DOI: 10.35595/2414-9179-2020-3-26-229-239

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ASSESSMENT OF THE RECLAMATION CONDITIONS OF IRRIGATED AREAS BY GEOSPATIAL ANALYSIS AND RECOMMENDATIONS FOR THEIR IMPROVEMENT

ABSTRACT

This research focuses on determination of irrigation — drainage networks conditions, salinity of irrigated areas in Shavat district of Khorezm region (Uzbekistan) by geospatial analysis and giving recommendations for their elimination. Additionally, obtaining monthly ground truth data from observation wells and interpolate them with IDW interpolation algorithm methods of Geographic Information Systems (GIS) technologies in order to monitoring changes of groundwater level and mineralization in vegetation period of main agricultural crops are highlighted. Besides that, by using remote sensing technologies, the obtained data about the irrigation regime was determined in agricultural areas. As a result of the usage of GIS and RS methods, there have been created thematic maps on analysing salinity of soils, the actual condition of irrigation and collector of networks, actual level and mineralization of groundwater as well as their dynamic changes. On the basis of the obtained results, there have been given recommendations for improving the conditions of ameliorative arable lands on keeping the level of groundwater at a specified depth and cultivation of agricultural crops in periods of water scarcity.

KEYWORDS: irrigation, drainage networks, irrigated area, geospatial analysis, remote sensing

INTRODUCTION

Salinization of soil is one of the major land degradation types and it has greatly influence sustainable agricultural development [*Guan et al.,* 2001]. In the Strategy of Actions on five priority areas of development of the Republic of Uzbekistan for 2017−2021, approved by Presidential Decree of Uzbekistan, dated February 7, 2017 No PD-4947, there have been paid a special attention for further improvement of the reclamation conditions of irrigated lands, the development of reclamation and irrigation facilities, along with the widespread introduction of intensive irrigation methods, primarily improving the reclamation conditions of irrigated lands (Decree of the President of the Republic of Uzbekistan, 2017, No PD-4947).

According to the Resolution of the President of the Republic of Uzbekistan, dated November 27, 2017, No PQ -3405 "State Program of irrigation development and improvement of irrigated lands reclamation status for 2018−2019", for further improvement of melioration conditions of irrigated lands were suggested as one of the main tasks (Decree of the President of the Republic of Uzbekistan, 2017, No PD-3405].

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Undeniably, the study on the reclamation conditions of irrigated lands plays an important role along with the efficient usage from available water resources and obtaining high-quality crop production in Uzbekistan (Annual report of Shavat regional department of water management, irrigation and drainage expedition, 2017−2018).

Currently, the irrigation network operates uninterruptedly throughout the year as a result of the use of the cotton-winter wheat rotation system. The load on the collector-drainage networks has significantly increased. In its turn, all these have affected the ameliorative state of soil, as well as the process of irrigation and collector-drainage networks. The use of irrigation and collector-drainage networks at the required level and the provision of recommendations based on modern technologies and traditional knowledge on the elimination of water shortages are one of the actual tasks of today. Advantages of GIS application gives opportunities on the advanced analysis and promising directions in irrigated agriculture and melioration issues [*Pron'ko et al.,* 2013].

Study Area

Khorezm region is located in the north-west of Uzbekistan and occupies the part of the ancient irrigated lands on the left bank of the lower Amudarya River. The territory of Khorezm region is bordered by the north-eastern part of the Amudarya River and the Republic of Karakalpakstan, to the south and south-west by the deserts of Karakum and Kyzylkum. Khorezm region is located in the desert area. Climate conditions of Khorezm oasis are rapidly changing and distinctive, and it significantly differs from other regions of the Republic (Annual reports of the Left Bank Amudarya Basin Administration of Irrigation Systems, 2017−2018).

The average temperature in Khorezm region is +12,9 °C. It is cold including all winter months. According to the information from Urgench Observation Centre, the average temperature in January is -14.3 °C, and the average temperature in June is +27,4 °C. The climate of the region is influenced by warm airflow from the Kyzylkum sands from one side and water regime of the Amudarya River on the other side.

Late spring frosts are a major threat to the cultivation of agricultural crops. The most effective part of temperature will be later, at the end of March and beginning of April, the temperature will not exceed +10−15 °C. Then these temperatures will rise sharply, resulting in a temperature of 2660−2780 °C during the growing season, with a warm period of 201−208 days.

The climate of Khorezm region is sharply continental with long and hot summers, the autumn is relatively warm, the winter is short, dry-cold, and the winter is virtually frost-free. In a year 100−150 mm of precipitation is very low. Most of the precipitation falls in spring. The precipitation does not play a major role in providing ground water. Annual evaporation of water in the area is about 1000−1200 mm, which is 8−10 times more than the amount of precipitation. (Annual reports of the Left Bank Amudarya Basin Administration of Irrigation Systems, 2017−2018).

The average annual air temperature was +12.9 °C in 2019. The average annual relative humidity was 53.0 %. The average annual wind speed was 3.1 m/s and annual precipitation was 125.3 mm (Annual reports of the Left Bank Amudarya Basin Administration of Irrigation Systems, 2017−2018).

