

RESEARCH ARTICLE

STABLE GROUNDWATER TABLE AND RISING SALINITY IN ANGOR DISTRICT OF SURKHANDARYA REGION (UZBEKISTAN): SEASONAL ANALYSIS

Arifjanov Aybek^a, Samiyev Luqmon^{a,b,c*}, Li, Fadong^{e,f,g,h}, Gafurov Zafar^d, Eshboyev Navruz^a, Abduraimova Dilbar^a, Xiaohui Pan^{a,i,j}, Xumora Jalilova^a, Akramov Jamoliddin^b

^aTashkent Institute of Irrigation and Agricultural Mechanization Engineers, National Research University, Tashkent, Uzbekistan

^bResearch Institute of Environment and Nature Conservation Technologies, Tashkent, Uzbekistan.

^cFergana Polytechnic Institute. Uzbekistan.

^dInternational Water Management Institute. Uzbekistan.

^eShandong Yucheng Agro-ecosystem National Observation and Research Station (SYA-NORS), Ministry of Science and Technology

^fYucheng Comprehensive Experiment Station, Chinese Academy of Sciences

^gInstitute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (IGSNRR-CAS)

^hUniversity of Chinese Academy of Sciences (UCAS) No.11A, Datun Road, Chaoyang District, Beijing, 100101, China. TEL/FAX: +86-10-6488-9530, Office @ B512. E-mail: lifadong@igsrr.ac.cn

ⁱState Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China

^jKey Laboratory of GIS and RS Application Xinjiang Uygur Autonomous Region, Urumqi 830011, China

*Corresponding Author Email: luqmonsamiev@mail.ru

This is an open access journal distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited

ABSTRACT

Article History:

Received 14 March 2025
Revised 02 April 2025
Accepted 24 May 2025
Available online 13 June 2025

Seasonal changes in groundwater levels and salinity were investigated in the irrigated lands of Angor district, Uzbekistan from 2018 to 2023. Using field data from 129 wells and GIS-based interpolation, the study found a generally stable water table (mean depths of 2.28 m in April, 2.29 m in July, 2.23 m in October), but a significant increase in groundwater mineralization from 1.65 g/L in April to 2.04 g/L in October. This rise in salinity after the growing season indicates growing soil salinization risk. Spatial analysis revealed higher salinity near desert margins and in areas of intensive irrigation, highlighting key drivers of degradation. The results suggest current irrigation practices in Angor are unsustainable. To ensure long-term agricultural viability, improved land and water management strategies are urgently needed.

KEYWORDS

soil salinization; irrigation management; seasonal variation; GIS mapping; water table fluctuations

1. INTRODUCTION

Global groundwater depletion has become a critical issue, with an estimated loss of about 4500 km³ between 1900 and 2008 (Konikow, 2011). At the same time, water demand for irrigation has intensified, especially in arid regions (Rahman et al., 2016). These trends affect aquifer recharge and river runoff, linking groundwater dynamics to broader water security concerns (Rahman et al., 2016). In irrigated areas, inefficient irrigation and extensive land use can cause rising water tables, waterlogging, and soil salinization (Groll et al., 2013; Kulmatov et al., 2020). Higher air temperatures increase evapotranspiration, leaving more salts on the surface (Corwin, 2021). Neglecting changes in groundwater depth and salinity can undermine salinity management efforts across regions (Khamidov et al., 2022). Soil salinity is especially problematic in semi-arid regions where shallow groundwater (GWT) supports capillary salt transport to roots (FAO, 2002). Studies show that the critical depth for salinity effects varies (e.g., 1.5–3 m in parts of China), and similar variability exists in Uzbekistan (Zhang et al., 2001; Kulmatov et al., 2020; Ibrakhimov et al., 2007). Geographic Information Systems (GIS) and

remote sensing (RS) are powerful tools for mapping groundwater and salinity in arid areas (Mohamed et al., 2011). Methods like kriging and inverse distance weighting (IDW) allow spatial interpolation of groundwater parameters (Varouchakis et al., 2013). Understanding the local groundwater and salinity dynamics in Angor district is important for managing irrigated land. However, few detailed studies exist for this region. The objectives of this study are to:

- Assess the seasonal dynamics of groundwater table (GWT) depths and groundwater mineralization (GWM) in the irrigated lands of Angor district (2018–2023).
- Map the spatial distribution of groundwater levels and salinity using statistical methods and GIS-based IDW interpolation.
- Identify hydrogeological and human drivers (e.g., irrigation practices, land use, climate) influencing groundwater and salinity patterns.

This study aims to provide a comprehensive understanding of groundwater–salinity interactions in Angor, highlighting the implications for sustainable water management and agriculture.

