

Tracking the temperature of Tharthar Lake and its effect on monthly evaporation using Landsat 8 images for the period (2022-2024)

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Abstract

Water is the basis of life and a key component of various economic activities upon which humans depend. Lakes are an important reservoir of freshwater worldwide, particularly in arid and semi-arid countries such as Iraq. One of the most significant challenges associated with water storage in Iraq is the substantial loss due to evaporation, estimated at 9 billion cubic meters annually. Hence, this study aims to estimate evaporation from Tharthar Lake, Iraq's largest water reservoir, with a capacity of approximately 85 billion cubic meters. Analysis of the L' 'Lake's imagery revealed relative variability in surface area, ranging from 1509.79 to 1574.59 km², primarily due to fluctuations in water inflow and outflow. Shallow areas showed greater thermal responsiveness, while deeper regions remained more thermally stable. The results indicated that monthly evaporation varied significantly, from a minimum of 90.45 mm in January to a maximum of 422.85 mm in August. Overall, the findings confirm that Tharthar Lake is highly influenced by 'Iraq's climatic regime, which is witnessing a steady annual increase in temperature. Overall, the use of thermal infrared sensors (TIRS) on Landsat 8 satellites is more effective than ground-based stations for monitoring lake surface temperatures across large temporal and spatial scales. This remote sensing approach enhances reliability while reducing both time and labor requirements.

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1. Introduction

Lakes and reservoirs play a critical role in storing and regulating freshwater supplies, particularly in arid and semi-arid regions. These water bodies store 87-88% of Earth's liquid surface freshwater (Yao et al., 2020; Hirji & Duda, 2024), providing essential services such as water supply, food security, and climate resilience (Hirji & Duda, 2024). However, many lakes face threats from salinization, water diversion, pollution, and climate change (Williams, 1999; Williams, 2002). Recent studies reveal widespread declines in global lake water storage, attributed to climate warming, increased evaporation, and human water consumption (Yao et al., 2023; Zhao et al., 2024). These changes impact water availability, biodiversity, and ecosystem functions (Williams, 1999). Effective management of lakes requires integrated approaches that consider water quality, quantity, and basin-wide factors (Parparov & Hambright, 1996). Lakes also serve as sentinels and regulators of climate change, providing valuable data on environmental shifts (Williamson et al., 2009).

Iraq faces significant water resource challenges due to its arid climate, characterized by high temperatures and limited rainfall (Al-Maliki et al., 2022; Ali et al., 2024). The country has constructed large-scale water storage infrastructure, including dams and reservoirs, to meet agricultural, domestic, and industrial demands (Hamid et al., 2024). However, climate change is exacerbating

water scarcity, with predictions of decreased precipitation, increased evapotranspiration, and potential drying of major rivers by 2040 (Al-Ansari, 2013; Al-Maliki et al., 2022). Studies have shown significant reductions in climatic water availability and increases in crop water demand across most of Iraq (Salman et al., 2020). These challenges are further compounded by population growth, urbanization, and inefficient water use (Ali et al., 2024). To address these issues, Iraq requires a strategic water management vision, including regional cooperation, improved agricultural practices, and investments in research and development (Al-Ansari, 2013).

The Iraqi government launched the Tharthar Dam Project in 1956 as one of the country's most important hydrological initiatives. The project was designed primarily for flood mitigation and water storage, diverting excess water from the Tigris River through the Samarra Dam Regulator into Tharthar Lake, and subsequently releasing it back into the Tigris and Euphrates Rivers via the Dividing Regulator. It involves developing natural depressions as reservoirs, along with constructing barrages, regulators, and dykes to control and manage water flow. To enhance operational efficiency, an expert system was developed for managing the Tharthar Lake system under varying hydrological conditions. As a result, the project plays a critical role in 'Iraq's water resource management strategy and its efforts to mitigate flood risks. Beyond its hydrological function, Tharthar Lake

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offers multiple socio-economic and environmental benefits, including irrigation of vast tracts of agricultural land, aquaculture development, tourism, groundwater recharge, and climate moderation.

Given the strategic importance of Tharthar Lake, the efficient monitoring and management of its water resources are essential, especially amid increasing climatic stress. One effective method for assessing changes in water temperature and evaporation is the use of remote sensing technologies—particularly Land Surface Temperature (LST) measurements derived from the Thermal Infrared Sensor (TIRS). TIRS detects infrared radiation through the thermal Bands 10 and 11 on the Landsat 8 and 9 satellites, providing high-resolution data that are crucial for hydrological and environmental research (Yang et al., 2020; Aya, 2025). The advancement of satellite technologies—with improved spatial resolution, shorter revisit times, and broader coverage—has significantly enhanced our understanding of energy and moisture exchanges between Earth's surface and the atmosphere (Oroud, 2019; Ahmed, 2022). These capabilities are especially valuable for estimating evaporation from water bodies by accurately capturing surface temperature data.

This study aims to assess seasonal and interannual variations in Land Surface Temperature (LST) over Tharthar Lake using data from the Thermal Infrared Sensor (TIRS) on Landsat 8 and 9, and to estimate corresponding evaporation rates under varying climatic conditions. It seeks to evaluate the impact of rising temperatures—driven by climate change—on surface water dynamics, with a particular focus on evaporation losses from the Lake. By analyzing spatial temperature patterns and thermal variability across the Lake's surface, the research identifies factors influencing heat distribution and water loss.

