify critical areas [6], [7], [16], [17]. Also, geostatistical analysis methods are a good tool for water resources management and provide effective results for determining long-term trends of groundwater [8]. Statistical methods of trend analysis vary from simple linear regression to more advanced parametric and non-parametric methods [9]. Many researchers have studied precipitation and temperature trend analysis [10], [11], and few studies have been conducted for groundwater level trend analysis. Several researchers have attempted to study trend analysis using statistical methods to analyze groundwater levels [12], [13], [15-23]. In this study, an analysis of the level and level of mineralization of groundwater in the irrigated lands of Buvaida district of Fergana region for 2023 was carried out. Analyzes are performed before irrigation (April), during irrigation (July) and after irrigation (October). Geographic information technologies and geostatistical analysis methods were used in this work.

2 Analysis of literature on the topic

G.A. analyzed issues of the level and level of mineralization of underground water in space and time. Mavlyanov, M.M. Krylov, N.A. Kenesarin, A.A. Khudayberdiev, N.N. Khodjibaev, S.M. Mirzaev, E.I. Chembarisov, G.U. Yusupov, R.A. Kulmatov. The research works of Djumanov and others are devoted. In these research works, changes in the regime of groundwater level and mineralization level over the years were studied depending on the environment and certain recommendations were given. Observations in the presented research work were made based on the data of the year 2023.

3 Research meteodology

The territory of Buvayda district is located north of the city of Kokand. Buvayda district borders Bagdad, Uchkoprik, Dangara, Altiariq districts of the region, Pop district of Namangan region. The area is 0.28 thousand km2 (Fig. 1).

The terrain of Buvayda district is mostly flat. The climate is continental. The average temperature in January is 2.3 °C, in July it is 27.5 °C. Annual rainfall is 120-130 mm. The vegetation period is 218 days. Strong winds blow in spring and autumn. Clay, sandy, irrigated grassland soils are widespread.

The data was obtained from the reclamation expedition of the Fergana region of the Ministry of Water Management of the Republic of Uzbekistan and statistically analyzed for 12 months of 2023 using the MS-Excel program. Second, the data was imported into ArcGIS software, and the Inverse Weighted Distance (IDW) interpolation method was used to estimate the attribute values of locations within the available data range using known data values. To determine the level and mineralization of underground water, samples were taken from 115 monitoring wells.

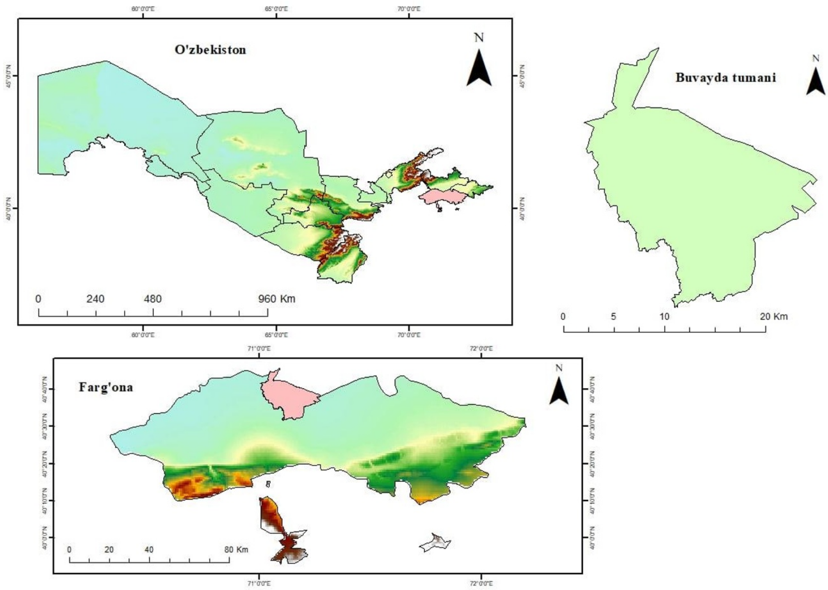

Fig. 1. Geographical location of the study area

4 IDW interpolation method

In this method, the value of a variable at a point not selected from neighboring points is estimated using a relation. In this method, weights are determined based on the distance from each known point to the unknown point and regardless of how the points are distributed around the estimated point. As a result, closer points are given more weight and farther points are given less weight. In fact, the shorter the distance, the greater the effect. This method assigns a weight to each of the measured samples to estimate the unknown point.