In Khorezm, it is determined by providing natural and groundwater irrigation, irrigation and evaporation costs as well as drainage flows. The natural groundwater flow is in the north-west at a very low slope (0,00025−0,00027). Groundwater leakage occurs mainly on alluvial sands with a velocity of 3−8 m/day.

Many scientists, including [*Beysenbaev et al.*, 1993; *Isabaev et al.*, 1991; *Khamidov et al.*, 1993; *Mirzadjanov et al.*, 1993; *Matyakubov*, 2001; *Rakhimbaev et al.*, 1980; *Faures et al.,* 2007; *Irmak et al.*, 2011] and others have carried out research work for studying the reclamation state of irrigated lands and developing measures to improve in the conditions of Khorezm oasis.

Based on the recommendations, developed by the above-mentioned scientists and using data from their research results, the objective of the study is to apply GIS and RS technologies for assessing the level of soil salinity in irrigated areas, drainage systems and conditions of crop types in Shavat district of Khorezm region.

It is worth mentioning that based on the objectives of the study, the necessary information about irrigated lands of the district was collected and analysed. Particularly, the distribution of mechanical composition of the soil in Shavat district (table 1).

The area of irrigated lands in Shavat district of Khorezm region is 28,931 ha, out of which 24,484.6 ha have been determined by the mechanical arrangement of soils by installing pits (wells). This is 85 % of the irrigated area in the district.

Table 1. Information on mechanical composition of the soils in irrigated lands in Shavat district of Khorezm region

No	Name of massive	Mechanical Composition					Total
		Sandy	Loamy	Lightweight	Medium	Heavy	
1	Beruni	0	0	402	1009	348	1759
2	O. Khidirov	0	104.6	309.44	908.96	344	1667
3	K. Rakhimov	0	100	602	1002	248	1952
4	Gulistan	0	82	276	1389	210	1957
5	Bustan	75.1	1306	21.4	167.5	0	1570
6	Shavat don	125.4	413.5	75.1	0	0	614
7	Inak Hovli	25.6	0	0	374.4	0	400
8	Friendship	38	0	234.1	1162.7	371	1805.8
9	K. Otaniyazov	0	209	239.1	363.4	1008	1819.5
10	Mehnatabad	0	225.8	488.3	1052.1	402	2168.2
11	Makhtumkuli	0	459.4	275.5	1598.4	97.7	2431
12	Sakhibkar	0	148.8	751.6	367.6	0	1268
13	Rizq	130	175	0	0	0	305
14	Uzbekistan	0	0	154.8	952.6	608	1715.4
15	Khorezm	0	0		1038.8	590	1628.8
16	Shavat	0	963.1	139.4	174.4	123	1399.9
17	“Oydin yordamchi” farm	0	0	10	0	0	10
18	Other plants	0	0	0	5	0	5
19	Sweet rent	0	0	0	0	4	4
20	Bogi Bustan	0	0		0	5	5
By district:		**394.1**	**4187.2**	**3978.74**	**11565.86**	**4358.7**	**24484.6**

Map of the massives location in Shavat district of Khorezm region is presented in fig. 1, by which it was examined the operation of irrigation and collector-drainage networks.

Proper implementation of agro-reclamation activities is directly related to improvement of land reclamation, increase of soil fertility and mainly leaching. For this reason, according to the mechanical composition of the soils and level of salinity in the region, the leaching rate and the exact terms of activities have been developed.