2- Study Area

The study area is situated within the Iraqi Al-Jazeera Plateau, spanning the administrative boundaries of Salah al-Din and Anbar Governorates (Figure 1). Geographically, it lies between longitudes 42°59' to 43°42' E and latitudes 33°39' to 34°36' N. Tharthar Lake, the largest freshwater lake in Iraq, is located between the Tigris and Euphrates rivers. It has a maximum storage capacity of approximately 85 billion cubic meters, with a water surface elevation of 65 meters above sea level and a surface area of 2,710 km² at full capacity. The dead storage volume is about 35.45 billion cubic meters, with a water level of 40 meters above sea level and a corresponding surface area of 1,589.17 km². The Lake serves as a vital flood control reservoir, storing excess water to protect cities along the Euphrates River. It also plays a critical role in the national water distribution system by regulating flows to both the Tigris and Euphrates rivers. The region experiences a semi-arid climate with extreme seasonal temperatures—averaging around 36°C in summer and dropping to 7°C in winter. According to 'Thornthwaite's drought index, the region's aridity coefficient ranges between 4.7 and 8.2 (Awwad & Remal, 2021; Al-Fahdawi et al, 2022). Long-term precipitation data over 50 years show a declining trend, with a rate of -0.885 mm/year (Muslih, 2022; Oroud Altubeiri, 2023; Al-Timimi, et al, 2024). Topographically, the

basin features a notable elevation range, from 1,371 meters above sea level in the northern areas down to approximately 60 meters in the south, yielding a vertical relief of 1,311 meters. The total area of the lake basin is estimated at 32,237.93 km² (Figure 2).

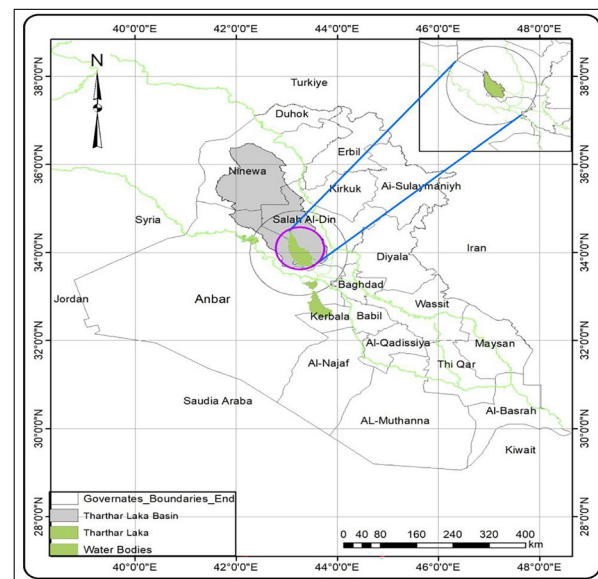


Figure 1. Location of the study area.

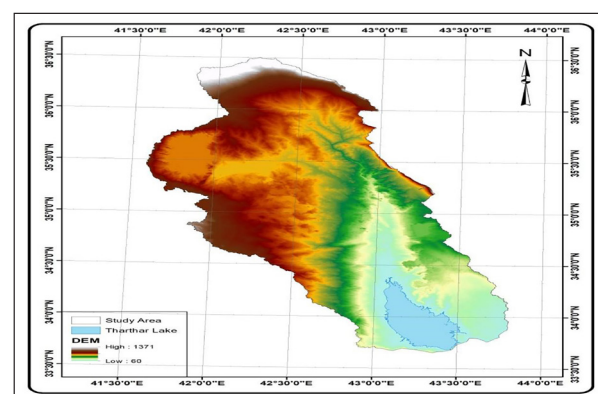


Figure 2. Topography of the study area.

3. Methods

Given the spatial and temporal variability of temperature across the Tharthar Lake region—and the limited availability of nearby meteorological stations—this study employed remote sensing techniques to monitor surface temperature and estimate evaporation rates. These spatial methods offer a reliable means of generating a geospatial database for water resource management in Iraq. By analyzing satellite-derived temperature and surface water extent over two hydrological years (October 2022–September 2024), the study aimed to develop scientific models that represent the Lake's dynamic thermal and hydrological behavior.

Two primary datasets were used. Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images were obtained from the United States Geological Survey (USGS) database. A total of 24 images (one per month) were selected, each with a spatial resolution of 30 × 30 meters. In addition, hydrological records, including monthly inflow and outflow volumes, were sourced from relevant Iraqi governmental authorities. As the study area spanned

multiple Landsat scenes, mosaicking was performed using ArcGIS to unify the scenes into a single composite image.

The Normalized Difference Water Index (NDWI) was used to extract the Lake's surface area for each month. NDWI exploits the high reflectivity of water in the green band and its low reflectivity in the near-infrared (NIR) band: NDWI equation: (Jassim, 2017)

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

Values closer to +1 indicate water bodies, while values near or below zero indicate land features such as vegetation or urban areas. NDWI was applied to each image to delineate the Lake's boundary and calculate its surface area monthly.