$$Z^* = \sum_{i=1}^{n} \lambda_i \cdot Z\ (x_i)$$

$$\lambda_i = \frac{1}{h_i^n}$$

Here $Z*$ is the estimated value of the spatial variable, $Z\ (xi)$ is the observed spatial variable at the point, li is the statistical weight assigned to the sample xi and the importance of the i-point estimate, h is the distance between the points xi and the variable is the estimated point, and n is the distance power.

5 Results and discussion

5.1 Statistical analysis of groundwater level and mineralization

In irrigated lands, groundwater was located close to the soil surface, with an average depth of 2.0 m and a depth of 2.5 m. Average monthly values of groundwater level are 2.05 m and 2.27 m in April and July, respectively, and 2.38 m in October (Table 1). The largest difference between the minimum and maximum values of the groundwater level was observed in October up to 3.24 meters. The minimum values of the groundwater level were in April (1.35

m) and 1.53 m in July, and 1.61 m in October. Naturally, if we take into account that irrigation practices are carried out regularly during the initial observation periods (April and July), the indicators will be almost the same. However, in October, after the end of the growing season, the seepage water is 4.85 meters below the surface. The suspension of irrigation in October caused the groundwater level to drop to 3.24 meters compared to the irrigation period.

Table 1. Average values of groundwater level and mineralization

Parameters	Goundwater level, m.			Groundwater mineralization, g/l		
	April	July	October	April	July	October
Average	2.05	2.27	2.38	2.06	2.10	2.18
St.dev	0.41	0.41	0.49	0.68	0.86	0.76
Maximum	4.40	4.40	4.85	4.83	4.61	5.30
Minimum	1.35	1.53	1.61	0.69	0.71	0.54
Fluctuation	3.05	2.87	3.24	4.14	3.90	4.76
N	115	115	115	115	115	115

The average values of the level of mineralization of underground water have the following fluctuations in months: in April (2.06 g/l), July (2.10 g/l) and October (2.18 g/l). The lowest level of mineralization was 0.68 g/l observed in April, and the highest was 5.30 g/l in October. This trend can be justified by the large-scale implementation of rainfall and soil washing activities in April, salt balance and high temperature of water supplied for irrigation in October.[18-23]

5.2 Assessment of groundwater level and mineralization changes using GIS

A Geoinformation System (GIS) was used to assess the spatiotemporal dynamics of groundwater levels and mineralization in irrigated areas. GIS can be used in many fields, especially in this research work, because it is a time-saving and efficient method to create spatio-temporal maps of groundwater levels and mineralization.

