Assessment of land reclamation status using remote sensing and GIS in territory of Pakhtakor district of Uzbekistan

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Abstract. The importance of land distribution across all sectors of the national economy cannot be overstated, particularly in agriculture. Agricultural land plays a critical role in meeting the population's food needs and satisfying the demand for raw materials in the industry. The fertility of the land is the main productive property in agriculture. Continuous improvements in land productivity, combined with the adoption of innovative technologies, are key factors in modern agriculture development. However, natural and anthropogenic factors are negatively impacting agricultural land productivity, leading to a decrease in productivity. To prevent this, urgent measures must be taken to improve the reclamation conditions of agricultural lands, develop regions following climate change, and effectively organize cadastral reclamation activities. Additionally, monitoring the reclamation condition of agricultural lands is crucial in times of scarcity. This research focuses on the assessment of the melioration condition of agricultural land in the Pakhtakor district of the Republic of Uzbekistan, using geoinformation technologies and remote sensing data. These technologies enable the low-cost, timely, and high-accuracy measurement of changes in soil conditions over large land areas. By continuously monitoring the earth's surface, we can identify existing problems and develop timely solutions to address them. In research, enhancing agricultural land productivity is a critical task for modern agriculture development. Innovative technologies and effective monitoring strategies, such as geoinformation and remote sensing techniques, are essential to achieving this goal. Through this research, we hope to contribute to the continued improvement of land management practices and sustainable agriculture in Uzbekistan.

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1 Introduction

Geoinformation systems and technologies (GIS) and remote sensing technologies are advanced tools for assessing the reclamation condition of agricultural lands [1]. Given the gradual decrease in productivity in agricultural lands, particularly irrigated lands[2], constant observations and effective monitoring systems are necessary, as well as the implementation of measures to increase agricultural productivity[3,4]. In Uzbekistan, reclamation activities are carried out based on mapping the level of seepage water in monitoring wells to determine the level of soil salinity in the contours of agricultural lands[5]. Remote sensing and geoinformation technologies offer new approaches to monitoring and mapping, enabling the analysis of recent changes in agricultural land reclamation[6,7]. For instance, remote sensing data, such as Landsat 8 OLI, are useful in evaluating the reclamation status of agricultural land[8,9]. The condition of agricultural lands is subject to changes due to natural and human factors[10,11].

In some cases, these changes lead to land being withdrawn from agricultural use, leading to ecological disturbance[6,12]. This necessitates continuous monitoring of the reclamation condition of irrigated lands in agriculture and the timely determination of preventive measures[13]. The research presented in this article aims to analyze the melioration condition of the agricultural lands in the Pakhtakor district by creating a map of vegetation and the increase in the level of seepage water in recent years, thus evaluating the melioration condition of the irrigated agricultural lands[14]. In this work, the effect of surface water level on irrigated agricultural land was evaluated based on the analysis of vegetation NDVI. Several researchers have also investigated the reclamation condition of irrigated lands in agriculture[11]. Salinity is one of the factors with the worst effect on the reclamation of irrigated lands in modern agriculture[15]. Mapping the salinity level of seepage waters near the soil surface and the degree of mineralization determines the reclamation measures to be implemented[16]. The use of GIS technologies today allows for creating an electronic database for reclamation cadastre faster than traditional methods.

2 Study area

The Pakhtakor district was established in 1967 within the Syrdarya region and later transferred to the Jizzakh region in 1974 (Fig. 1), utilizing lands in the southwest of Mirzachol[17]. The district's terrain is mostly flat, with an average elevation of 295 m. The groundwater is shallow and brackish, with the Southern Mirzachol canal running through the area and ditches dug for wastewater drainage. The climate is strictly continental, with July temperatures averaging 30-35°C and reaching up to 40°C, while January temperatures average 4°C. Annual rainfall is around 280-300 mm, with a vegetation period of 205-210 days. The soils in the district are primarily gray, light gray, and saline.