Quick Response Code



Access this article online

Website:
www.watconman.org

DOI:
10.26480/wcm.02.2025.414.419

2. MATERIALS AND METHODS

2.1 Study area

Angor district was established on April 16, 1952, on the territory of the former Termez and Sherabod districts. Located in the southern part of the

region, Angor district lies 33 km northwest of the city of Termez. The district shares borders with Kyzylrik to the north, Termez to the south, Jarkurgan to the east, and Muzrabod to the west and southwest. With an area of 0.39 thousand square kilometers, Angor is one of the smaller districts in the Surkhandarya region (Figure 1). The study area is situated along the left bank of the Qorasuv River.

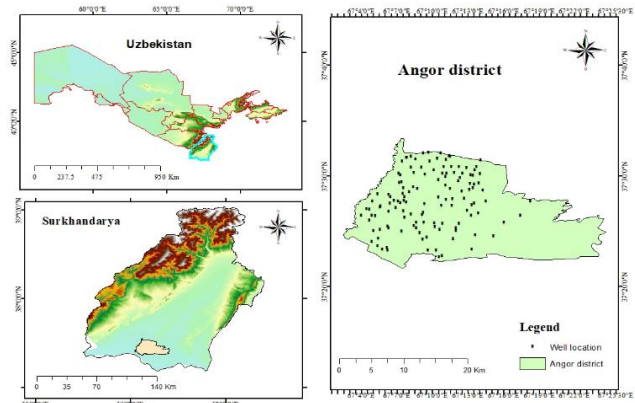


Figure 1: Map of the study area

The digital elevation model (DEM) was extracted from the USGS Shuttle Radar Topography Mission (SRTM). For continuous monitoring of the groundwater table (GWT) and groundwater mineralization (GWM), 129 observation wells have been installed across the district (Figure 1). The district's climate is classified as sharply continental, signifying hot, dry summers and cold winters. Based on long-term data from the Termez meteorological station, the mean annual temperature in the district over the past 24 years ranges between 17.1 °C and 19.8 °C. The average maximum temperature varies between 32 °C and 35 °C, while the average minimum temperature ranges from 0 °C to 0.5 °C (Figure 2). In the Angor district, the groundwater table generally ranges from 2.0 to 3.0 meters, creating a significant risk of soil salinization caused by capillary rise. Groundwater mineralization typically ranges from 1 to 3 g/l in most areas, increasing to 5–10 g/l near desert regions due to high evaporation rates and inefficient irrigation practices. Limited natural recharge and inadequate drainage further exacerbate the challenges of salinization.

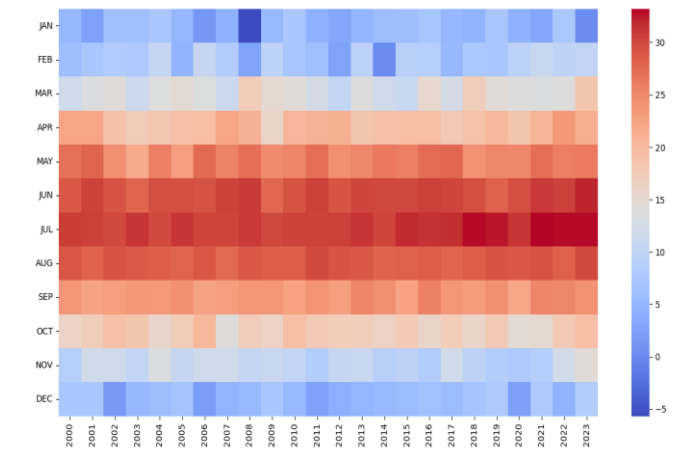


Figure 2: Average air temperature

The highest average and maximum air temperatures are recorded in June and July, reaching 32 °C and 46.3 °C, respectively. The minimum air temperature is recorded during winter, reaching as low as -18 °C.

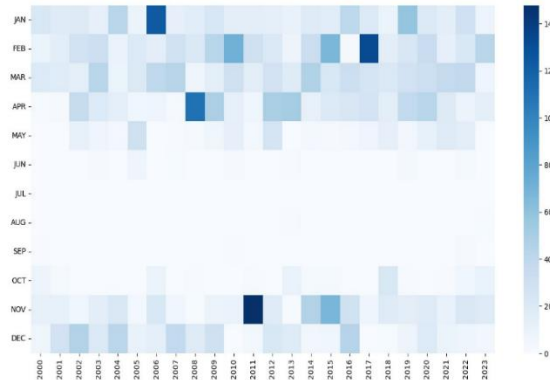


Figure 3: Average annual precipitation

The district's climate is predominantly sharply continental, reflecting arid conditions. The region receives an average annual precipitation of 154.4 mm, which is unevenly distributed across the seasons. The highest precipitation occurs in spring (25.1 mm) and winter (22.3 mm), while autumn sees the lowest levels (5.6 mm). During summer, precipitation is nearly absent. The highest recorded rainfall occurred in 2006, totaling 230.9 mm, while the minimum rainfall of 76.8 mm was recorded in 2000 (Figure 3).