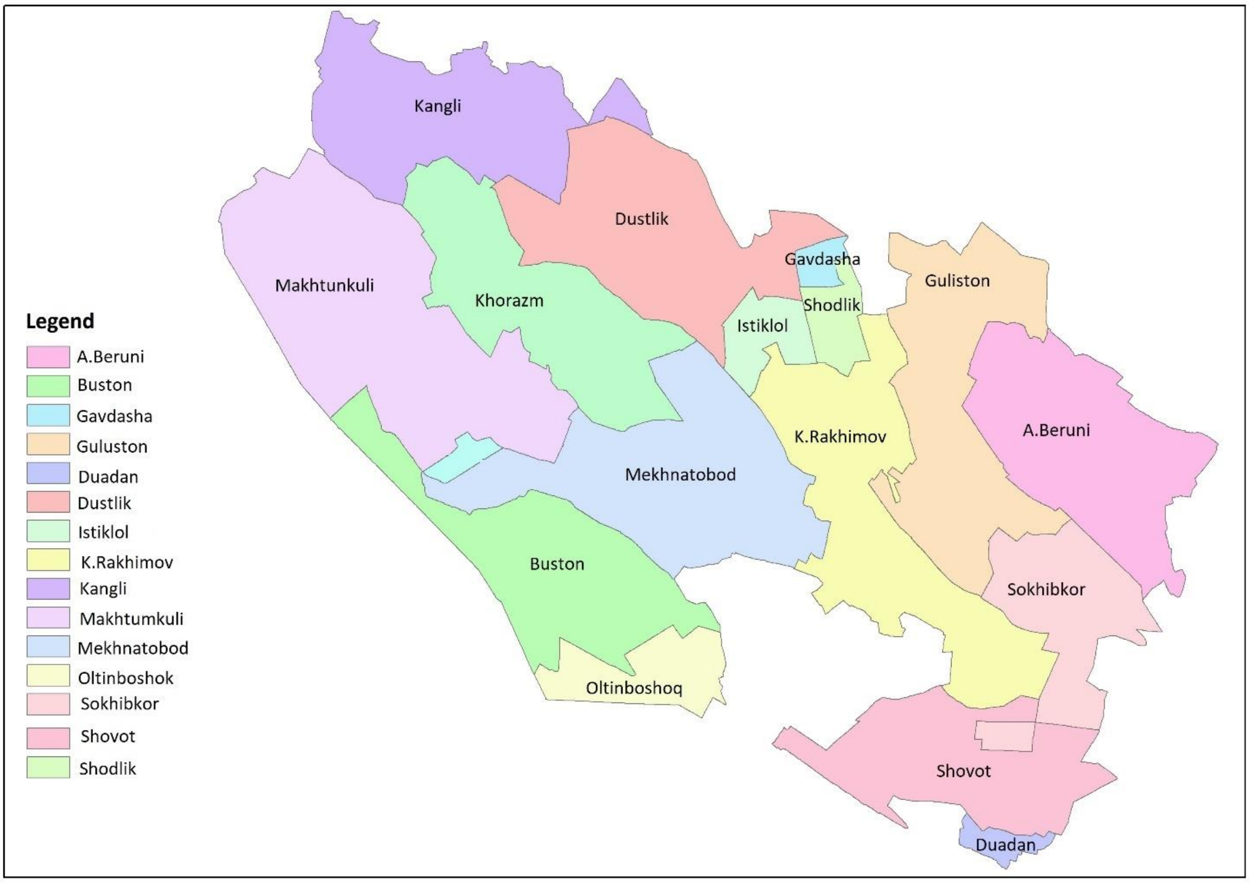

Fig. 1. Massives location in Shavat district

It should be noted that the agro-ameliorative measures undertaken do not take into account the fact that the soil sheets are composed of different constituents, because the mechanical composition of the upper soil layers is the same, but the lower parts of the soil can have different mechanical properties. This does not affect the soil profile. In order to wash salts of this kind, leaching rate must be increased by 25–30 % (multi-layered soils).

Leaching the soil is performed during the first ten days of November, while the soil and irrigation water are not sufficiently cool. It is during this period that the salts in the soils are much more comfortable to melt and they can be easily leached from the soil profile.

The key indicator contributing to the deterioration of soil reclamation and reduced productivity is soil salinity level. This is 68.9 % or 149 611.4 ha in the Khorezm region. In particular, salinity of irrigated soils in Shavat district of Khorezm region is 75. 5% (18 159.0 ha). Table 2 shows the regional salinity levels of different soils.

In the region types of soil salinity is chloride-sulphate and sometimes chloride-type. In general, the irrigated area in the region is considered to be unsatisfactory land reclamation (table 2). The saline free soils are 67 565.7 ha of irrigated land, which is 31.1 % of the irrigated area.

The average saline soils are distributed in all districts of the region, accounting for 23.7 % (5 712.6 ha) in Shavat district. Strong and highly saline soils are 12.5 % (3 006.1 ha) in Shavat district, and their soils are poorly reclaimed (table 2).

Table 2. Information on the level of salinization of irrigated lands in the districts of Khorezm region

No	Name of massive	Irri-gated area, ha	The level of salinity										Saline lands	
			not salinized		weak		average		strong		very strong			
			ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1	Bagot	17717	7384,7	41,7	6301,2	35,6	2718,2	15,3	867,5	4,9	445,4	2,5	10332,3	58,3
2	Gurlen	26051,7	11426,8	43,9	9018,5	34,6	4241,4	16,3	640,1	2,5	724,9	2,7	14624,9	56,1
3	Kushkupir	25215	7089,7	28,1	7311,9	29	6301,3	25	1850,0	7,3	266,1	10,6	18125,3	71,9
4	Khiva	14735	8217,8	55,8	4490,4	30,5	1430,3	9,7	256,4	1,7	340,1	2,3	6517,2	44,2
5	Yangiarik	14293	7738,2	54,1	4644,6	32,5	1547,3	10,8	135,6	0,9	227,3	1,7	6554,8	45,9
6	Shavat	24056	5897	24,5	9440,3	39,2	5712,6	23,7	1430,4	5,9	1575,7	6,7	18159	75,5
7	Hazarasp	27515,8	10975,3	39,9	11577,8	42,1	3222,2	11,7	478,4	1,7	1262,1	4,6	16540,5	60,1
8	Urgench	23776	8639,8	36,3	8182,7	34,4	4160,1	17,5	1589,7	6,7	1203,7	5,1	15136,2	63,7
9	Yangibazar	20477	174,4	0,9	6268,7	30,6	7434,6	36,3	3907,1	19,1	2692,2	13,1	20302,6	99,1
10	Khonka	23334,8	22,0	0,1	7941,2	34	12574,1	53,9	1701,1	7,3	1096,4	4,7	23312,8	99,9
Total		**217171**	**67565,7**	**31,1**	**75177,2**	**34,6**	**49342,1**	**22,7**	**12856,4**	**5,9**	**12230,1**	**5,7**	**149605,8**	**68,9**

MATERIALS AND METHODS OF RESEARCHES

The research was carried out on the geospatial analysis of reclamation condition of irrigated lands in Shavat district with the use of GIS and RS technologies. In addition, there have been analysed of irrigation and collector-drainage systems, the mechanical composition and salinity level of soils as well as water availability of the district.