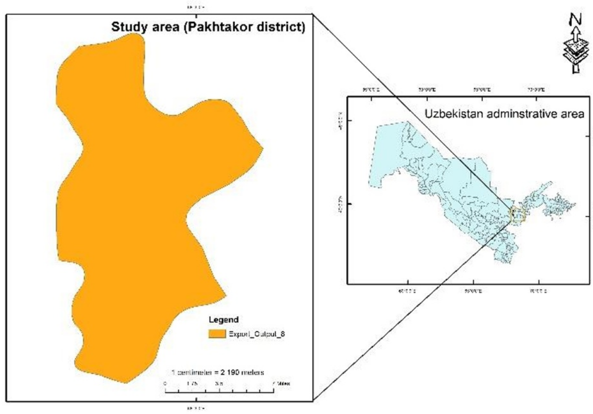


Fig. 1. Study area (Source: GRID-Arendal and www.earthexplorer.usgs.gov)

The district economy mainly focuses on agriculture, although industrial, transportation, and communication enterprises exist. The main agricultural activities include cotton growing, grain growing, vegetable growing, policing, horticulture, and cattle breeding. The district is home to around 140 small enterprises and private firms, joint-stock companies, 2 cotton ginning factories, and agricultural machinery repair enterprises[18,19]. Cotton and grain growing are the leading branches of agriculture, with over 26,500 hectares of irrigated land planted, including 12,800 hectares of cotton, 11,100 hectares of grain, and 2,600 hectares of other crops. Assessing the reclamation condition of agricultural land in Pakhtakor district requires studying soil salinity data, the results of district reclamation cadastre assessment, drainage system distribution level, water flow, mineralization level, and vegetation cover. Utilizing GIS technologies and remote sensing materials in this assessment is considered an effective tool, allowing for the preparation of reclamation maps in a new way and obtaining information on the general condition based on vegetation cover.

3 Materials and methods

The study obtained data from monitoring wells in the agricultural lands of Pakhtakor district, Jizzakh region, to monitor the level of seepage water. The level of seepage water was observed concerning the level in observation wells, and data were collected in April, July, and October of 2020 and 2021, corresponding to the vegetation period of various plants. The obtained data were mapped using the IDW (Inverse Distance Weighted) method to determine the seepage water level in the Pakhtakor district [20]. The NDVI (Normalized Difference Vegetation Index) for the survey period of 2020 and 2021 was obtained from Landsat 8 OLI (Operational Land Imager) data, which is available through the USGS (United States Geological Survey) Earth Explorer database system[21,22]. The spatial resolution of Landsat images is 30 m. Processing classification steps were completed using ArcGIS 10.6 software packages and tools. Figure 2 shows the results of the study.