2.2 Landuse/Landcover.

Land use and land cover (LULC) in the Angor district significantly influence groundwater table (GWT) levels and groundwater mineralization (GWM), both of which are critical factors in soil salinization. The LULC map highlights diverse land cover types that directly impact groundwater dynamics and salinity risks in the district.

Table 1: Key land use and their impacts

Land use type	Description	Impact on Groundwater and Salinization
Cropland (Green)	The dominant land use, representing extensive agricultural areas dependent on irrigation.	Intensive irrigation raises groundwater levels, increasing the risk of capillary rise and soil salinization, especially in areas of poor drainage.
Bare/Sparse Vegetation (Orange)	Concentrated in the southeastern areas, characterized by limited vegetation and exposed soil.	Higher evaporation rates lead to increased salt accumulation in the soil, exacerbating salinization in these regions.

Table 1(Cont.): Key land use and their impacts		
Built-up Areas (Red)	Scattered urban zones, mainly in the central and western parts of the district.	Urbanization reduces groundwater recharge due to impermeable surfaces, leading to altered drainage patterns and localized mineralization.
Grassland and Shrubland (Light Green/Brown)	Areas with natural vegetation, supporting soil stability and water retention.	These areas promote groundwater infiltration and act as buffers, reducing the risk of salinization by preventing excessive evaporation and salt movement.
Tree Cover (Dark Green)	Limited coverage of trees, providing localized benefits for soil stabilization.	Helps in reducing wind erosion and enhancing water infiltration, stabilizing groundwater tables, and mitigating the effects of evaporation.
Water Bodies and Wetlands (Light Blue)	Small yet ecologically vital areas providing freshwater resources and contributing to groundwater recharge.	Act as natural reservoirs that dilute soil salts and recharge groundwater, mitigating the effects of mineralization in adjacent cropland and built-up areas.

In summary, croplands dominate the district, resulting in intensive irrigation that significantly affects groundwater levels and salinization. Areas with bare or sparse vegetation are particularly prone to salinity build-up, whereas built-up regions contribute to altered drainage patterns and reduced groundwater recharge (Figure 4).

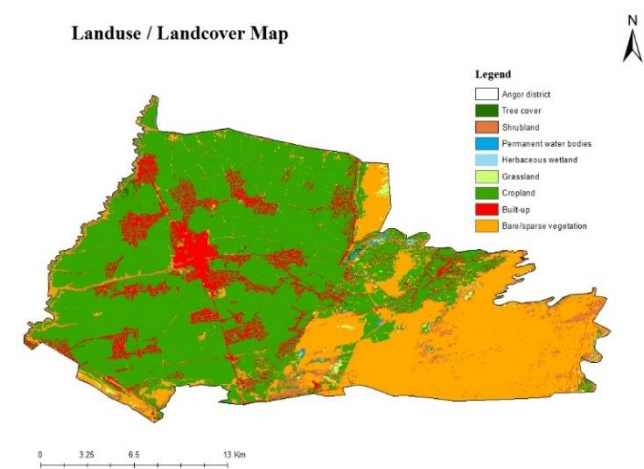


Figure 4: Landuse/Landcover map of Angor district

Natural vegetation in grasslands, shrublands, and tree-covered areas is crucial for stabilizing soil and maintaining groundwater balance. Water bodies and wetlands deliver essential ecological services by reducing mineralization levels and enhancing groundwater recharge. Sustainable management of these land use types is vital for preventing long-term soil degradation and preserving agricultural productivity in the Angor district.

3. RESEARCH METHODOLOGY

3.1 Data collection

The Surkhandarya Land Reclamation Expedition (SLRE) conducts regular evaluations of the groundwater table (GWT) and groundwater mineralization (GWM) in agricultural lands every three months during the vegetation period (April, July, and October). However, the acquired data are neither statistically analyzed nor evaluated by the SLRE. Therefore, the primary data on GWT and GWM for the period 2018–2023 were obtained from the reclamation expedition of the Surkhandarya region, operating under the Amu-Surkhan irrigation systems basin administration of the Ministry of Water Management, Republic of Uzbekistan. The climate dataset for the study area was sourced from the Termez meteorological weather station for the period 2000–2023.

