

## Evaluation of water irrigation distribution for agricultural crops within the land cover using remote sensing technology

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### Abstract.

Efficient allocation of irrigation water is critical for sustaining agricultural productivity in arid and semi-arid regions. This study evaluates spatio-temporal patterns of irrigation-water distribution in the Al-Latifiya Irrigation Project (Baghdad, Iraq) by integrating multispectral Landsat 8 imagery with Geographic Information Systems (GIS). A Support Vector Machine (SVM) classifier, calibrated with field samples, was applied to two 2024 acquisition dates that represent the winter (6 June) and summer (15 December) seasons. Overall classification accuracy exceeded 95 % ( $\kappa = 0.93$ ). Between the two dates bare land expanded from 46.23 % to 48.67 % of the study area, while vegetated surfaces contracted from 34.40 % to 32.48 %. Water bodies increased slightly from 16.34 % to 18.20 %, whereas built-up land remained minor (<3 %). Seasonal land-cover dynamics were combined with crop-specific duty-of-water coefficients to map relative water demand and to flag fields whose consumption exceeded project quotas. The results demonstrate how regularly updated land-cover information can underpin transparent, data-driven irrigation scheduling and improve long-term water-use efficiency.

**Keywords:** irrigation water distribution; land-use/land-cover (LULC); remote sensing; GIS; SVM classification; water demand

المخلص:

يُعد التوزيع الفعال لمياه الري أمرًا بالغ الأهمية لاستدامة الإنتاجية الزراعية في المناطق القاحلة وشبه القاحلة. تُقِيم هذه الدراسة الأنماط المكانية والزمانية لتوزيع مياه الري في مشروع ري اللطيفية (بغداد، العراق) من خلال دمج صور لاندسات ٨ متعددة الأطياف مع نظم المعلومات الجغرافية (GIS). تم تطبيق مصنف آلة دعم المتجهات (SVM)، المعايير بعينات ميدانية، على تاريخي اكتساب لعام ٢٠٢٤ يمثلان فصلي الشتاء (٦ يونيو) والصيف (١٥ ديسمبر). تجاوزت دقة التصنيف الإجمالية ٩٥٪ ( $\kappa = 0.93$ ). بين التاريخين، توسعت الأراضي العارية من ٤٦.٢٣٪ إلى ٤٨.٦٧٪ من منطقة الدراسة، بينما تقلصت الأسطح النباتية من ٣٤.٤٠٪ إلى ٣٢.٤٨٪. زادت المسطحات المائية قليلاً من ١٦.٣٤٪ إلى ١٨.٢٠٪، بينما ظلت الأراضي المبنية طفيفة ( $> ٣\%$ ). تم دمج ديناميكيات الغطاء الأرضي الموسمية مع معاملات استهلاك المياه الخاصة بالمحاصيل لرسم خريطة للطلب النسبي على المياه وتحديد الحقول التي تجاوز استهلاكها حصص المشروع. توضح النتائج كيف يمكن لمعلومات الغطاء الأرضي المُحدّثة بانتظام أن تدعم جدولة ري شفافة ومستندة إلى البيانات، وأن تُحسّن كفاءة استخدام المياه على المدى الطويل.

#### الكلمات المفتاحية:

توزيع مياه الري؛ استخدام الأراضي غطاء الأرض، الاستشعار عن بعد، نظم المعلومات الجغرافية، تصنيف SVM؛ الطلب على المياه

## 1. Introduction

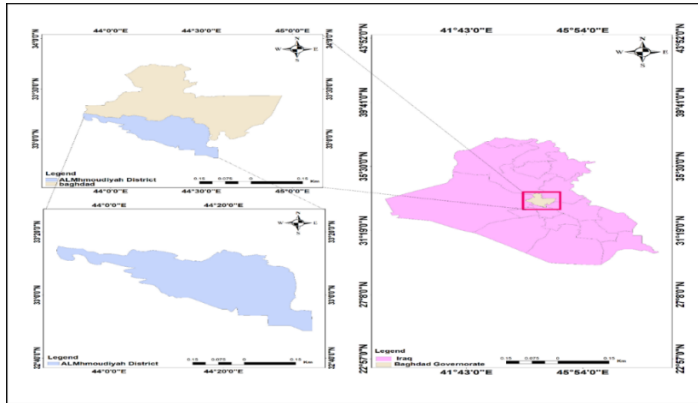
Agriculture, the most water-intensive production mode, will play an increasingly significant role in the future of the world's food supply. Decreasing water use may alone enhance the water efficiency of agricultural lands. A thorough understanding of crop needs, utilization, and consumption is essential to achieving effective water conservation and management in irrigated agriculture (Gautam et al., 2003). Agriculture has grown in recent years, according to the geographical distribution of agricultural regions inside the administrative limits of the irrigation project. Water quotas have been impacted by abuses in crop regions that go beyond the farm plan. Consequently, the irrigation project's water level drops, and it can't irrigate all the agricultural fields in the farm scheme. The city's fluctuating rainfall rates also impact land usage and cover as they