Monthly water levels and volumes were extracted from satellite images and cross-referenced with topographic maps of the Tharthar Lake basin. This enabled the estimation of water volume and elevation changes over the study period. To assess surface temperature dynamics, the thermal Band 10 from Landsat 8 was used following a multi-step procedure:

- Digital numbers (DN) from Band 10 were converted to spectral radiance using the following equation (Sajib et al., 2020): as Equation

$$L\lambda = ML \times Q_{cal} + AL$$

where:

- $L\lambda_{\{\lambda\}} =$ Spectral radiance ($W/m^2 \cdot sr \cdot \mu m$)
- $ML = 0.0003342$, $M_L = 0.0003342$, $ML = 0.0003342$, $AL = 0.1$, $A_L = 0.1$, $AL = 0.1$ (band-specific calibration constants)
- Q_{cal} = Band 10 DN value
- Radiance values were converted to Top-of-Atmosphere Brightness Temperature using (Allen et al., 2007), as Equation

$$TB = \frac{K2}{Ln} \times \frac{K1}{L\lambda + 1} - 273.15$$

Where:

- $K1 = 774.8853$, $K_1 = 774.8853$, $K1 = 774.8853$, $K2 = 1321.0789$, $K_2 = 1321.0789$, $K2 = 1321.0789$ (thermal conversion constants)
- $T_{BT} =$ Temperature in $^{\circ}C$
- Emissivity was calculated using vegetation proportion derived from NDVI values as follows Equation (Al-Qayyssi, et al., 2024; Yasir, et al., 2020)

$$P_v = \text{square} \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

Where:

- $P_v =$ Proportion of vegetation
- $\epsilon =$ Surface emissivity
- The Land Surface Temperature (LST) was computed using the formula (Ebtihal Taki et al., 2023): Equation

$$LST = \frac{TB}{1 + \lambda \times TB \div \rho} \times \ln(\epsilon)$$

Where:

- $\lambda =$ Central wavelength ($11.5 \mu m$ for Band 10)
- $\rho = 14380$, $\rho = 14380$, $\rho = 14380$ ('Planck's constant

constant)

- $\epsilon =$ Land surface emissivity
- Monthly evaporation rates were estimated based on the extracted LST values using empirical relationships. In addition, water losses were computed using the Langer method, which accounts for local climatic conditions and surface area to determine evaporation losses over time.

4. Results and Discussion

The satellite-derived surface temperature data from Tharthar Lake over the two-year study period (October 2022 to September 2024) reveal pronounced seasonal and spatial thermal variability consistent with the characteristics of semi-arid continental climates. The observed peak surface temperatures of $33.8^{\circ}C$ in July 2023 and $34.8^{\circ}C$ in August 2024 are indicative of strong solar insolation and atmospheric conditions such as clear skies and low-pressure dominance during summer months. These findings align with previous studies in similar climatic regions, where solar radiation and prolonged daylight hours are key drivers of elevated lake surface temperatures (Kumar, R., 2018). Conversely, the lowest temperatures of $9.6^{\circ}C$ and $8.7^{\circ}C$ during January reflect typical winter cooling, influenced by the Siberian high-pressure system and Mediterranean depressions, which is consistent with known regional climatology (e.g., Al-Ansari et al., 2013).

The seasonal temperature amplitude exceeding $25^{\circ}C$ plays a pivotal role in shaping the hydrological regime of Tharthar Lake, primarily by modulating evaporation rates. This strong thermal dynamic is critical because evaporation is the dominant form of water loss in such closed basins. The spatial temperature gradients further highlight the thermal heterogeneity of the Lake, with warmer, shallower southern and southwestern edges responding rapidly to seasonal warming, while deeper central regions maintain greater thermal inertia and stability due to water column mixing and depth effects (Salman, 2020). This spatial variability in temperature not only affects evaporation but may also influence stratification, nutrient cycling, and aquatic habitat quality, underscoring the need to incorporate spatial heterogeneity in future hydrodynamic and ecological models of the Lake.

The observed seasonal fluctuations in lake surface area, with a notable increase in variability during the 2023–2024 water year, suggest an intensification of climatic influences, particularly evaporation and inflow variability. The larger seasonal shrinkage in surface area (83.48 km^2 difference) relative to the previous year reflects heightened sensitivity to changing meteorological conditions. Such patterns have been documented in other endorheic lakes worldwide, where seasonal evaporation and precipitation fluctuations drive dynamic surface area changes (Yang et al., 2020). The fact that surface area closely follows temperature and evaporation trends further validates surface temperature as a proxy for hydrological stress in the Lake.

Water level measurements indicate relatively stable but slightly declining trends, reflecting a balance between inflows, evaporation, and water management practices. The stabilization of levels between 38.1 and 38.4 m during 2023–2024 suggests

active management interventions aimed at maintaining lake volume, which is essential for sustaining local water supply and ecological functions. Such anthropogenic regulation is a common response to water scarcity in arid environments, but must be balanced against long-term sustainability given increasing climate variability.