3.2 Measurement and Sampling of GWT and GWM

Groundwater samples were collected from 129 coordinated observation wells across the district to determine groundwater mineralization (Figure 1). Groundwater levels were measured using the Micro-Diver 11.11.02, manufactured by Van Essen Instruments. This device is recognized for its precision and durability, widely used in environmental research, groundwater management, and agricultural irrigation monitoring to track groundwater fluctuations and temperature changes in various settings. The water samples were analyzed for total dissolved solids (TDS) and chloride content (Table 1). Groundwater monitoring in the Angor district

was conducted at three critical intervals: prior to irrigation in April, during irrigation in July, and post-irrigation in October, offering valuable insights into seasonal variations in groundwater levels and mineralization.

Table 2: GWM classification for irrigated areas of Uzbekistan according to chloride (Cl) contents.	
TDS, g/l	Cl ⁻ , mg/l
0-1	0.0 – 0.164
1-3	0.164 – 0.494
3-5	0.494 – 0.822
5-10	0.822 – 1.64
>10	> 1.64

Vector maps depicting changes in the groundwater table and mineralization within the study area were generated using the Inverse Distance Weighting (IDW) method in ArcGIS 10.8 software.

3.3 Analyzing Data Statistically and Creating Spatial Maps

Statistical methods were employed to evaluate the acquired data. Descriptive statistics for seasonal variations in the groundwater table (GWT) and groundwater mineralization (GWM) were computed. All statistical analyses were conducted using Microsoft Excel software. The Inverse Distance Weighted (IDW) method was applied to interpolate GWT and GWM data, utilizing multi-year observations.

4. RESULTS

4.1 Analyzing statistical data related to groundwater levels and salinity

The groundwater table (GWT) in the irrigated lands was relatively close to the soil surface, with an average depth ranging from 2.0 m to 2.5 m. The average monthly GWT depths were 2.28 m in April, 2.29 m in July, and 2.23 m in October (Table 2). The minimum and maximum GWT depths below the land surface showed only slight variation. The minimum GWT depths were 1.5 m in April and July, and 1.46 m in October. This similarity in values during April and July reflects the regular irrigation practices conducted during these months. In October, following the conclusion of the growing season, the GWT measured 1.46 m below the ground surface. The cessation of irrigation in October did not result in a significant drop in the groundwater level. Average groundwater table and mineralization for April, July, and October 2018 and 2023.

Table 3						
Parameter	Groundwater table, m.			Groundwater mineralization, g/l		
	April	July	October	April	July	October
Mean	2.28	2.29	2.23	1.65	1.83	2.04
St.Dev	0.28	0.22	0.26	0.38	0.39	0.42
Minimum	1.47	1.5	1.46	1.26	1.06	1.23
Maximum	4	3.4	3.29	3.69	3.17	3.89
N	129	129	129	129	129	129

The maximum groundwater table (GWT) depths were recorded at 4.0 m in April, 3.4 m in July, and 3.29 m in October. In October, the GWT was relatively close to the soil surface, whereas in April, it was considerably deeper.

4.2 Groundwater table dynamics

Field data indicated that irrigated areas with a groundwater table (GWT) depth of less than 1.0 m were rarely observed in the Angor district over the past six years. Irrigated land with a GWT depth of 1.5–2.0 m increased from 0.63% (123 ha) of the total irrigated area in 2018 to 0.82% (160 ha) in 2021 and 0.90% (176 ha) in 2023. Similarly, the irrigated area with a GWT depth of 2.0–3.0 m accounted for 91% (17,857 ha) in 2019, peaked at 93% (18,149 ha) in 2021, and returned to 91.6% (17,930 ha) in 2023. The area with a GWT depth of 3.0–5.0 m constituted 4.9% (950 ha) in 2019, peaked at 5.3% (1,040 ha) in 2020, and declined to 3.8% (745 ha) by 2023. Irrigated areas with a GWT depth greater than 5.0 m represented 3.9% (765 ha) in 2018, declined to 2.6% (515 ha) in 2020, and slightly increased to 2.9% (560 ha) by 2023. Irrigated areas with a GWT depth of 2.0–3.0 m decreased by 349 ha between 2018 and 2023. This decline may be attributed to the high dependency on irrigation outflows and drainage water in these administrative districts. Finally, irrigated land with a GWT depth greater than 3.0 m decreased by 378 ha compared to 2018. These dynamic changes in GWT over the years are likely due to unsustainable management of land resources and irrigation water.

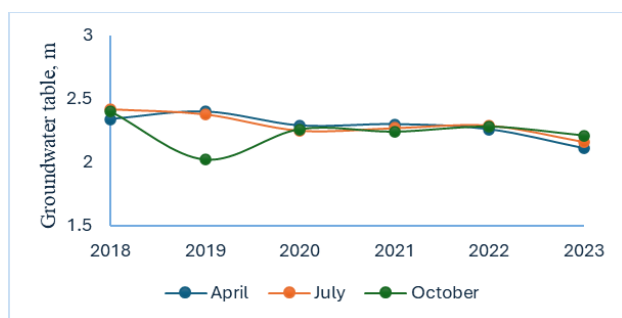


Figure 4: Average seasonal change of groundwater table.