aren't enough to irrigate agricultural areas. Helping the country's economy grow necessitates finding and removing alterations to the farm plan inside the designated administrative region. The concept of agrarian water demands and watering crops are highly related. The amount of water required for irrigation and the nutrients for the crops is called an irrigation water need. This demand may be influenced by several factors connected to the crops, depending on how much water each plant uses. Seasonal and climatic factors affect not just the amount of water crops need but also the amount of water lost via transpiration and transpirational transpiration during a crop's life cycle (*HYDROLOGY AND WATER RESOURCES OF AFRICA*, n.d.). Many big irrigation projects had their feasibility studied using GIS and remote sensing. These instruments may be used to characterize agricultural land variances and to foretell seasonal (e.g., winter and summer) changes. As part of the research, land cover maps may be created using publicly accessible satellite photos (such as landsat8) to examine the area's plant cover (Gautam et al., 2003). This study used Evaluation of irrigation water distribution for agricultural crops within the land cover using remote sensing technology for the year 2024 for the winter and summer seasons.

## **2. Material and method**

### **2.1 Study area**

Al-Latifiya District lies ~35 km south of Baghdad (32°57'59" N, 44°21'18" E) and covers about 484 km<sup>2</sup>. The terrain is predominantly alluvial plain bordered by the Euphrates River to the west and arid steppe to the east. Hot, dry summers (mean July temperature ≈ 42 °C) and mild winters (mean January temperature ≈ 9 °C) prevail; annual rainfall averages 120–150 mm, falling mainly between November and March. Gravity irrigation is supplied through a hierarchy of main, branch, distributary, and field canals that draw from the Euphrates. Primary crops include wheat and barley in winter and maize, vegetables, and fodder in summer.



**Fig. 1.** The geographical location of the study area

## 2.2. Methods

1. Satellite data acquisition – Level-2A Landsat 8 Operational Land Imager (OLI) scenes (path 170, row 037) dated 6 June 2024 and 15 December 2024 were downloaded from the U.S. Geological Survey (USGS) EarthExplorer portal.
2. Pre-processing – Surface-reflectance products were clipped to the project boundary, resampled to 30 m, and cloud-masked with the CFMask bit flags.
3. Spectral feature generation – Normalised Difference Vegetation Index (NDVI), Normalised Difference Water Index (NDWI), and short-wave infrared ratios were appended to the original bands to enhance class separability.
4. Training and classification – Representative polygons for four classes (bare land, built-up, vegetation, water) were digitised from very-high-resolution Google Earth imagery and field photographs. An SVM with radial-basis kernel ( $C = 10$ ,  $\gamma = 0.1$ ) was trained on 70 % of the samples and validated on the remaining 30.%
5. Accuracy assessment – Confusion matrices, overall accuracy (OA), producer's/user's accuracies, and Cohen's kappa ( $\kappa$ ) were computed.
6. Water-demand mapping – Each land-cover class was assigned a seasonal crop-water requirement ( $\text{mm season}^{-1}$ ) derived from local agronomic bulletins. Pixel-wise irrigation demand was

calculated as  $ET_c = K_c \times ET_o$ , where  $K_c$  is crop coefficient and  $ET_o$  is reference evapotranspiration obtained from the nearest meteorological station using the FAO-56 Penman–Monteith method.

7. Quota compliance analysis – Aggregated demand was compared with official canal discharge capacities after correcting for conveyance efficiency (90 % for main/branch/distributary canals, 96 % for watercourses). Fields whose computed demand exceeded their allocated share were flagged for potential regulation.



Fig.