Evaporation estimates derived from the Langer equation are consistent with temperature trends and demonstrate a clear increase in evaporative losses from one year to the next. The peak monthly evaporation rates above 400 mm in summer months, alongside total annual evaporation exceeding 2600 mm, emphasize the L' 'Lake's vulnerability to thermal stress and the resultant water loss. This increment of 56.47 mm in annual evaporation between the two years may appear modest but is significant given the cumulative impact on the L' 'Lake's water balance over time. Elevated evaporation rates during periods of low inflow magnify drought risk and can precipitate rapid lake level declines, negatively affecting water availability for agricultural, industrial, and domestic uses.

The pronounced thermal gradients and increasing evaporation underscore Tharthar ' 'Lake's sensitivity to climate change and highlight the importance of adaptive management strategies. The discussion of mitigation approaches such as surface covers (Rezazadeh et al., 2020) and windbreak plantations is highly relevant. These strategies have demonstrated effectiveness in reducing evaporation by creating physical barriers or altering microclimatic conditions, thereby conserving precious water resources in arid and semi-arid zones.

Rainfall variability, with a trend toward reduced and delayed precipitation, compounds the lake's hydrological challenges. The shift in rainfall timing and amounts disrupts the traditional hydrological regime, reducing the effectiveness of winter and early spring replenishment, which has been

documented in other Middle Eastern basins affected by climate change (Al-Ansari et al., 2018). The combination of decreased rainfall and increased evaporation promotes hydrological drought and accelerates desertification processes, reinforcing the need for integrated water resource management that incorporates climate adaptation measures and sustainable water use policies.

Overall, while this study provides valuable insights, several limitations warrant consideration. Monthly satellite observations may miss shorter-term temperature and water-level fluctuations driven by episodic weather events, which could influence evaporation dynamics. Also, although satellite data are effective for large-scale monitoring, limited ground-truthing of temperature, evaporation, and water-level data may introduce inaccuracies. In addition, the Langer equation, while practical, is a simplified approach that may not capture all physical processes influencing evaporation, such as wind speed variability, humidity gradients, or lake surface roughness.

Albeit with these limitations, the study significantly advances understanding of climate-lake interactions in the Tharthar Basin and offers several implications. The identification of temperature and evaporation as key drivers of lake dynamics supports prioritizing thermal monitoring in future water resource plans and drought mitigation strategies. Also, highlighting increasing evaporation trends and rainfall shifts informs climate adaptation policies, emphasizing the need for diversified water supply and demand management. The findings provide scientific evidence for policymakers to enforce sustainable lake management and coordinate regional efforts to address climate-induced water scarcity. Overall, the study establishes a baseline for ongoing remote sensing monitoring and more detailed modeling of hydrological and ecological processes in arid lake systems.

Table 1. Water levels(m), surface area (km²), and average temperature (°C) for the months covered by the study.

No	Date Of Capture	Visual Water Level Rise Start And End Of Month (M)	Water Volume InsideLake /Billion M3	Calculated Area From Satellite Visuals/Km2	Average Water Surface Temperature For Each Month
1	15/10/2022	39.22	35.22	1574.59	26.2
2	15/11/2022			1568.53	19.3
3	25/12/2022			1566.48	15.6
4	18/1/2023			1566.19	9.6
5	19/2/2023			1564.82	11.1
6	23/3/2023			1560.73	15.4
7	16/4/2023			1559.4	13.4
8	10/5/2023			1574.56	24.4
9	19/6/2023			1566.47	20.6
10	13/7/2023			1554.17	33.8
11	14/8/2023			1540.73	32.5
12	15/9/2023	38.4	33.19	1529.84	28.9
13	17/10/2023	38.1	32.69	1522.35	24.2
14	18/11/2023			1513.76	18.4
15	4/12/2023			1509.79	15.2
16	5/1/2024			1509.73	8.7
17	22/2/2024			1510.92	10.9
18	10/3/2024			1509.94	11.7
19	2/4/2024			1559.41	15.5
20	28/5/2024			1593.21	26.4
21	13/6/2024			1566.47	31.5
22	15/7/2024			1554.17	32.7
23	16/8/2024			1540.73	34.8
24	17/9/2024	38.4	33.18	1529.84	26.9