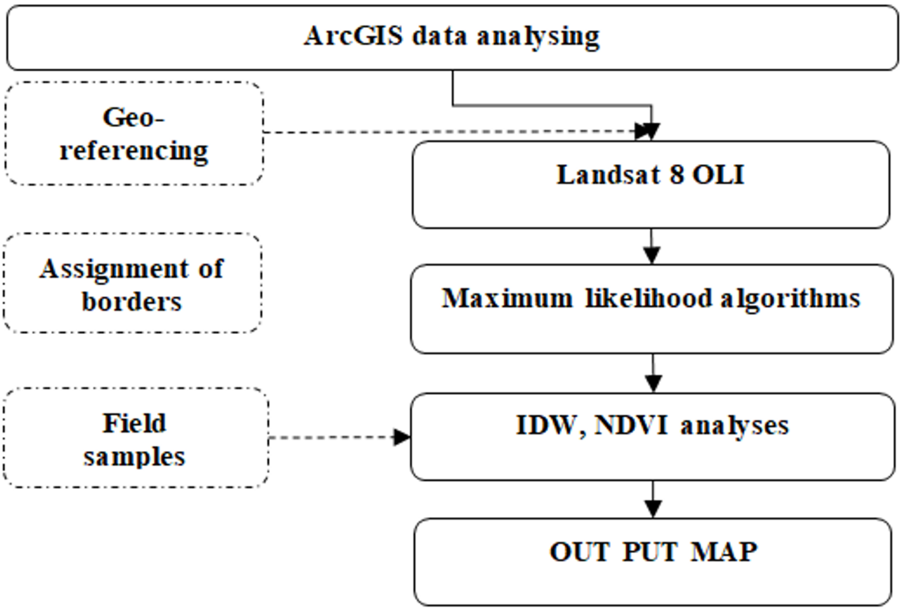
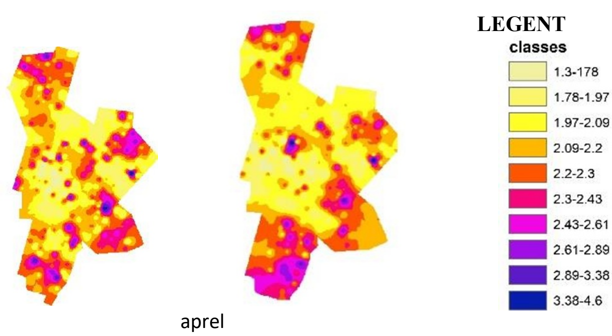


Fig. 2. Flow chart for adopted methodology

4 Results and discussion

The IDW method was used for the analysis of the study area, utilizing water level data from monitoring wells in the irrigated lands of Pakhtakor district during April, July, and October of 2020 and 2021 (Fig. 3). The results of the assessment of land reclamation and hydrogeological conditions in the agricultural lands of Pakhtakor district indicate a decrease in the level of seepage water when the depth of seepage water was analyzed between 2020-2021. At the beginning of the growing season in 2020, the distribution of the surface water level by area was 1-1.5 m in 0.07% of areas, 1.5-2.0 m in 2.81% of areas, 2-3 m in 96.46% of areas, and 0.66% of areas located at 3-5 meters. By the middle of the vegetation, it was 1.5-2 m in 4.20% of areas, 2-3 m in 92.98% of areas, and 3-5 meters in 2.81% of areas. By the end of vegetation, it was located at 1.5-2 m in 2.64% of areas, 2-3 m in 82.04% of areas, and 3-5 meters in 15.32% of areas.



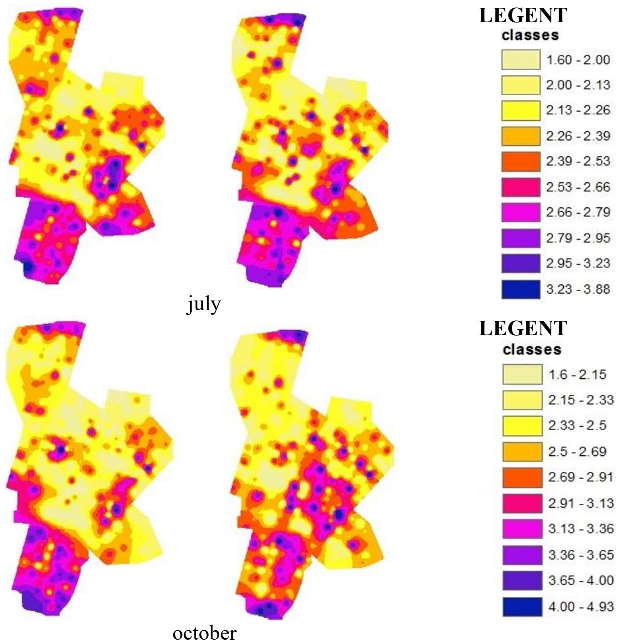


Fig. 3. The result of IDW analysis of study area.