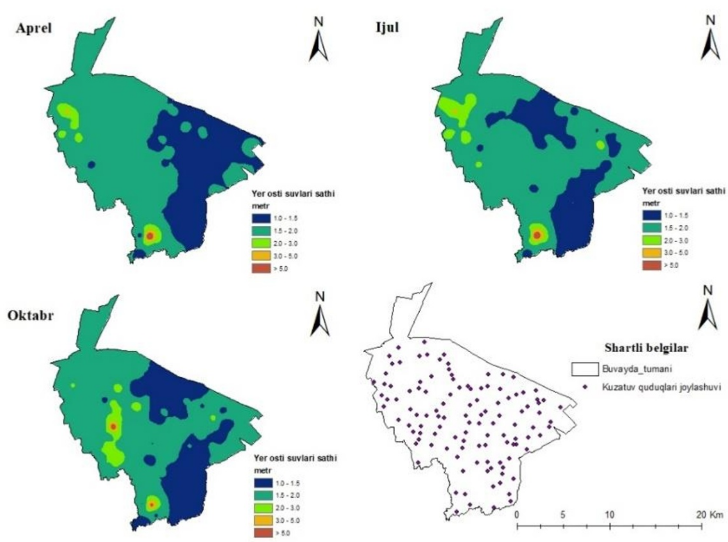

Fig. 2. Groundwater level dynamics

Regarding Figure 2, created by the IDW interpolation method, the areas with groundwater levels of 1-1.5 m, 1.5-2 m, and 2-3 m attract attention. Areas with groundwater levels of 0–1 m were recorded in very small areas in 2023, while areas with 3–5 m were observed mainly during the last month of April. But this increase has small values.

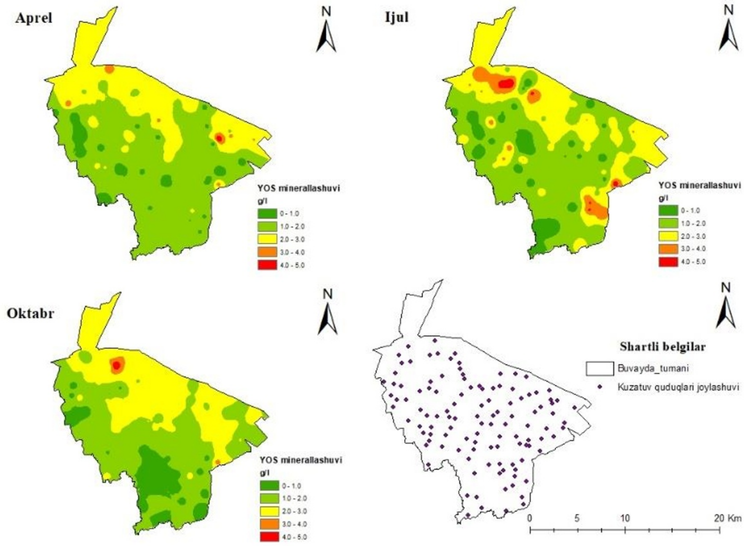

Fig. 3. Dynamics of groundwater mineralization

No irrigated areas with mineralization of 5 - 10 g/l were identified during the inspection period. However, the map shows regions with mineralization of 1-2 g/l and 2-4 g/l (Fig. 3). In July, in the north-western and eastern parts of the district, areas with a level of mineralization of underground water up to 4-5 g/l were observed. The reason for this is the salt balance of the irrigation water used for irrigation and the intensity of the evaporation process under the influence of high air temperature. In October, i.e. after the end of irrigation, the irrigated lands with mineralization of underground water of 1-3 g/l occupied large areas.

6 Conclusions

Groundwater level and mineralization analysis studies are important for understanding one of the main sources of secondary soil salinization, a major cause of irrigated land degradation. In this case, using statistical analysis tools to detect changes and GIS software to map the results is very useful. This study is aimed at analyzing the changes in the groundwater level between January and December 2023 using geostatistical methods for 115 observation wells located in the Buvayda district of the Fergana region. Spatial analysis using the Inverse Distance Weighting (IDW) method facilitated estimation of unknown points based on known ones. The study successfully identified fluctuations in groundwater levels, with model results closely matching observed data. In addition, assessment errors have provided insights into optimal placement of new observation wells, minimizing uncertainties. The groundwater level is 1.5 m below the indicated depth, mainly due to salt washing operations; near the land surface in April. In July and October, the groundwater level did not exceed the critical depth. Average monthly values of groundwater level are 2.05 m and 2.27 m in April and July, respectively, and 2.38 m in October. The level of mineralization of groundwater varied over the months as follows: 2.06 g/l in April, 2.10 g/l in July and 2.18 g/l in October.

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