The groundwater table (GWT) decreased significantly before the start of irrigation practices in April compared to other months (Figure 4). The sharp decline in the GWT observed in October 2019 was attributed to increased irrigation demand during the growing season and reduced rainfall, which resulted in diminished groundwater recharge. In general, the depth of groundwater near the surface is largely influenced by the volume of irrigation water applied.

4.3 Groundwater mineralization dynamics

Detailed fieldwork results on groundwater mineralization (GWM) from 2018 to 2023 revealed that approximately 91% of the total irrigated area predominantly consisted of groundwater with mineralization levels between 1–3 g/l. Irrigated lands with GWM levels of 0–1 g/l increased significantly, from 660 ha (3.4%) in 2018 to 3,760 ha (19.2%) of the total irrigated area in 2021. In the district, irrigated lands with GWM levels of 3–5 g/l declined from 180 ha in 2018 to 28 ha in 2023, representing a significant improvement. The trend for irrigated lands with GWM levels of 0–1 g/l remained relatively stable, while areas with GWM levels exceeding 10 g/l displayed significant variability over the period. This variability was predominantly observed in bare irrigated lands, where high evaporation rates, likely influenced by global climate change, were prevalent. However, this variability did not significantly impact GWM levels of 0–1 g/l in areas with deeper GWT, allowing these levels to remain relatively stable over time.

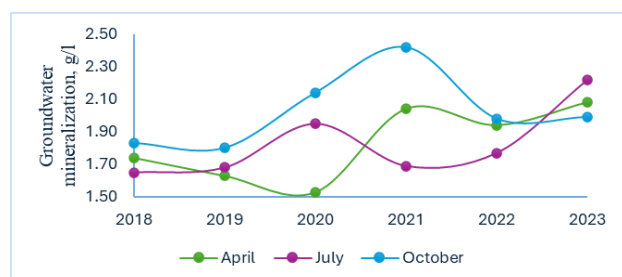


Figure 5: Average seasonal change of groundwater mineralization.

Figure 5 illustrates the long-term seasonal variations in groundwater mineralization (GWM) in the Angor district. The average GWM levels during the study period were 1.65 g/l in April, 1.83 g/l in July, and 2.04 g/l in October. The highest recorded GWM level was 3.89 g/l, while the lowest was 1.06 g/l in April 2020, attributed to an increase in rainfall from the normal 20.1 mm to 43.7 mm.

4.4 Evaluating alterations in groundwater levels and salinity through GIS

The Geographic Information System (GIS) was employed to analyze temporal changes in the groundwater table (GWT) and its mineralization in irrigated regions. GIS has proven to be a highly efficient tool for spatial and temporal mapping of groundwater characteristics across diverse applications.