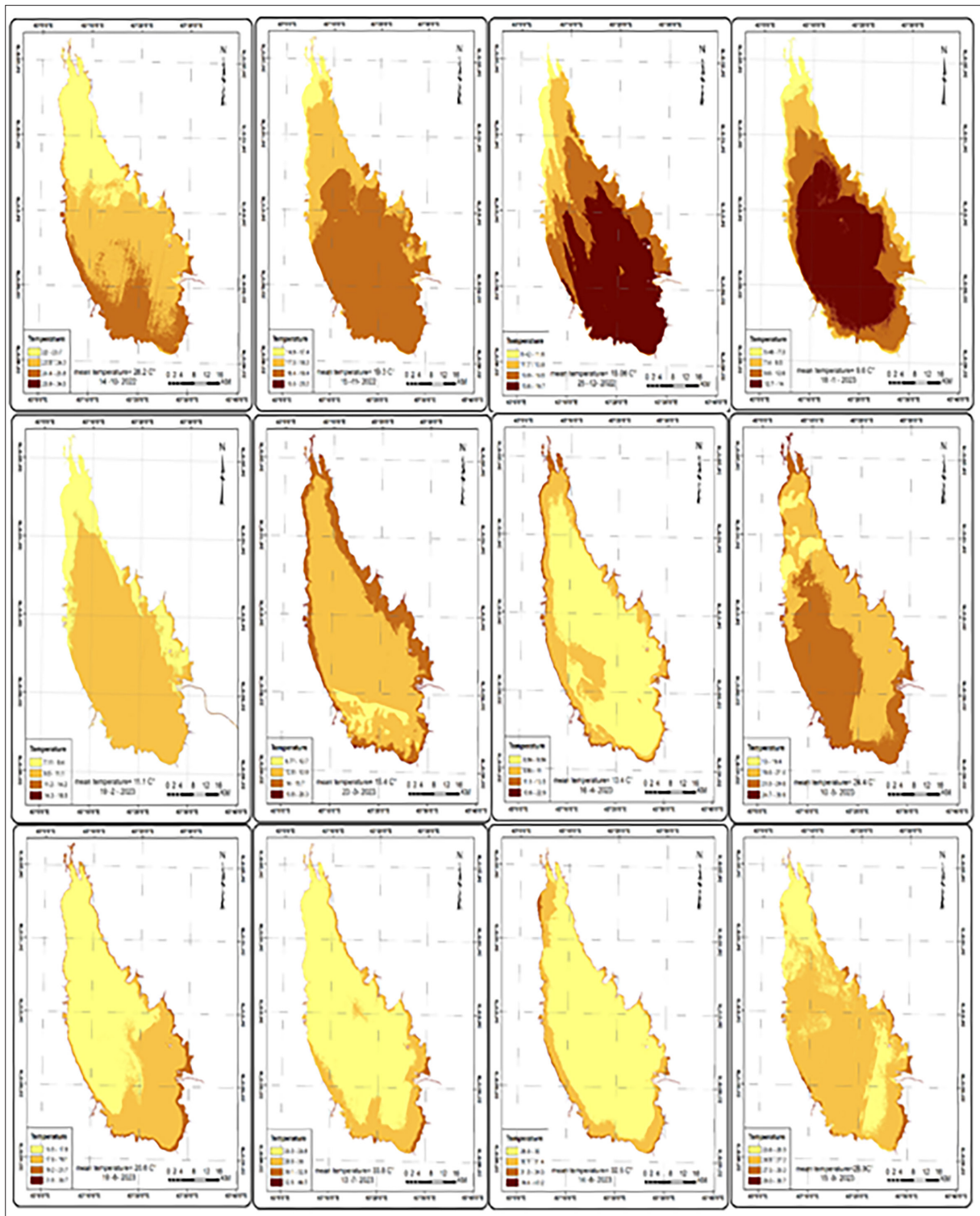
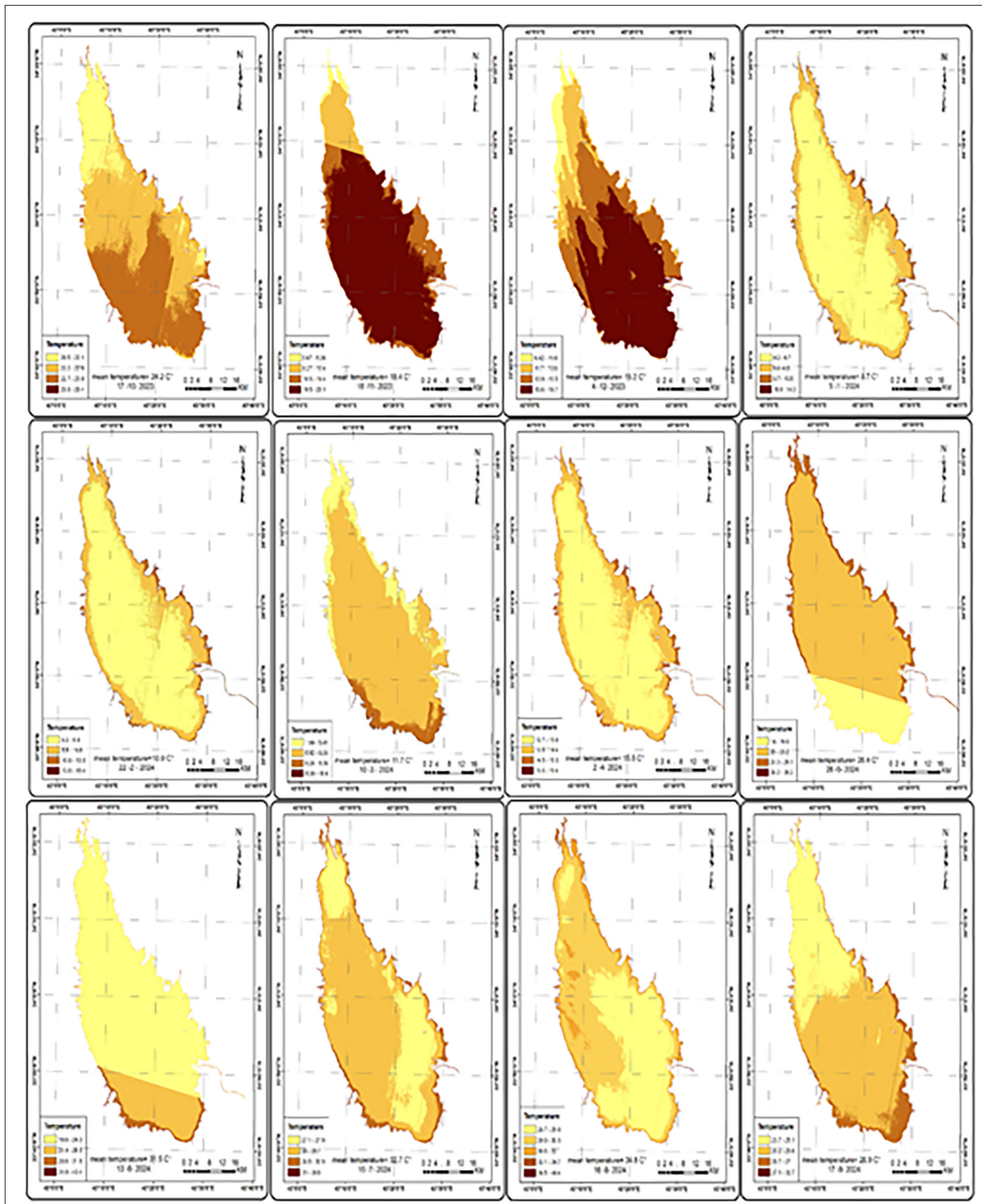