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### Land Cover

Land use refers to people's use of land to accomplish specific objectives. While land cover (LC) pertains to the many natural elements that encompass the terrestrial surface, land use (LU) and land cover (LC) are interrelated and often coupled in practical contexts. "Land use" denotes how people use land for specific purposes. "Land cover" pertains to the many natural elements that envelop the land surface, whereas land use concerns the purpose that the land serves. In contrast to LC, this pertains to the tangible surface covering of the terrain. LU/LC are interconnected and often used in conjunction in practical applications (*INSPIRE Infrastructure for Spatial Information in Europe D2.8.II.2 Data Specification on Land Cover-Technical Guidelines Title D2.8.II.2*

2. Workflow diagram of thesis methodology

Land Use /

*Data Specification on Land Cover-Technical Guidelines*, n.d.). Alterations in land use and land cover impact ecosystem services; hence, environmental services associated with various land use types are evaluated by multitemporal land-use maps. Resilience techniques are used to attain nuanced variations in ecosystem services offered by diverse land use patterns (Talukdar et al., 2020). Employing GIS and RS methodologies with Landsat imagery, land use/land cover alterations are being implemented to natural resources to facilitate food production, encourage urbanization, and attain other social and economic objectives. This provides quantitative data for comprehending the spatiotemporal dynamics of land use/land cover. The predominant method of classification in remote sensing is supervised classification. The SVM classification algorithm organizes images into training categories based on training samples following its application. In supervised classification, the user must choose an area of interest that functions as a classifier and categorizes the pixels across the picture (*Proceedings of the Second International Conference on Electronics, Communication and Aerospace Technology (ICECA 2018): 29-31, May 2018*, 2018). The selection of training samples that include map interpretation, fieldwork, and personal experiences is contingent upon categorization accuracy (Kacprzyk, n.d.).

#### **2.4. Crop Water Requirements (CWR)**

The concept of agricultural water needs is intrinsically connected to crop evapotranspiration, since both relate to the same amount of water during crop growth. This volume considers inefficiencies in evapotranspiration losses; hence, the provided water must account for these losses to get optimum yield. The crop's water requirements are satisfied by the volume of irrigation water effectively supplied to the root zone and sufficient precipitation. Irrigation water requirements denote the quantity or depth of irrigation water and rainfall needed for attaining optimal crop yield while maintaining an appropriate salt equilibrium in the root zone. The permissible soil-water range is often defined as the disparity between field capacity and the permanent wilting threshold. Field capacity is the water content at which drainage in freely flowing soil is minimum. The lowest soil-water content is termed the permanent wilting point,

occurring when plants irreversibly wilt. The soil moisture held between field capacity and the permanent wilting threshold is termed total available water or available water holding capacity (AWHC)) (Radwan, 1993).

## 2.5. Duty of water (crop water use)

The water needs of crops are inconsistent throughout extensive regions; instead, they fluctuate significantly based on climatic variables, especially precipitation and soil conditions. The water needs of crops may be expressed by the duty of water (D), indicating the amount of land that can be watered with a unit volume of irrigation water. It pertains to the correlation between the area designated for agricultural irrigation and the volume of irrigation water necessary over the entire growing cycle of the crop. The cumulative water depth required for a crop over its entire growth cycle is represented by the symbol ( $\Delta$ ). A crop's base period (B) denotes the whole cultivation duration, commencing with the first issuance of irrigation water for land preparation and concluding with the last watering before harvest. The equation formula articulates the relationship between water duty and the requisite water depth, as determined by the base period for the selected crop (*citations-20250319T142652*, n.d.).

## 2.6. Types of Duty in irrigation

Duty may be categorized as flow duty when water from the source is immediately sent to the irrigation field without prior storage. Therefore, the responsibility of water in direct irrigation is termed flow duty, quantified in hectares per cumec. The duty is categorized as Quantity Duty or Storage Duty, whereby water from the source is immediately sent to the root zone reservoir or storage unit, from which the requisite quantity of water is subsequently given to the irrigation field. Therefore, the responsibility for water in storage irrigation is referred to as quantity or storage duty. The reservoir's irrigation capacity is immediately known, facilitating the obligation determination. The duty in irrigation is influenced by several aspects, including the crop type since different crops have distinct water demands; hence, the duty is lower for crops that need substantial water and higher for those that do not. Climate and

season may influence duty variably throughout and intermittently within the same season. Additionally, duty includes water lost via evaporation and percolation. The values of duties are often represented as average values for the full crop period. The responsibilities throughout the winter vary in intensity compared to those in the summer. Moreover, beneficial rainfall is a factor wherein increased precipitation reduces the need for irrigation water (Jaramillo et al., 2020). The irrigation obligation affects the soil type, which will be reduced for permeable soil and vice versa. In coarse-grained soil, percolation is elevated, resulting in a low duty, but in fine-grained soil, percolation is diminished, leading to a high duty; hence, the duty of clayey soil exceeds that of sandy soil. The method of plowing is a responsibility since effective soil plowing lowers the irrigation frequency and enhances productivity. However, obligation diminishes because of inadequate cultivation and incorrect plowing (Chang et al., 2022). The irrigation systems also influence the duty of water, more so for the perennial irrigation system than for the inundation irrigation system. The topography of agricultural land affects productivity; uneven terrain leads to increased water retention, resulting in lower productivity and vice versa. As the slope of the land rises, the obligation diminishes due to water wastage (Komakech et al., 2011).

