

Lift Irrigation Planning for Drought-Prone Koraput, India

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HIGHLIGHTS

- A renewable energy-based lift irrigation system was designed for drought-prone Koraput to support millet cultivation.
- Smart irrigation and CROPWAT analysis were used to optimize water use and improve efficiency.
- The project includes storage infrastructure and farmer training to enhance resilience and livelihoods.

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ABSTRACT

The Koraput district, prone to frequent droughts, requires sustainable irrigation strategies to support agriculture, particularly millet cultivation, which is both climate-resilient and water-efficient. This study focuses on the planning and design of a lift irrigation system suited to the region's agro-ecological conditions. The system aims to optimize the use of local water resources, ensuring reliable irrigation and improving crop productivity. Key elements of the project include the identification of suitable sites for lift stations, the design of pump systems capable of transporting water to higher elevations, and the construction of storage tanks to manage seasonal water shortages. A 10 HP pump has been proposed, supported by renewable energy to ensure energy efficiency and reduce operational costs. Smart irrigation techniques are integrated to minimize water wastage and enhance system performance. Technical assessments using CROPWAT show that maize requires 62.1 mm (net) and 43.5 mm (gross) irrigation, while millet needs 106.0 mm (net) and 74.2 mm (gross). The crop water demand was estimated at 451.6 mm/dec for maize and 375.5 mm/dec for millet. Structural design for the underground tank specifies a 400 mm wall thickness, 2296.8 mm² minimum steel reinforcement, and 1.5 N/mm² tensile stress. A triangular channel, 4.42 m deep and 11.05 m wide with a 1:1 side slope, was designed for water conveyance.

1. INTRODUCTION

Irrigation refers to the artificial application of water to soil or land to facilitate crop growth, support landscaping, or manage ecosystems in areas where rainfall is insufficient. As a cornerstone of modern agriculture, irrigation supplements natural precipitation, enabling farmers to maintain optimal conditions for plant development and productivity.

Several irrigation methods are commonly used, each suited to specific environmental and crop requirements. Surface irrigation distributes water across the soil surface, allowing it to infiltrate naturally. Sprinkler irrigation mimics rainfall by spraying water over crops through pressurized systems, while drip irrigation delivers water directly to the root zones via a network of emitters and pipes, maximizing water use efficiency.

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Irrigation significantly contributes to agricultural productivity by boosting crop yields, enhancing produce quality, and enabling farming in arid and semi-arid regions. However, poor irrigation management can lead to problems such as water wastage, soil salinization, and ecological damage. Hence, sustainable irrigation practices are crucial for conserving water resources and minimizing environmental harm.

Lift irrigation is a specialized technique used to convey water from sources located at lower elevations—such as rivers, reservoirs, or wells—to higher terrain where agricultural fields are situated. This system relies on pumps, mechanical devices, or in some cases, manual labor to elevate water and transport it through canals or pipelines.

Historically, lift irrigation has evolved from rudimentary manual systems to advanced, mechanized installations. Its primary advantage lies in enabling irrigation in topographically challenging or water-scarce regions. Moreover, lift irrigation allows for better control over water distribution, which supports more efficient water use and improved crop management. Nevertheless, it involves substantial capital investment and requires regular maintenance. Therefore, integrating sustainable design and operational practices is essential to ensure long-term viability and environmental compatibility.

2. LITERATURE REVIEW

Ghobrial and Eisa (1986) address the challenge of modifying weirs in the Fayoum, Egypt, resulting in invalid or unknown head-discharge ratings. Despite the initial flow measurement efforts, insufficient accuracy was achieved. The study then employs hydraulic theory to derive acceptable ratings for the modified weirs, demonstrating improved accuracy and efficiency compared to traditional measurement methods. This research provides valuable insights for managing irrigation systems effectively.

Belasy et al. (2014) explore the impact of bottom pipes on weir flow and focusing on the Bahr Hassan Wasef Weir. Using the I-D Sobek model, they simulate modifications to Fayoumi Standard weirs with added pipes for increased downstream flow. Field Measurements and mathematical modelling reveal significant differences in discharge compared to clear overflow weirs. The study aims to assist irrigation engineers in accurately estimating discharge for similar structures.

U. Surendran et al. (2015) titled "Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable

water resources management: A case study in the Palakkad district of humid tropical Kerala, India," the authors employed CROPWAT 8.0 to compute crop water requirements for various crops in Palakkad district. The research focused on assessing water resources and managing them sustainably. The study revealed the total water requirement for different crops and highlighted the need for efficient water resource management to address future demands.