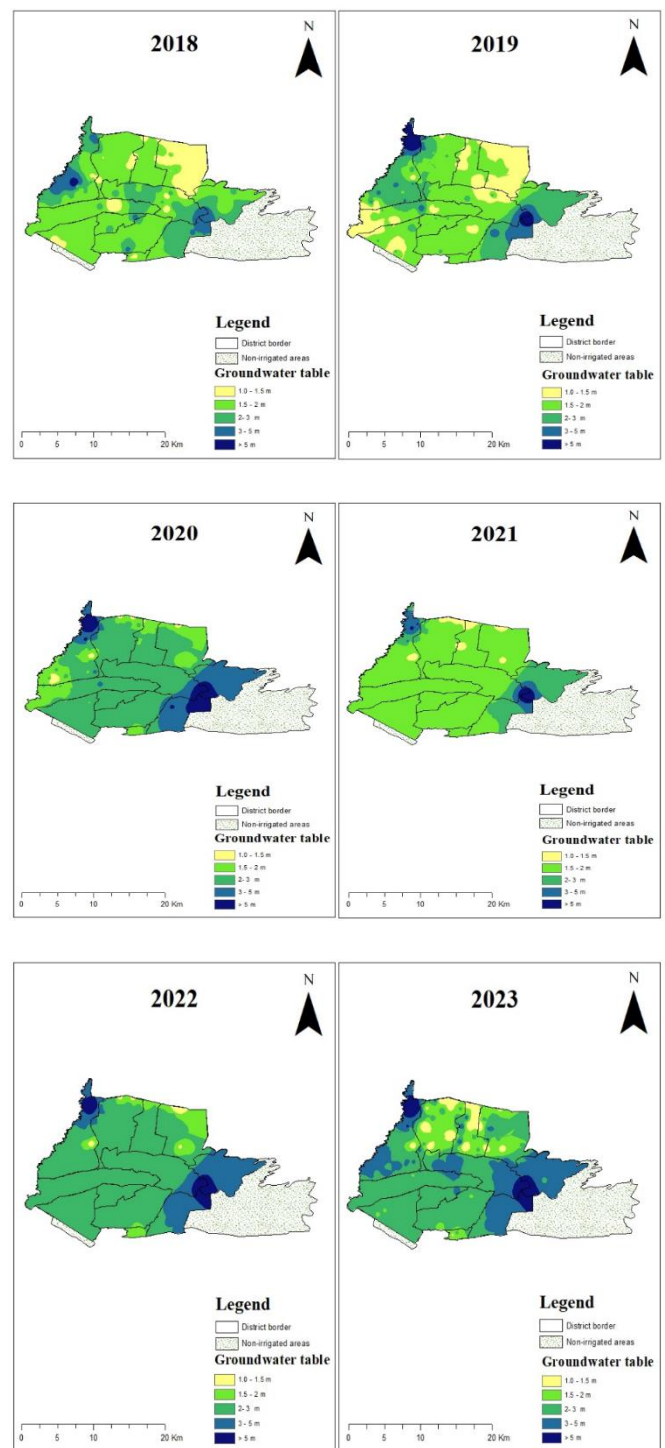


Figure 6: Dynamic changes of the groundwater table (GWT) 2018-2023

Figure 6, generated using the IDW interpolation method, depths areas with

groundwater tables at 1-1.5 m, 1.5-2 m, 2-3 m, and 3-5 m, which are particularly striking. Areas on GWT 0–1 m were noticed in very small areas during the period 2018–2023, while areas with >5 m were mainly observed during the past two consecutive years (2022, 2023), which can be seen as having increased relatively small. In the studied area, regions where the groundwater level is 1.5-3 meters deep cover extensive areas.

The Land Use/Land Cover (LULC) map (Figure 4) reveals significant correlations between land use patterns and groundwater dynamics in the district, which is predominantly covered by cropland dependent on irrigation. Groundwater tables near the surface (1.5–2.0 meters) are concentrated in areas of intensive agriculture, where excessive irrigation and inadequate drainage systems lead to elevated water levels. Built-up areas, primarily located in the central and western parts, reduce natural recharge due to impermeable surfaces and increase surface runoff into adjacent agricultural lands, exacerbating elevated groundwater levels. Regions with bare or sparse vegetation, predominantly in the southeastern district, have deeper groundwater tables (3.0–5.0 meters). However, these areas experience rapid fluctuations due to limited infiltration, making them susceptible to long-term degradation caused by poor water retention. Conversely, areas with grassland, shrubland, and tree cover exhibit more stable groundwater levels. Enhanced natural infiltration and reduced dependence on irrigation help maintain safer water tables, minimizing the risk of capillary rise and salinization.