Table 1. Seasonal water level in Pakhtakor district for 2020-2021

Months	Years	Irrigated area, thousand, ha	Water level in the field, m							
			1-1.5 m		1.5-2 m		2-3 m		3-5 m	
			thousand, ha	%	thousand, ha	%	thousand, ha	%	thousand, ha	%
April	2020	28.786	0.02	0.07	0.81	2.81	27.766	96.46	0.19	0.66
	2021	28.786	0.03	0.10	1.566	5.44	26.915	93.50	0.275	0.96
July	2020	28.786	-	-	1.21	4.20	26.766	92.98	0.81	2.81
	2021	28,786	-	-	1.55	5.38	26.626	92.50	0.61	2.12
October	2020	28.786	-	-	0.76	2.64	23.616	82.04	4.41	15.32
	2021	28.786	-	-	0.3	1,04	24.906	86.52	3.58	12.44

In 2021, the distribution of surface water levels at the beginning of the growing season was observed to be 1-1.5 m in only 0.10% of areas, 1.5-2 m in 5.44% of areas, 2-3 m in 93.50% of areas, and only 0.96% were located in the 3-5 meter range. By the middle of the vegetation period, surface water levels were observed to be 1.5-2 m in 5.38% of areas, 2-3 m in 92.50% of areas, and 3-5 meters in 2.12% of areas. By the end of the vegetation period, surface water levels were located at 1.5-2 m in only 1.04% of areas, 2-3 m in 86.52% of areas, and 3-5 meters in 12.44% of areas. These results indicate a decrease in the level of seepage water during the autumn season (see Table 1-2).

Table 2. Changes in depth area of seepage waters in Pakhtakor district

Years	Division of water level into areas according to depth						
	field	0-1 m	1-1.5 m	1.5-2 m	2-3 m	3-5 m	>5 m
2020	28786	-	-	1210	26766	810	-
2021	28786	-	-	1550	26626	610	-

During the 2020-2021 growing season, the mineralization of seepage water increased. At the beginning of the 2020 growing season, 3.11% of areas had seepage water with 0-1 g/l mineralization, 87.32% had 1-3 g/l, 8.53% had 3-5 g/l, and 1.04% had 5-10 g/l. By July, 5.70% of areas had 0-1 g/l mineralization, 90.03% had 1-3 g/l, 3.99% had 3-5 g/l, and 0.28% had 5-10 g/l. By October, these values changed to 5.94%, 91.70%, 2.36%, and 0%, respectively.

At the beginning of the 2021 growing season, the areas with 0-1 g/l mineralization of seepage water were 3.23%, the areas with 1-3 g/l were 87.90%, the areas with 3-5 g/l were 8.26%, and the areas with 5-10 g/l were 0.61%. By July, these values changed to 6.22%, 92.18%, 1.46%, and 0.14%, respectively. By October, the values changed to 1.74%, 94.37%, 3.51%, and 0.38%, respectively. As a result, during recent growing seasons, the mineralization of seepage water in more than 1.6-4.27% of areas exceeded the unsatisfactory level of 3 g/l.

Table 3. Information on the mineralization of groundwater in Pakhtakor district for 2020-2021

Months	Years	Irrigated area, thousand to	Mineralization of seepage waters in the field.							
			0-1 g/l		1-3 g/l		3-5 g/l		5-10 g/l	
			thousand, ha	%	thousand, ha	%	thousand, ha	%	thousand, ha	%
April	2020	28.786	0.895	3.11	25.136	87.32	2.455	8.53	0.3	1.04
	2021	28.786	0.93	3.23	25.302	87.90	2.379	8.26	0.175	0.61
July	2020	28.786	1.64	5.70	25.916	90.03	1.15	3.99	0.08	0.28
	2021	28.786	1.79	6.22	26.536	92.18	0.42	1.46	0.04	0,14
October	2020	28.786	1.71	5.94	26.396	91.70	0.68	2.36	-	-
	2021	28.786	0.5	1.74	27.166	94.37	1.01	3.51	0.11	0.38

The level of seepage water and the level of mineralization in agricultural lands do not fail to influence the development and productivity of crops. NDVI analysis was performed for the same period of time, 2020 and 2021 (April, July, October) for the Pakhtakor district (Fig.4).