Bangi (2016) addresses the declining trend in tank irrigation systems in South India due to factors like inadequate rainfall and silt deposition. Focusing on the Muchkandi minor irrigation tank near Bagalkot, Karnataka. The study proposes the design and development of a new minor irrigation tank. This aims to rejuvenate existing tanks for irrigation and groundwater recharge, highlighting the importance of sustainable water management in arid and semi-arid regions.

Dave et al. (2017) explore the design and seismic analysis of ground-supported water tanks, crucial structures subjected to hydrostatic and hydrodynamic pressures alongside seismic forces. Utilizing IS codes for design and seismic analysis; the study focuses on rectangular ground-supported tanks. It emphasizes the relationship between tank capacity, moment capacity, reinforcement area, base shear, impulsive height, and overturning moment, providing insights into the structural integrity of such tanks.

Sethaputra et al. (2017) propose a method for sizing small irrigation weirs, addressing technical constraints and budget limitations commonly encountered in weir design. Their study introduces equations from the "KKU-2527 Weir" design manual, offering flexibility in weir dimensions to accommodate site conditions. This approach allows for on-site modifications, such as adjusting the stilling basin elevation or weir width to optimize hydraulic characteristics and overcome construction challenges, providing practical solutions for local administrative Organizations.

Sagar Mhamunkar et al. (2018) focuses on the design and analysis of an overhead water tank in Phule Nagar, Ambernath. With over 68% of India's population residing in rural areas, addressing domestic water scarcity is crucial. The research aims to provide innovative solutions by studying elevated storage reservoirs (ESRs) to ensure structural safety and minimize damage from natural hazards like earthquakes. It references Indian standards from 2009, emphasizing the adoption of limit-state design methods to achieve crack-free structures.

Memon and Jamsa (2018) analyse the significance of irrigation scheduling in optimizing crop water management for soybean and tomato cultivation. Leveraging FAO-Cropwat 8.0 software, they address the pressing need for efficient water use in agriculture, particularly in water-scarce regions like Godhra Taluka, Gujarat, India. Their research is valuable. Insights into mitigating yield reduction and ensuring food security amidst escalating water scarcity challenges.

Abed and Al-Ansari (2019) examine water scarcity in southern Iraq, utilizing FAO CROPWAT 8.0 software to determine crop water requirements (CWRs) and irrigation schedules. Their study underscores the model's utility in managing water resources effectively amidst changing climatic conditions, offering valuable insights for sustainable agriculture in Iraq.

Aravind et al. (2021) utilized CROPWAT 8.0 software to estimate the water requirement of sugarcane in Coimbatore District. Their study aimed to calculate net irrigation needs and monthly water requirements for sugarcane cultivation. Findings underscored the importance of modern irrigation techniques for reducing water usage, potentially expanding agricultural production. The estimated crop water requirement for sugarcane in Coimbatore was determined to be 1438.7 mm.

Anjana and Baliga (2021) conduct a comparative study on the design of elevated circular concrete water tanks. Recognizing water's essentiality for all living beings, particularly in water-scarce areas, the research focuses on supplying water through publicly built tanks. The study utilizes manual design methods based on IS codes and software analysis using ETABS. By comparing results from manual and software design approaches, the research observes a reduction in steel usage.

K. Wagh et al. (2021) focuses on the design and analysis of underground water tanks, specifically ctangular ones, utilizing Staad Pro software. Underground water tanks encounter unique loads, predominantly horizontal or lateral pressures from earth and water. The research emphasizes the varying load distribution along the tank's side walls, with greater loads at the bottom diminishing linearly towards the top.

Nazir and Kumar (2022) addressed the design and analysis of circular overhead Intake water tanks using StaadPro V8i SS6 software. Recognizing water's vital role in sustaining life, particularly in densely

populated areas, the research underscores the importance of efficient water storage and supply systems. Emphasizing the fluctuating demand for water throughout the day, the study highlights the need for crack-free tank construction to ensure consistent water availability. Additionally, it acknowledges the significance of water in agricultural and industrial sectors, advocating for updated tank designs to meet evolving demands effectively.

Bhende and Jamale (2022) conduct a comparative analysis of different shapes of underground water tanks, focusing on thermal energy storage capacity and thermal stratification under laminar natural convection. Their study investigates 10 different tank shapes, revealing that spherical and barrel-shaped tanks exhibit superior thermal energy storage capacity compared to cylindrical tanks. The research emphasizes the influence of tank surface area on storage capacity and categorizes shapes based on their thermal stratification characteristics.