Workflow of this research is carried out by the following methods:

1. Creating an actual database of irrigation and collector-drainage networks and existing observation wells in the area;

2. Obtaining monthly data on groundwater level changes and mineralization from observation wells in the district;

3. Creating a zonal map in order to showing the mineralization of groundwater in the region using IDW (Inverse Distance weighing) interpolation algorithm of ArcGIS10.5. IDW basically depends on two assumptions: 1) the unknown value of a point is influenced more by nearby control points than by those farther away, and 2) the degree of influence (weight) of points on each other is directly proportional to the inverse of the distance between the points raised to a power 6 and can be represented by the following equation [*Bartier et al.*, 1996];

4. Extracting areas with mineralized content of water more than 2 g/l;

5. Creating a zonal map in order to categorize area of ground water distributed;

6. Detecting and extracting areas with groundwater depths above than 180 cm;

7. Conducting RS in terms of assessing the current irrigation and collector-drainage networks and to identify crop types in the district.

Application of Methodology

Utilizing the above methodology, the following were carried out in Shavot district:

- a map of the existing irrigation and collector-drainage networks in Shavat district was created using GIS technology based on base maps;
- a mechanical composition of the soil was determined by massive in the pilot area (Sokhibkor massive) (Annual report of Shavat regional department of water management, irrigation and drainage expedition, 2017−2018);
- groundwater level and mineralization data from overall 205 monitoring wells was analysed and mapped using IDW interpolation method of GIS technologies in the

vegetation period of the year (2017−2018);
- a map of groundwater mineralization over 2 g/l has been mapped and map was validated to soil salinization ground trough data of Sokhibkor massive;
- operational regime of irrigation and collector-drainage networks were monitored assessed by remotely sensing method. For remotely analysis, multispectral images of the Sentinel-2 were used for NDWI (Normalazed Difference Water Index) on June 20, 2019. NDWI is used for assess water status and irrigation network by the combination of NIR and shortwave infrared (SWIR) channel of image [*Gao*, 1996]. The main purpose of this season (date) is to ensure that irrigation and collector-drainage networks are in maximum operating mode;
- based on 210 soil samples taken from the territory of the "Sokhibkor" massive, a map was developed, which describes the soil salinity level of the area.

RESULTS OF RESEARCHES AND THEIR DISCUSSION

Based on the analyses of the obtained data, more hydromorphic soils are prevalent in the experiment area. Groundwater regime in hydromorphic soils greatly influences the timing, quantity and irrigation rates of the crops, and the land reclamation status. Therefore, it is of great practical importance to study the layout of groundwater in the alluvial soils, which are part of the hydromorphic soils.