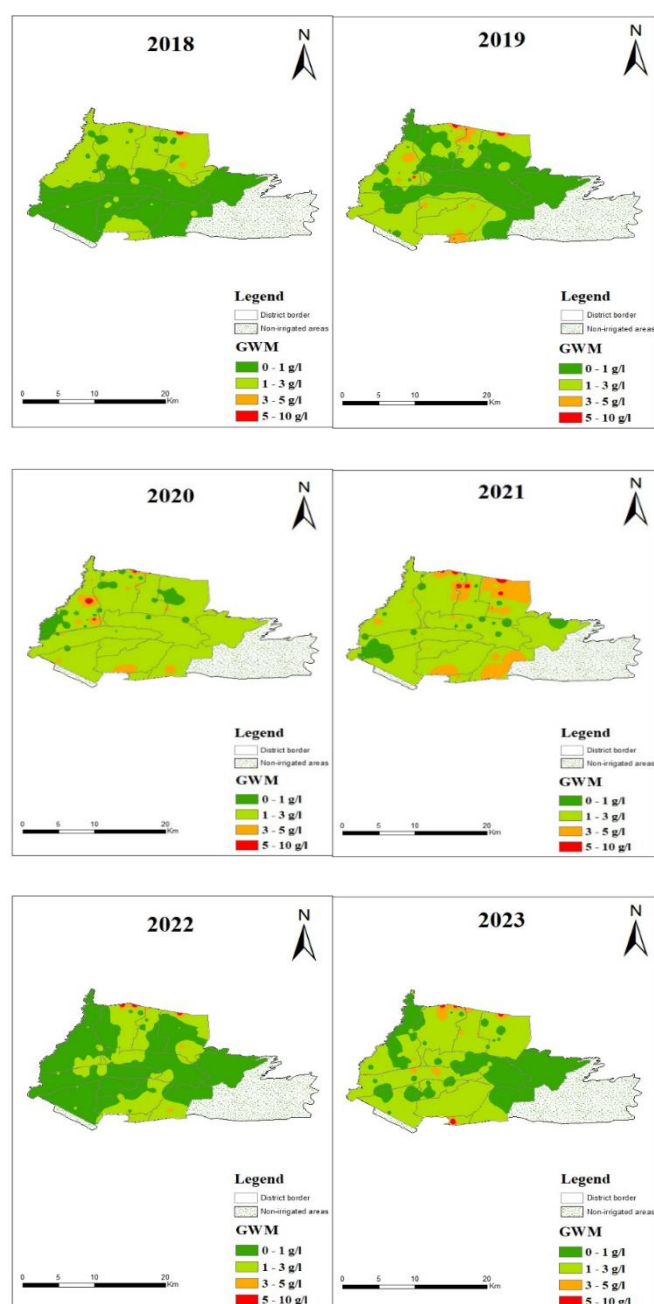


Figure 7: Dynamic changes of the groundwater mineralization (GWM) 2018-2023

During the investigation period, no irrigated areas with groundwater mineralization (GWM) levels exceeding 10 g/l were identified. However, the map indicates regions with GWM levels ranging from 0–1 g/l and 1–3 g/l (Figure 7). Over the past six years, extensive irrigated farmland with groundwater salinity levels between 1 and 3 g/l has been observed. In the northern irrigated regions, zones with GWM levels of 5–10 g/l were consistently identified throughout the study period. This elevated salinity is attributed to proximity to non-irrigated lands and the bordering desert. These areas, with evaporation rates reaching 85–90% under arid conditions, are prone to rapid water loss. Limited vegetation reduces moisture retention, accelerating evaporation and resulting in salt accumulation over time.

The district's reliance on surface water irrigation, covering over 70% of agricultural land, significantly influences these mineralization patterns. Inefficient irrigation practices, frequently exceeding 1,500 cubic meters per hectare, lead to water seepage into deeper soil layers, dissolving salts accumulated from previous evaporation cycles. Without adequate drainage systems, waterlogging impacts over 40% of irrigated land, intensifying the evaporation process. In regions near the desert or non-irrigated lands, inefficient water use, high evaporation rates, and inadequate drainage systems have contributed to GWM levels rising to 5–10 g/l in 10–15% of the district's irrigated areas.

5. DISCUSSION

GIS mapping and IDW interpolation (Figures 6–7) revealed distinct spatial groundwater and salinity patterns in Angor district. Areas with shallow water tables (1–2 m depth) were predominantly identified in intensively irrigated cropland zones, notably in central and western parts, attributed to extensive irrigation and inadequate drainage systems (Groll et al., 2013; Kulmatov et al., 2020). Conversely, deeper groundwater tables (3–5 m) characterized bare or sparsely vegetated lands in the southeastern region, reflecting limited recharge and higher susceptibility to seasonal fluctuations (Corwin, 2021). Vegetated areas such as grassland and woodland maintained relatively stable groundwater levels due to higher infiltration rates and lower irrigation demands (Khamidov et al., 2022).

Spatial patterns of groundwater salinity (Figure 7) were closely associated with land use types. Elevated salinity levels (5–10 g/L) were observed in northern irrigated zones adjacent to non-irrigated desert lands, resulting primarily from high evaporation rates (85–90%) and minimal groundwater recharge (Kulmatov et al., 2020; FAO, 2002). In contrast, moderate salinity levels (1–3 g/L) prevailed across most agricultural areas, reflecting the dilution effect of regular irrigation practices. The study period (2018–2023) recorded no areas surpassing 10 g/L, indicating relatively controlled high-salinity conditions.

Groundwater salinity patterns in Angor district were strongly influenced by irrigation methods. Approximately 70% of agricultural practices relied on surface water, often applied excessively ($\geq 1500 \text{ m}^3/\text{ha}$), facilitating deep seepage and leaching accumulated salts downward (Groll et al., 2013; Zhang et al., 2001). The absence of efficient drainage systems exacerbated waterlogging issues, affecting around 40% of irrigated lands, thereby intensifying soil salinization risks (Kulmatov et al., 2020). Marginal regions near deserts or non-irrigated fallow lands exhibited pronounced salinity levels (5–10 g/L) in approximately 10–15% of the fields, attributed to ineffective irrigation, heightened evaporation, and inadequate drainage mechanisms (Kulmatov et al., 2020; Ibrakhimov et al., 2007).