Geressu et al. (2023) introduce a multi-objective optimization approach for the design of diversion weir structures. Traditionally, weir design relies on empirical recommendations, lacking consideration of trade-offs between design objectives. Their proposed method incorporates diverse stability metrics and cost considerations, offering insights into optimal parameter values for weir components. This approach enhances weir design by revealing potentially superior solutions, facilitating informed decision-making in the construction project.

Ranjan et al. (2023) investigated the water requirements of wheat crops in the vicinity of the Tonna Pumping Canal using CROPWAT software. It utilized 2017-2018 climate data to assess crop water needs, determining reference crop evapotranspiration (ET_o) via the FAO Penman-Monteith method. Results indicated varying water demand throughout wheat growth stages, with the canal capable of meeting irrigation needs.

3. STUDY AREA

Koraput district in Odisha boasts significant features such as major rivers, waterfalls, and the imposing Deomali mountain. It spans 8,807 km² with a population of 1,379,647 and a literacy rate of 36.20%. Notable locations include Jeypur, Duduma, Bagra, and the Sunabeda MiG factory. The district's cultivable land covers 301,000 hectares, and it enjoys good connectivity with other Odisha districts. Koraput's attractions encompass Gupteswar, Neelabadi, Nandapur, Sunabeda, Duduma Waterfall, and Ankadeli.

The Jaypore-deoghathi range is a part of the Kolab basin, Koraput. It extends from 18°45'46''N latitude and 82°32'25'' E longitude (Fig 1). Soil found in these regions is generally red loamy, red sandy, or

sandy clay loam. The average Temperature of the Kolab basin of Koraput is around 24°C, although it varies from around 19°C during Winter (January) to 28°C during Summer (May).