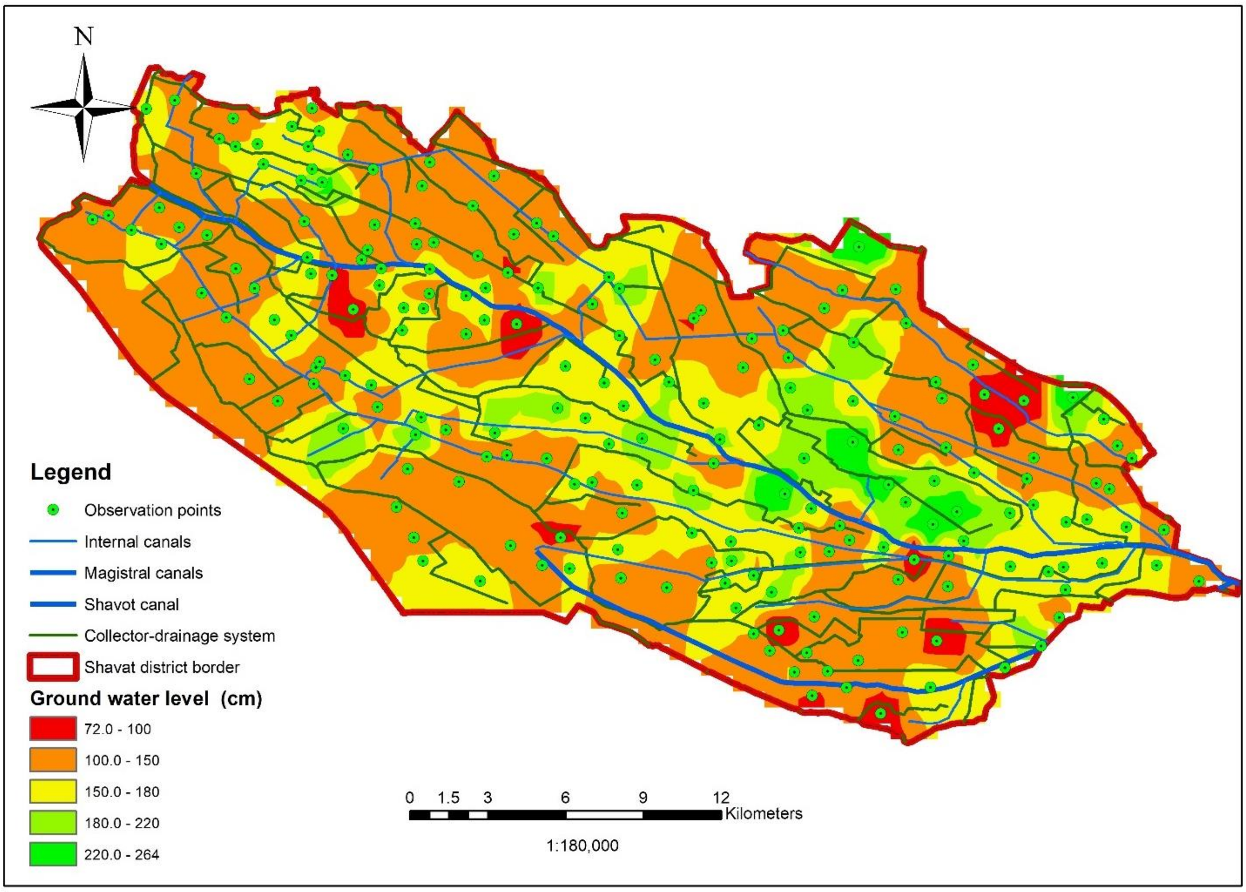

Fig. 2. Zonal distribution of groundwater level

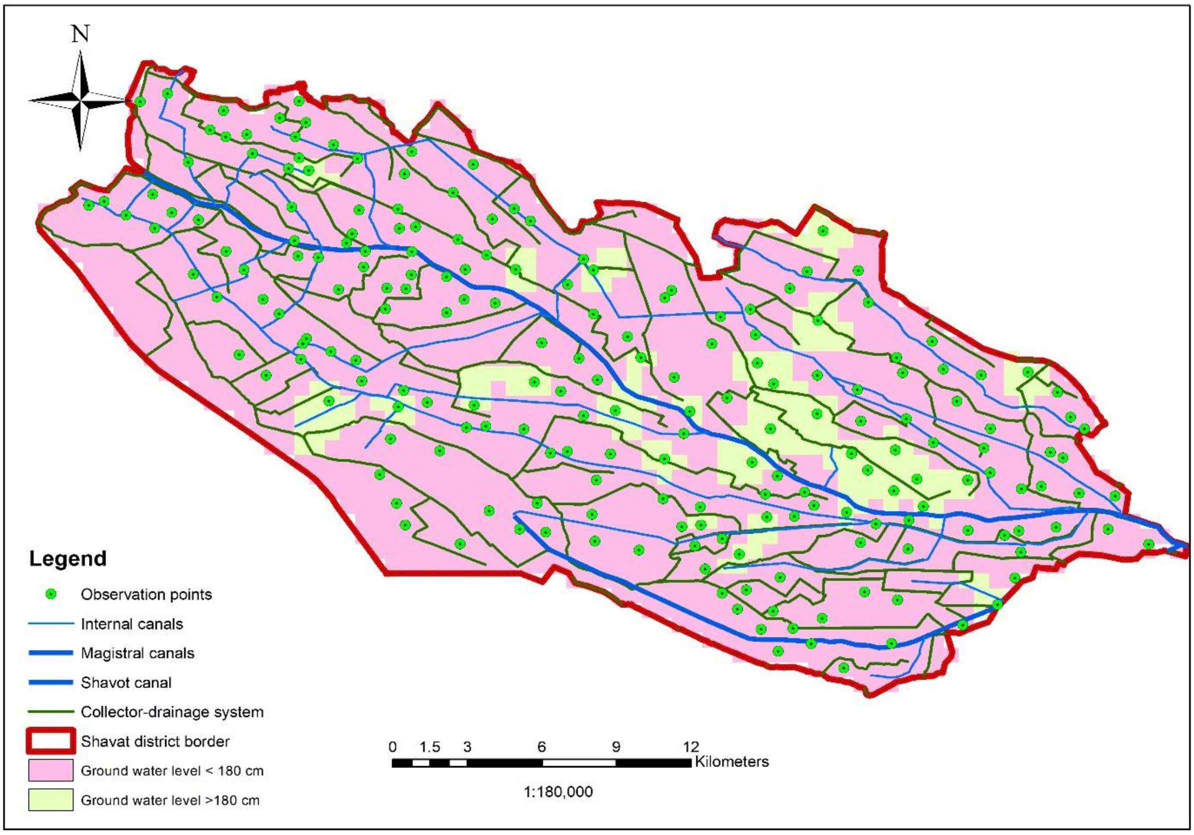

Fig. 3. The zonal distribution of groundwater level with above and below than 180 cm