Figure 1. Variation of lake surface temperature for the period 2022-2024



Continuing from Figure 1. Variation of lake surface temperature for the period 2022-2024

4 - Calculating evaporation using the Langer equation (simplified by Penman):

$$E = (700 \cdot (T + 0.006h) / (100 - A) + 15(T - T_d)) / (80 - T) \quad (T - T_d) = 0.0023h + 0.37T + 0.53R + 0.35R_{ann} - 10.9$$

Where:

E = evaporation rate from the water surface (mm/day)

T = average temperature (°C)

T_d = average dew point temperature (°C)

A = latitude (34)

h = elevation above sea level (45m)

R = monthly average daily temperature range (14.05 om)

R_{ann} = average temperature of the warmest and coldest months (23.2) (Hassan, 2013)

The final monthly evaporation values were calculated using the Langer equation for the 2022-2023 hydrological year, as shown in Table 2. The highest calculated monthly evaporation values, 402.9 mm, were recorded during July

due to the highest temperatures, while the lowest evaporation value, 123.7 mm, was recorded during January due to the lowest temperatures. In the 2023-2024 hydrological year, the highest total monthly evaporation value, 422.8 mm, was recorded during August, while the lowest monthly evaporation value, 90.4 mm, was recorded during February.

In addition, integrative analyzes between remote sensing data and hydrological modeling indicate that Lake Tharthar shows an increasing response to short- and long-term climate fluctuations, making it a sensitive system to any change in energy or water inputs. Determining the quantitative relationship between temperature change, evaporation rates, and changes in surface area provides a scientific basis for estimating early warning indicators of drought. These results also confirm the necessity of developing high-accuracy predictive models based on thermal and temporal data to improve water resources management and enhance the resilience of the 'lake's ecosystem in the face of accelerating climate change.

Table 2. Calculating monthly and annual evaporation using the Langer equation for the 2022-2023 hydrological year

Langer	Temp 0 C	T-Td	EVAP.mm/day	Evap.mm/month
Oct	26.2	14.46	9.25	277.53
Nov	19.3	11.91	6.32	189.47
Dec	15.06	10.34	4.89	146.78
Jan	9.6	8.32	3.26	97.80
Feb	11.1	8.88	3.68	110.48
Mar	15.4	10.47	5.00	150.10
Apr	13.4	9.73	4.37	131.04
May	24.4	13.80	8.43	252.85
Jun	20.6	12.39	6.86	205.67
Jul	33.8	17.28	13.43	402.91
Aug	32.5	16.82	12.63	378.90
Sep	28.9	15.46	10.59	317.80
Total				2661.35

Table 3. Calculating monthly and annual evaporation using the Langer equation for the 2023-2024 hydrological year

Langer	Temp 0 C	T-Td	EVAP.mm/day	Evap.mm/month
Oct	24.2	6.28	6.34	190.16
Nov	18.4	11.58	5.99	179.62
Dec	15.2	10.39	4.94	148.14
Jan	8.7	7.99	3.02	90.45
Feb	10.9	8.80	3.63	108.76
Mar	11.7	9.10	3.86	115.71
Apr	15.5	10.51	5.04	151.08
May	26.4	14.54	9.35	280.37
Jun	31.5	16.43	12.03	360.82
Jul	32.7	16.87	12.74	382.27
Aug	34.8	17.68	14.09	422.85
Sep	26.9	14.72	9.59	287.58
Total				2717.82

5. Conclusion

This study of Tharthar 'Lake's satellite-derived surface temperature and hydrological data over the two years from October 2022 to September 2024 reveals significant seasonal and spatial thermal variability characteristic of semi-arid continental climates. The pronounced temperature fluctuations, with summer peaks and winter lows, strongly influence evaporation rates and surface water dynamics. These patterns align with regional climatology, underscoring the dominant role of solar radiation, atmospheric pressure systems, and climatic seasonality in shaping lake thermal regimes. Spatial temperature heterogeneity highlights differential responses between shallow and deep lake zones, with implications for evaporation, water-column mixing, and aquatic ecosystem health. The observed increase in seasonal surface area variability and evaporation rates between study years indicates heightened sensitivity to climatic fluctuations, further stressing the vulnerability of closed-basin lakes like Tharthar to ongoing climate change.