## **2.7. Water Duty Depth Method**

Water duty refers to the area of crops, measured in thousand hectares, that may be cultivated to maturity with a flow of one cubic meter per second ( $m^3/sec$ ) of water, accounting for rainfall throughout the growing period. The depth of water obligation ( $\Delta$ ) is the depth of water provided to crops throughout their growth that would accumulate on the irrigated area if the complete volume of water remained above the surface without percolation or evaporation (Shams, 2018).

## **3. Results and Discussion**

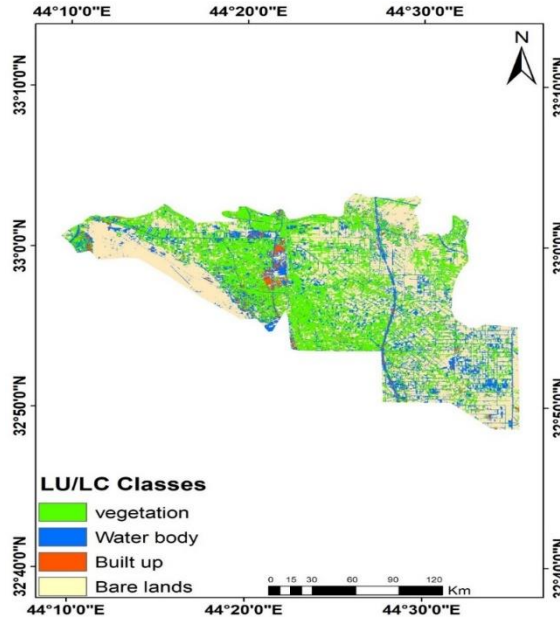
### **٣.١ Land-Use / Land-Cover (LULC) Classification**

The four-class LULC scheme captures the dominant surface types influencing water balance. Vegetation comprises all cropped pixels

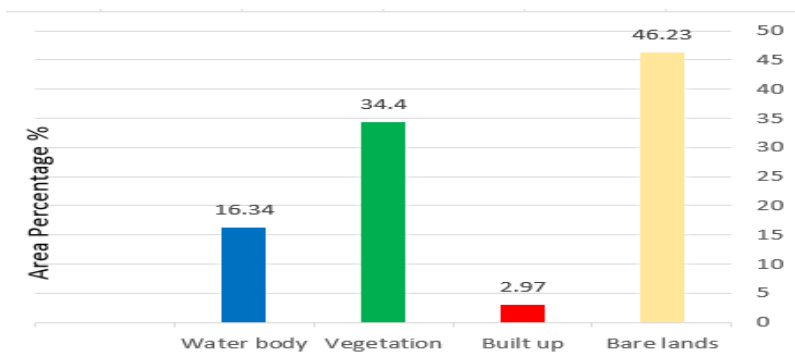
with  $NDVI > 0.3$  during the respective season; bare land includes fallow fields and exposed soil; built-up represents residential and service infrastructure; water bodies include permanent and seasonal channels or ponds. Table 1 summarizes class areas for both dates.