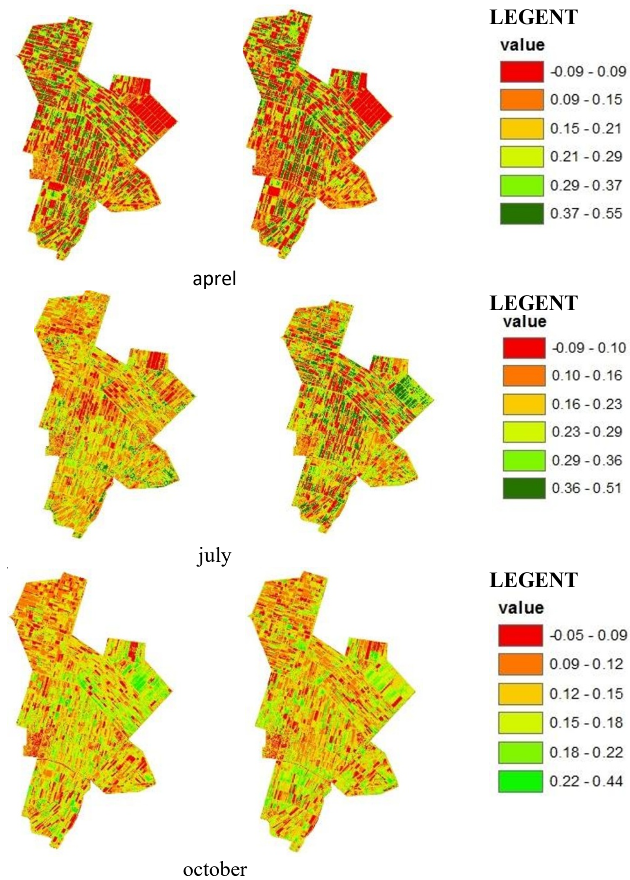


Fig. 4. NDVI analysis map of study area.

According to the results of the NDVI analysis, the index indicators in the study area were better in 2020 and 2021 compared to April. However, the NDVI indicators decreased in July and October. This situation suggests that changes in water and mineralization levels occur following the development of crops.

5 Conclusions

Upon analyzing the data, it was found that the level of seepage water in the irrigated lands of the Pakhtakor district did not increase during the years 2020-2021. However, it should be noted that the water level has not exceeded the limit of 2-3 meters recommended by ISMITI and stated in the project during the growing season. Only in April and July the water level has been observed to be higher than 2 meters. Furthermore, the mineralization of seepage waters during the main vegetation period has been evaluated as unsatisfactory, exceeding 3 g/l in 1.60% of the area. The data indicates that more than 18.15% of the land in the district is moderately and strongly saline. This level of salinity could have adverse effects on crop production and quality. The accumulation of salts in the soil reduces the water uptake capacity of crops, leading to a decrease in yield and quality.

Moreover, the high salt concentration could lead to root damage and hinder the absorption of essential nutrients, causing further decline in the overall health of the crop. To mitigate the negative impact of salinity, appropriate measures should be taken to improve soil quality. This could be achieved by applying soil amendments, such as gypsum, to enhance the soil's ability to remove excess salts. Additionally, the use of drip irrigation instead of traditional flood irrigation can help to reduce the accumulation of salts in the soil. Adopting proper soil management practices can improve the overall productivity and quality of the region's crops. It should also be noted that the NDVI analysis indicated that the NDVI index is better in 2020 and 2021 compared to April. However, the NDVI index decreases in July and October, suggesting a change in water level and mineralization following the crop's development. Thus, it is important to closely monitor the water levels and mineralization of seepage waters during the growing season and take appropriate measures to maintain optimal conditions for crop growth.

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