Our findings provide crucial insights into climate-lake interactions in arid environments and establish a valuable baseline for ongoing remote sensing efforts and refined hydrological modeling. The demonstrated linkage between thermal dynamics, evaporation, and lake hydrology underlines the importance of integrating temperature monitoring into water management and climate adaptation policies. This research supports informed decision-making for sustainable water use. It highlights the urgency of coordinated regional strategies to mitigate climate-induced water scarcity in the Tharthar Basin and similar ecosystems.

References

- Ahmed, K. (2022). Detection of the Bathymetry and Shoreline of Terkos Lake Turkey Using Digital Image Processing and GIS. *Iraqi National Journal of Earth Science (INJES)*, 22(1), 55-64. doi: 10.33899/earth.2022.133434.1011
- Al-Ansari, N. A. (2013). "Management of Water Resources in Iraq: Perspectives and Prognoses." *Engineering* 05(08): 667-684.
- Al-Asadi, L. S. M., H. A. M. S. Al-Juboori and M. A. Fakhratov (2024). "Organizational and technological solutions for controlling concrete structures projects in the dry hot weather in Iraq." *BIO Web of Conferences* 107: 06012.
- Al-Bayati, A. H. I., Hammad, J. A., Majdoub, R., & Jabbar, S. A. (2025, February). Pedological Study And Productive Capacity Of Some Soils Within The Euphrates River Sediments At The City Of Al-Ramadi In Iraq. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1449, No. 1, p. 012097). IOP Publishing.
- Al-Fahdawi, A. H. A., & Satam, A. T. M. (2022, October). A Study Of The Water Reality Of Managing The Euphrates River In Anbar Governorate In Light Of The Growing Water Demand For The Period (2020-2040). In *AIP Conference Proceedings* (Vol. 2400, No. 1). AIP Publishing.
- Ali, S. H., A. R. Qubaa and A. B. M. Al-Khayat (2024). "Climate Change and its Potential Impacts on Iraqi Environment: Overview." *IOP Conference Series: Earth and Environmental Science* 1300(1): 012010.
- Allen, R. G., Tasumi, M., & Trezza, R. (2007). Satellite-Based Energy Balance For Mapping Evapotranspiration With Internalized Calibration (METRIC)—Model. *Journal Of Irrigation And Drainage Engineering*, 133(4), 380-394.
- Al-Maliki, L. A., S. K. Al-Mamoori, N. Al-Ansari, K. El-Tawel and F. G. Comair (2022). "Climate change impact on water resources of Iraq (a review of literature)." *IOP Conference Series: Earth and Environmental Science* 1120(1): 012025.
- Al-Qayyssi, K. A., Mohammed, K. S., Al-Dulaimi, S. Z., & Al-Rawi, M. K. (2024). Estimating Soil Erosion in Al-Aubyth Valley Using Modern Techniques and the RUSLE Equation. *Journal homepage: <http://ieta.org/journals/ijdne>*, 19(5), 1551-1561. <https://doi.org/10.36103/j93nst49>
- Al-Timimi, Y. K., Al-Lami, A. M., Basheer, F. S., & Awad, A. Y. (2024). Impacts Of Climate Change On Thermal Bioclimatic Indices Over Iraq. *Iraqi Journal Of Agricultural Sciences*, 55(2), 744-756. DOI: <https://doi.org/10.36103/j93nst49>
- Awwad, A., & Ramal, K. (2021). Climatic Water Balance For Al-Rutba Province - Western Iraq. *Journal Of Alanbar University For Humanities*, 2021(2).109.
- Aya, M., & Kadhim, A. (2025). Land Surface Temperature Estimation from Landsat Thermal Infrared Imagery in Karbala, Iraq. *Iraqi National Journal of Earth Science (INJES)*, 25(1), 343-353. doi:10.33899/earth.2024.144879.1179
- Blanken, P. D., Rouse, W. R., Culf, A. D., Spence, C., Boudreau, L. D., Jasper, J. N., & Verseghy, D. (2000). Eddy Covariance Measurements Of Evaporation From Great Slave Lake, Northwest Territories, Canada. *Water Resources Research*, 36(4), 1069-1077.
- Ebtihal Taki, A. K., & Watheq Fahem, A. J. (2023). Land Surface Temperature Dynamics in Response to Changes in Land Cover in An-Najaf Province, Iraq. *Korean Journal of Remote Sensing*, 39(1), 99-110
- from reanalysis and satellite-derived products: Implication for single-channel land surface temperature retrieval. *Remote*
- Hamid, H. M., F. W. Al-Azawi and Z. F. Makki (2024). "Assessing Hydrological Characteristics in Iraq Dams." *Pakistan Journal of Agricultural Research* 37(1).
- Hirji, R. F. and A. Duda (2024). "Integrated management of lakes, reservoirs, and their basins is critical for a climate-resilient planet: an urgent wake-up call from collective amnesia." *Water Policy* 27(1): 66-87.
- Jassim, Omar, Jamal. (2017). Estimating the storage capacity curve of Hamrin Dam Lake in Iraq using Geographic Information Systems and Remote Sensing. Jordan, Mutah University, Master's Thesis (unpublished).
- Kinana Ghazi Haleme, Saadoun Zahir Al-Dulaimi, Abdul Salam Arif Abdul Razzaq, and Kamal Abed Ala Alah Algayssi, The Relationship Between Large-Scale Relative Vorticity Fields And Rainfall In Syria During The Period, 1980-2020.
- Kong, X., Li, Y., Wang, L., & Liu, H. (2024). Lake Surface Temperature Retrieval Study Based On Landsat 8 Satellite Imagery—A Case Study Of Poyang Lake. *Atmosphere*, 15(4), 428.
- Kumar, R., Verma, R., & Aggarwal, R. K. (2018). Empirical model for the estimation of global solar radiation for Indian locations. *International Journal of Ambient Energy*, 42(2), 124-130. <https://doi.org/10.1080/01430750.2018.1525588>
- M, G. (2008). "Lake Management Perspectives in Arid, Semi-Arid, Sub-Tropical and Tropical Dry climate."
- Muslih, K. D. (2022). Annual And Monthly Trends Of Cooling And Heating Degree-Days In Four Different Cities In Iraq As An Index Of Energy Consumption. *Asia-Pacific Journal Of Atmospheric Sciences*, 58(1), 33-43.
- Oroud, I. M. (2019). The Annual Surface Temperature Patterns Across The Dead Sea As Retrieved From Thermal Images. *Arabian Journal Of Geosciences*, 12(22), 695
- Oroud, I. M., & Altubeiri, Z. S. A. (2023). Estimation Of Evaporation From The Surface Water Of The Gulf Of Aqaba Using Band 10 Onboard Landsat 8. *Dirasat: Human And Social Sciences*, 50(6).
- Parparov, A. and K. D. Hambricht (1996). "A Proposed Framework for the Management of Water Quality in Arid-Region Lakes." *Internationale Revue der gesamten Hydrobiologie und Hydrographie* 81(3): 435-454.