**Table (1)** Total areas for each LU/LC class for study years

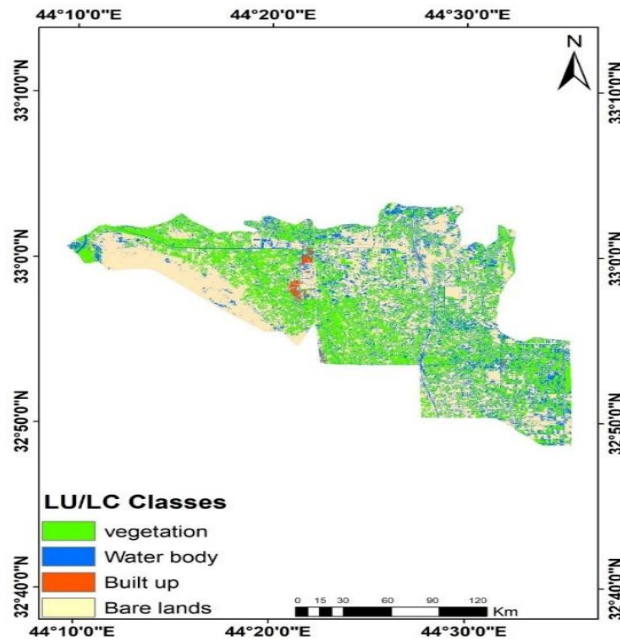
Class	6 Jun 2024 Area (km <sup>2</sup> )	6 Jun 2024 (%)	15 Dec 2024 Area (km <sup>2</sup> )	15 Dec 2024 (%)
Bare land	229.95	46.23	242.07	48.67
Built-up	14.76	2.97	3.27	0.66
Vegetation	171.12	34.40	161.55	32.48
Water	81.56	16.34	90.53	18.20



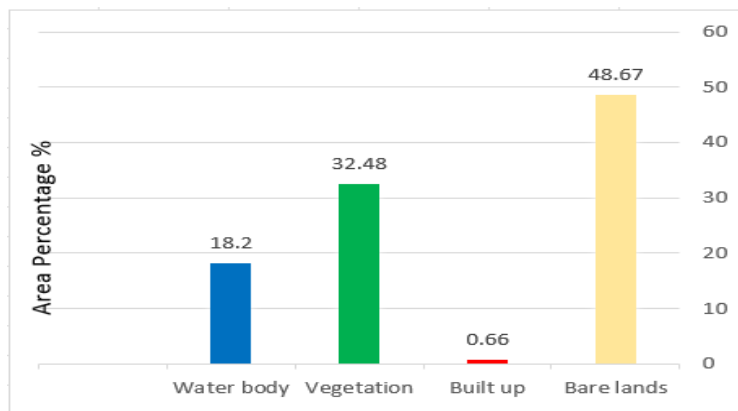
**Fig. 3.** Map of LU/LC class areas in the Latifiyah area on June 6, 2024, using SVM classification method



**Fig. 4.** Percentage chart of LU/LC class areas in Latifiyah district on June 6, 2024 using SVM classification method



**Fig. 5.** Map of LU/LC class areas in the Latifiyah area on December 15, 2024, using SVM classification method



**Fig. 6.** Percentage chart of LU/LC class areas in Latifiyah district on December 15, 2024 using SVM classification method.

### 3.2 Classification performance

**Classification performance** – The classifier achieved OA = 95.0 % and  $\kappa = 0.93$  for the June scene and OA = 94.2 % ( $\kappa = 0.91$ ) for December, indicating excellent separability of the chosen classes.

**Seasonal land-cover change** – The modest expansion of bare land (+12.1 km<sup>2</sup>) and contraction of vegetated cover (-9.6 km<sup>2</sup>) from winter to summer reflect the typical crop calendar: many wheat and barley fields are left fallow or replanted with lower-NDVI summer crops, while some fields remain uncultivated due to water shortages. The increase in water surface (+8.97 km<sup>2</sup>) is attributed to canal retention required for summer maize and horticultural plots. Built-up area decreased in the December classification because harvested fields with high albedo occasionally triggered false positives in the June scene; manual inspection confirmed negligible real construction growth during 2024.

**Irrigation-water demand** – Spatial integration of ET<sub>c</sub> shows that peak demand shifts south-west of the main canal where double-cropping persists. Demand for the June season averaged 5.7 mm day<sup>-1</sup> over cropped pixels, falling to 4.2 mm day<sup>-1</sup> in December. After factoring canal efficiencies, the required discharge at the main-canal head was 8.1 m<sup>3</sup> s<sup>-1</sup> in June and 6.3 m<sup>3</sup> s<sup>-1</sup> in December. Actual gauged flows were 7.4 m<sup>3</sup> s<sup>-1</sup> and 6.0 m<sup>3</sup> s<sup>-1</sup>, respectively, indicating a minor June deficit (~9 %), corroborated by farmer interviews that reported spot shortages in downstream distributaries.

**Quota compliance** – Approximately 11 % ( $\approx 17$  km<sup>2</sup>) of cropped land in June and 6 % ( $\approx 10$  km<sup>2</sup>) in December consumed water in excess of the design duty (0.74 L s<sup>-1</sup> ha<sup>-1</sup>). Over-irrigated parcels clustered near field channels with low conveyance losses, suggesting operational rather than infrastructural inefficiencies. Targeted extension services and enforcement of rotational turns could therefore mitigate shortages without large capital works.