These findings underline both the scientific and practical contributions of the present research. Scientifically, the study elucidated seasonal and spatial dynamics of groundwater and salinity in an understudied irrigated area, leveraging advanced spatial mapping (GIS/IDW interpolation) and statistical analyses to pinpoint primary drivers of soil salinization. Practically, generated maps and statistical insights identified critical high-risk zones, aiding targeted management actions such as improving drainage in vulnerable areas and enhancing groundwater recharge strategies. Consequently, this integrated analytical approach equips local water management authorities with practical tools to optimize groundwater resource utilization, irrigation scheduling, and well-placement strategies, thus promoting sustainable agriculture in arid and semi-arid regions (Mohamed et al., 2015; Varouchakis et al., 2013).

6. CONCLUSIONS

This study analyzed six years (2018–2023) of groundwater data in Angor's irrigated fields. Key findings are: (1) The groundwater table is generally stable and shallow (<2.5 m) due to intensive irrigation; (2) Groundwater salinity increases from spring to fall (1.65→2.04 g/L on average),

indicating salinization risk after the growing season; (3) Spatial analysis shows higher water tables and salinity in heavily irrigated croplands and near desert fringes, implicating irrigation overuse and climate as main drivers. Integrating geostatistics with GIS proved effective for mapping these trends. To sustain agricultural viability, improved land and water management are imperative. For example, adopting efficient irrigation methods (e.g., drip systems) and building drainage can prevent waterlogging and salt accumulation. Government programs should monitor and regulate irrigation volumes, especially in areas with <2 m water tables.

For future research, we recommend:

- Long-term monitoring of GWT and salinity under different management scenarios (e.g., trial of drainage schemes, use of lower-salt irrigation water).
- Modeling studies to predict how projected climate change will interact with irrigation to affect salinity.
- Economic assessments of salinity mitigation measures to guide farmer adoption.
- Application of remote sensing (e.g., soil moisture satellites) to supplement well data.

Such studies will build on this work's framework, further aiding water managers and farmers. The integration of field monitoring with GIS in Angor can serve as a model for other semi-arid irrigation districts, contributing to improved water conservation and soil protection practices.

REFERENCES

- Corwin, D.L., 2021. Earth's salinization problem: causes, concentrations, and mitigation. *European Journal of Soil Science*, 72, Pp. 842–862. <https://doi.org/10.1111/ejss.13010>
- FAO., 2002. Biodrainage—principles, experiences and applications. Knowledge Synthesis Report No. 6. Food and Agriculture Organization of the United Nations, Rome.
- Groll, M., Opp, C., and Aslanov, I., 2013. Aeolian resuspension of Aral Sea

sediments. *Aeolian Research*, 9, Pp. 49–62. <https://doi.org/10.1016/j.aeolia.2012.08.002>.

- Ibrakhimov, M., Khamzina, A., Forkutsa, I., Paluasheva, G., Lamers, J.P.A., Tischbein, B., Vlek, P.L.G., and Martius, C., 2007. Wind erosion impacts on irrigated agriculture in Khorezm. *Irrigation and Drainage Systems*, 21, Pp. 219–236.
- Khamidov, M., Ishchanov, J., Hamidov, A., Donmez, C., and Djumaboev, K., 2022. Groundwater salinity trends in irrigated areas under climate change. *International Journal of Environmental Research and Public Health*, 19, Pp. 8794.
- Konikow, L.F., 2011. Contribution of global groundwater depletion since 1900 to sea-level rise. *Geophysical Research Letters*, 38, L17401. doi:10.1029/2011GL048604
- Kulmatov, R., Mirzaev, J., Abuduwaili, J., and Karimov, B., 2020. Water table regime of irrigated lands in Surkhandarya (Uzbekistan). *Journal of Arid Land*, 12(1), Pp. 90–103.
- Kulmatov, R.A., Adilov, S.A., and Khasanov, S., 2020. Trends in groundwater salinity in Uzbekistan. *IOP Conference Series: Earth and Environmental Science*, 614, 012149. <https://doi.org/10.1088/1755-1315/614/1/012149>.
- Mohamed, L., Sultan, M., et al., 2015. Integrated modeling of groundwater flow and salinity in irrigated basins. *Surveys in Geophysics*, 36(5), Pp. 717–742.
- Rahman, A.T.M.S., Kamruzzaman, M., Jahan, C.S., Mzaumder, Q.H., and Hossain, A., 2016. Evaluation of spatio-temporal dynamics of water table in NW Bangladesh: an integrated approach of GIS and Statistics. *Sustainable Water Resources Management*, 2, Pp. 297–312. doi: 10.1007/s40899-016-0057-4
- Varouchakis, E.A., and Hristopulos, D.T., 2013. Temporal trends of groundwater level and salinization. *Environmental Monitoring and Assessment*, 185(1), Pp. 1–19.
- Zhang, D.F., and Wang, S.J., 2001. Critical depth of water table to salt accumulation. *Environmental Geology*, 41, Pp. 96–100.