- Ramel, K. A., AL Mehemdi, Y. H., & Awad, A. Y. (2024). Analysis Of The Trends Of Change In Temperature And Precipitation And Their Impact On Water In Anbar Governorate (1980-2023) <https://doi.org/10.35516/hum.v5i1i5.10019>
- Rezazadeh, A., Akbarzadeh, P., & Aminzadeh, M. (2020). The effect of floating balls density on evaporation suppression of water reservoirs in the presence of surface flows. *Journal of Hydrology*, 591, 125323.
- Sajib, M. Q. U., & Wang, T. (2020). Estimation Of Land Surface Temperature In An Agricultural Region Of Bangladesh From Landsat 8: Intercomparison Of Four Algorithms. *Sensors*, 20(6), 1778
- Salman, S. A., S. Shahid, H. A. Afan, M. S. Shiru, N. Al-Ansari and Z. M. Yaseen (2020). "Changes in Climatic Water Sensing, 12(5), 791. <https://doi.org/10.3390/rs12050791>
- Williams, W. D. (1999). "Salinisation: A major threat to water resources in the arid and semi-arid regions of the world." *Lakes & Reservoirs: Science, Policy and Management for Sustainable Use* 4(3-4): 85-91.
- Williams, W. D. (2002). "Environmental threats to salt lakes and the likely status of inland saline ecosystems in 2025." *Environmental Conservation* 29(2): 154-167.
- Williamson, C. E., J. E. Saros, W. F. Vincent and J. P. Smol (2009). "Lakes and reservoirs as sentinels, integrators, and regulators of climate change." *Limnology and Oceanography* 54(6part2): 2273-2282.
- Yang, J., Duan, S. B., Zhang, X., Wu, P., Huang, C., Leng, P., & Gao, M. (2020). Evaluation Of Seven Atmospheric Profiles From Reanalysis And Satellite-Derived Products: Implication For Single-Channel Land Surface Temperature Retrieval. *Remote Sensing*, 12(5), 791.
- Yao, F., B. Livneh, B. Rajagopalan, J. Wang, J.-F. Crétau, Y. Wada and M. Yasir, M., Hui, S., Rahman, S. U., Ilyas, M., Zafar, A., & Mehmood, A. (2020). Estimation Of Land Surface Temperature Using LANDSAT-8 Data-A Case Study Of District Malakand, Khyber Pakhtunkhwa, Pakistan. *Journal Of Liberal Arts And Humanities*, 1, 140-148.
- Yasir, M., Hui, S., Rahman, S. U., Ilyas, M., Zafar, A., & Mehmood, A. (2020). Estimation Of Land Surface Temperature Using LANDSAT-8 Data-A Case Study Of District Malakand, Khyber Pakhtunkhwa, Pakistan. *Journal Of Liberal Arts And Humanities*, 1, 140-148