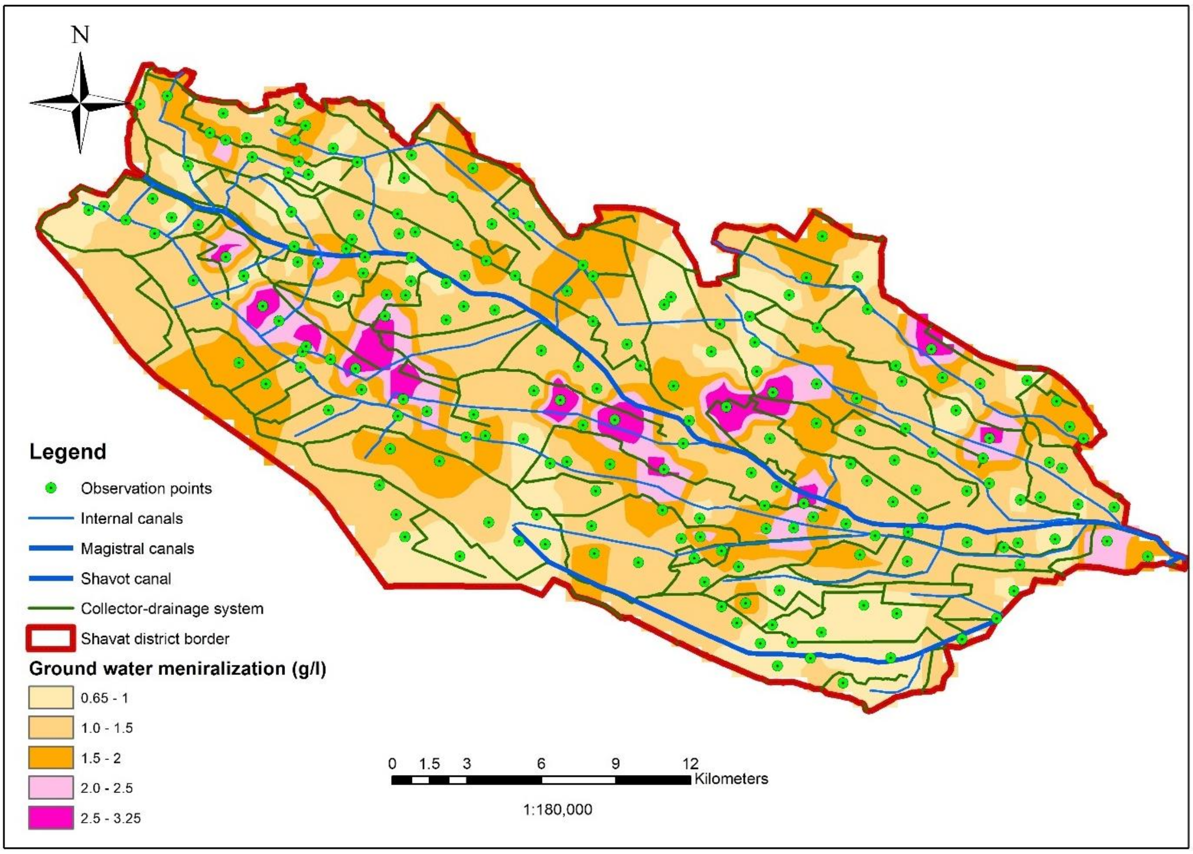

Fig. 4. Groundwater mineralization in the district

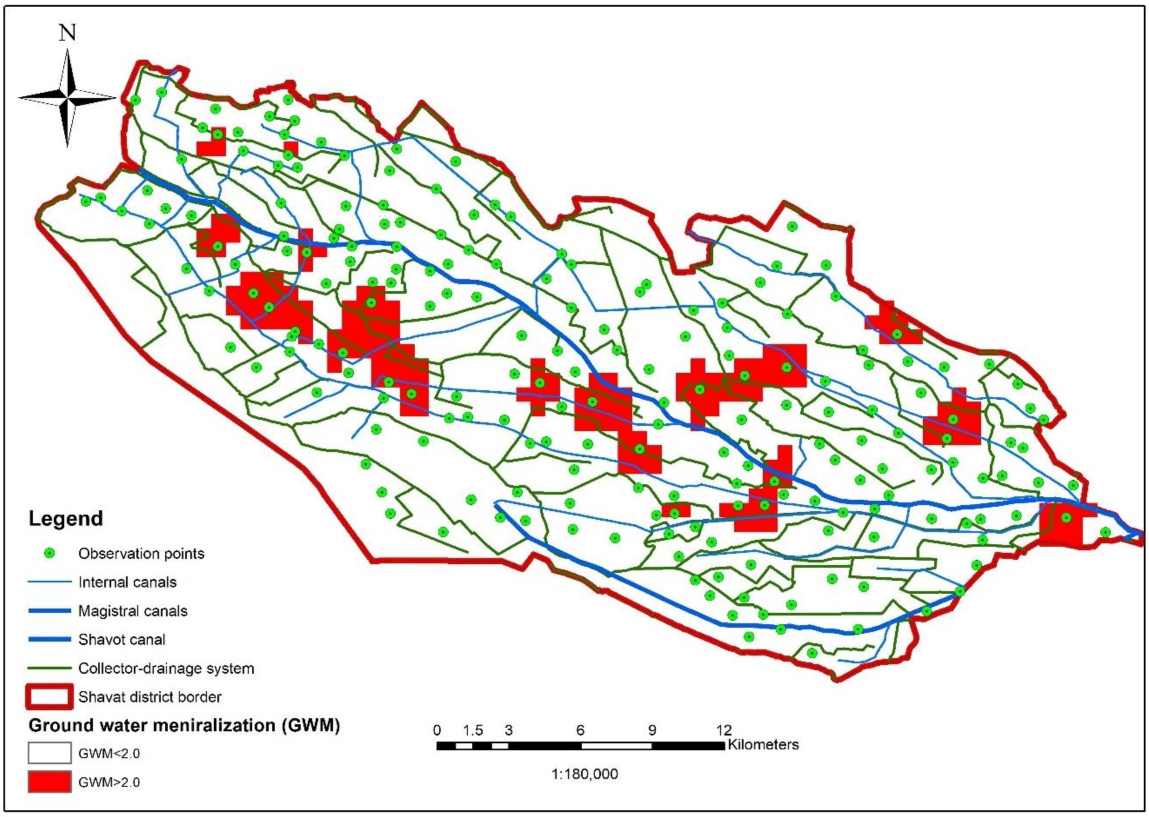

Fig. 5. Extracting groundwater mineralization over than 2 g/l fields

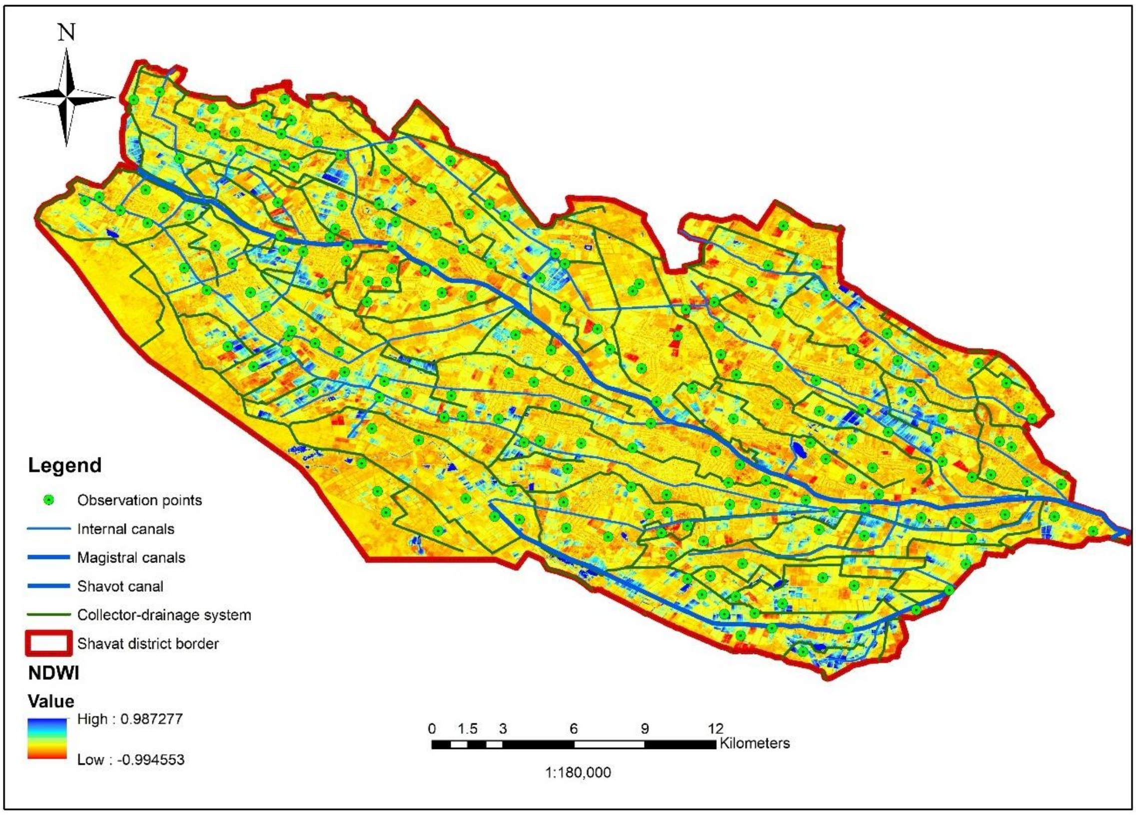

Fig. 6. Condition of irrigation and collector-drainage networks of Shavat district (rice fields are shown as lake)

Data from all monitoring wells in the district were collected every month during the growing season to determine the changes in groundwater levels in the pilot area. Based on the results, a map, depicting groundwater level was developed (fig. 2).

Fig. 3 shows the groundwater level over and below than 180 cm. Over and below groundwater changes were identified and a thematic map was created based on the results. Zone of below than 180 cm of groundwater level was about 88−90 % of total area.

Analysis of groundwater surveillance results shows that only 4−5 % of the area covered by groundwater level above than 100 cm. The area which groundwater level below than 220 cm was about 3−4 % of total irrigated area (fig. 2). Based on the results of analysis, between 0.65−1.5 g/l mineralized ground water area is about 80−90 %, over 2 g/l covered 10−15 % of the total irrigated area of the district. The area of mineralization of ground water during the growing season is 80−90 % with 0.65−1.5 g/l, indicating that the application of sub-irrigation methods for irrigation of saline soils is a good result (fig. 4).