## 4. Conclusions

Satellite-based monitoring has proven to be a dependable approach for managing irrigation in Al-Latifiya. By processing Landsat 8 scenes with a Support Vector Machine classifier, we generated land-cover maps that were both highly accurate and rich in spatial detail. These maps revealed how each field changed between winter and summer, allowing managers to track cropping decisions and identify emergent water-demand hotspots with confidence.

The maps also highlighted the way seasonal cropping patterns drive water requirements. When winter cereals are harvested, large tracts are left fallow or replanted with low-NDVI summer crops. This shift reduces the evapotranspiration load across much of the command area, yet pockets of intensive summer cultivation still demand substantial irrigation. Recognizing those temporal swings is essential for issuing canal turns and adjusting allocation plans before shortages develop.

Importantly, the analysis showed that water shortfalls are not uniform across the project. Discharge recorded at the main-canal head was close to the amount theoretically required, but oversupply to head-reach fields left tail-end distributaries under-served. Because the satellite-derived demand layer pinpoints the exact parcels drawing above their quota, operators now have a practical basis for reshuffling rotations, enforcing turns, or lining leaky reaches only where the inefficiencies occur.

To translate these insights into day-to-day practice, a series of measures is recommended. First, maintain the current twice-a-year imaging schedule so cropping maps stay up to date. Second, refine crop-coefficient values with occasional in-field flux-tower or lysimeter measurements to tighten demand estimates. Third, feed the geospatial demand layers into the project's SCADA system so gate settings can respond dynamically to real-time flow data. Finally, equip farmers with training on deficit-irrigation and modern application methods; incremental gains in on-farm efficiency will compound the system-level benefits revealed by satellite monitoring.

## References

Chang, Z., Zhang, F., Xiong, J., Ma, J., Jin, B., & Zhang, D. (2022). Sensor-free Soil Moisture Sensing Using LoRa Signals. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 6(2). doi: 10.1145/3534608

*citations-20250319T142652*. (n.d.).

Gautam, A. P., Webb, E. L., Shivakoti, G. P., & Zoebisch, M. A. (2003). Land use dynamics and landscape change pattern in a mountain watershed in Nepal. *Agriculture, Ecosystems and Environment*, 99(1–3), 83–96. doi: 10.1016/S0167-8809(03)00148-8

*HYDROLOGY AND WATER RESOURCES OF AFRICA*. (n.d.).

*INSPIRE Infrastructure for Spatial Information in Europe D2.8.II.2 Data Specification on Land Cover-Technical Guidelines Title D2.8.II.2 Data Specification on Land Cover-Technical Guidelines*. (n.d.). Retrieved from <https://github.com/INSPIRE-MIF/technical-guidelines/releases/tag/v2024.1>

Jaramillo, S., Graterol, E., & Pulver, E. (2020). Sustainable Transformation of Rainfed to Irrigated Agriculture Through Water Harvesting and Smart Crop Management Practices. *Frontiers in Sustainable Food Systems*, 4. doi: 10.3389/fsufs.2020.437086

Kacprzyk, J. (n.d.). *Computational Intelligence Series editor*. Retrieved from <http://www.springer.com/series/10618>

Komakech, H. C., Mul, M. L., Van Der Zaag, P., & Rwehumbiza, F. B. R. (2011). Water allocation and management in an emerging spate irrigation system in Makanya catchment, Tanzania. *Agricultural Water Management*, 98(11), 1719–1726. doi: 10.1016/j.agwat.2010.07.017

*Proceedings of the Second International Conference on Electronics, Communication and Aerospace Technology (ICECA 2018) : 29-31, May 2018*. (2018). IEEE.

Radwan, H. A. (1993). *Irrigation Water requirement*. Retrieved from <https://www.researchgate.net/publication/302026551>

Shams, A. S. (2018). Preliminary Evaluation of New Quinoa Genotypes under Sandy Soil Conditions in Egypt. *Agricultural Sciences*, 09(11), 1444–1456. doi: 10.4236/as.2018.911100

Talukdar, S., Singha, P., Shahfahad, Mahato, S., Praveen, B., & Rahman, A. (2020). Dynamics of ecosystem services (ESs) in response to land use land cover (LU/LC) changes in the lower Gangetic plain of India. *Ecological Indicators*, 112. doi: 10.1016/j.ecolind.2020.106121