In the area where the collector-drainage lines are connected, the salinity of the irrigated area is higher (fig. 5). The main reason for this was that the first irrigation was carried out through the irrigation network, and the subsequent irrigation was irrigated through high-mineralized (over 2 g/l) collector-drainage waters in the time of water shortage. Irrigation of high-mineralized collector-drainage waters resulted in increased salinity of irrigated areas.

Remote sensing analysis on the effects of irrigation water to groundwater level and mineralization (data from June 20, 2019) was conducted and it was observed that irrigation was not caused by crop demand and that 15−20 % of the field irrigation water was added to groundwater (1^{st} irrigation) (fig. 6). However, it was also possible to obtain data on crop cultivation using remote sensing techniques [*Harma et al.*, 1993].

Fig. 7 presents soil salinity levels based on soil samples taken this year across the Sohibkor massive.

The soil salinity level in the Sokhibikor massive was analysed, as a result, including 35 % of the area up to 2.5, 31 % of the area up to 2.50−3.54, 26 % of area is 3.54−4,8,7 % of the area is 4.8−6.6 and 1 % of the area is 6,6−8,35.

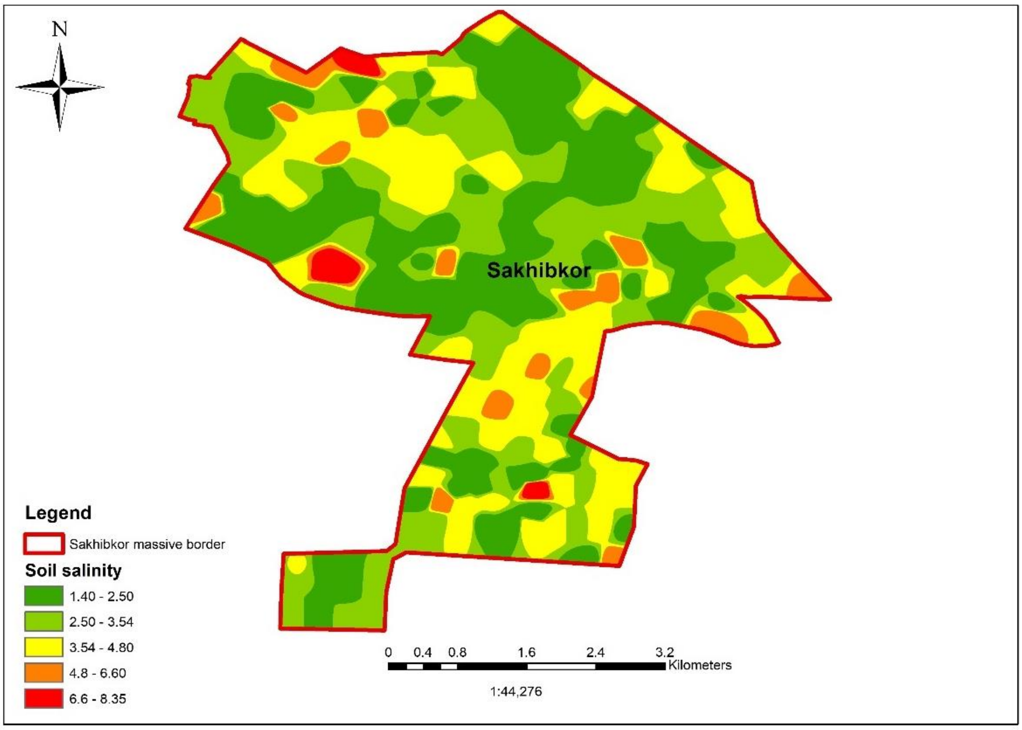

Fig. 7. Changes of soil salinity level in "Sokhibkor" massive

CONCLUSIONS

Based on the results of above analyses and scientific research conducted by scientists, the following recommendations are made to improve the reclamation state of irrigated areas, obtaining high yields from agricultural crops and identifying crop types from distance [*Khamidov et al.,* 1993; *Matyakubov,* 2001; *Faures et al.,* 2007; *Irmak et al.,* 2011; *Harma et al.,* 1993; *Conrad et al.,* 2014]:

- supplying water based on crop demanding;
- implementing of water-saving irrigation technologies (drip, sub irrigation, etc.);
- cultivation of low-watering crops in the times of water shortage;
- implement measures to prevent water evaporation in the field in case of water shortages;
- stopping use of drainage water in the period of water scarcity, or mixing with river water at prescribed rates of 1−2 g/l for irrigation agricultural crops;
- control and monitoring irrigation and collector-drainage networks monthly;
- development and implementation of work plan on priority of irrigation and repair of collector-drainage networks;
- improvement of irrigation techniques and technologies of agricultural crops taking into account the water supplementary of irrigated areas;
- improvement of irrigation and collector-drainage networks (efficient water use, reclamation of irrigated areas, etc.);
- implementation of high agricultural practices to improve soil fertility;
- implementing wide use of GIS and RS technologies for proper irrigation management and analysis of the condition of collector-drainage networks;
- improving identification of the need for water of crop by using remote sensing.

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