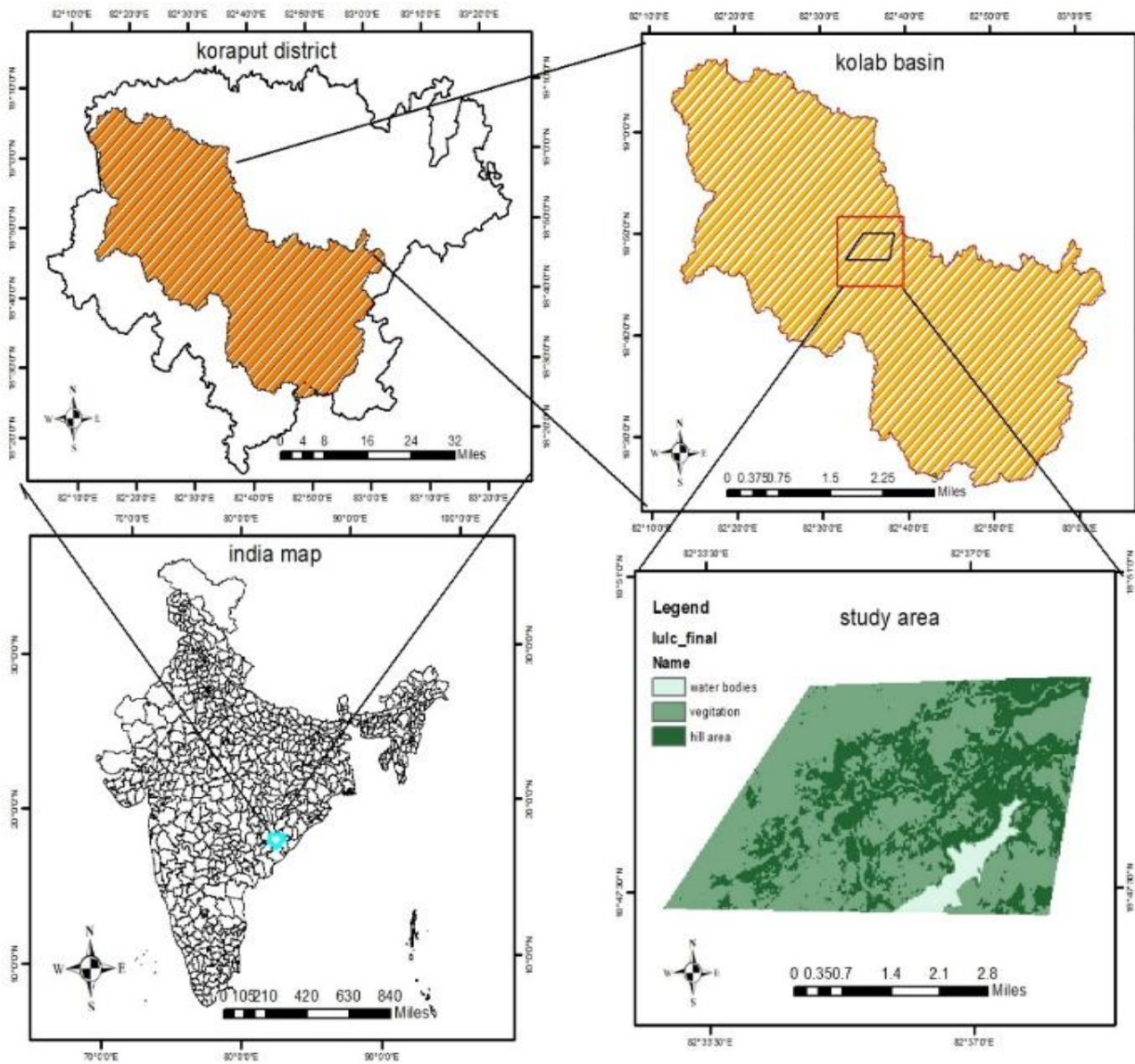


Figure 1. Study area

4. METHODOLOGY

CROPWAT 8.0, a software tool developed by the FAO to estimate crop water requirements (CWR), effective rainfall, and irrigation scheduling. Climatic data such as temperature, humidity, wind speed, sunshine hours, and rainfall were input into the model. Reference evapotranspiration (ET_o) was calculated using the FAO Penman–Monteith method, which incorporates parameters like net radiation, mean air temperature, wind speed at 2 meters, and vapor pressure deficit. Effective rainfall was estimated using the USDA Soil Conservation Service method to account for infiltration losses and surface runoff,

ensuring accurate calculation of the portion of rainfall contributing to crop water needs.

Crop-specific parameters were defined for maize and millet, including crop coefficients (K_c), rooting depth, yield response factor (K_y), and critical depletion fraction. The growth stages of each crop—initial, development, mid-season, and late season—were incorporated to reflect changes in water demand throughout the crop cycle. Soil data such as texture and water-holding capacity were included to model the daily soil-water balance, which is essential for determining when and how much irrigation is required.

Crop evapotranspiration (ETc) was determined by multiplying the crop coefficient (Kc) by the reference evapotranspiration (ETo). The net irrigation requirement was calculated by subtracting effective rainfall and existing soil moisture from the total crop water requirement. Based on these values, gross irrigation requirements were derived and used to develop optimal irrigation schedules. For maize, the total gross and net irrigation needs were 62.1 mm and 43.5 mm, respectively, while millet required 106.0 mm gross and 74.2 mm net. These results informed efficient irrigation strategies tailored to each crop's specific needs under regional climatic conditions.

5. RESULTS AND DISCUSSION

The reference evapotranspiration (ETo) in the Koraput district, determined using CROPWAT software, is 4.18 mm/day, with effective rainfall measured at 1168.8 mm. For maize, the gross and net irrigation requirements were estimated to be 62.1 mm and 43.5 mm, respectively, while for millet these were 106.0 mm and 74.2 mm. The crop water requirement for maize was found to be 451.6 mm/dec with an irrigation requirement of 60.3 mm/dec. For millet, the crop water requirement was 375.5 mm/dec with an irrigation requirement of 87.2 mm/dec, indicating that millets consume less water overall.

In the hydraulic structure design, a weir was planned with a design discharge of 12000 cumec. The crest height above the riverbed was set at 103 m, with the bed level at 100 m. Using the standard discharge formula with an assumed discharge coefficient of 2.2, the effective head (He) was iteratively calculated to be 13.4 m. The effective length of the weir was recalculated considering pier contractions, resulting in a final value of 112.02 m. The downstream profile of the weir was determined using the U.S. Bureau of Reclamation method for vertical upstream face weirs, resulting in a downstream curve defined by the equation $y=0.055x^{1.85}$. Coordinates for the downstream face were calculated up to $x = 19.11$ m. The upstream profile followed the standard expression involving the head over the crest, leading to a parabolic curve computed for values of x between -0.5 m and -3.62 m.

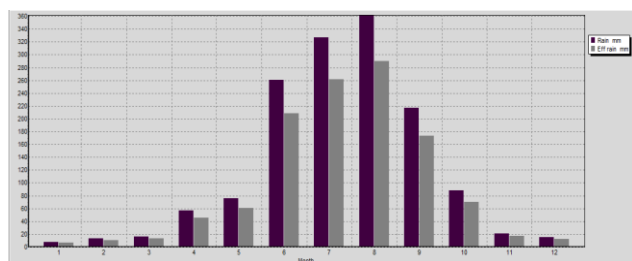


Figure 2. Effective rainfall plot

An intake well of 9 m internal diameter and 9m height was designed with wall thickness considered at 700 mm. For the condition where the tank is empty and soil pressure acts externally, the active pressure was computed to be 162.69 kN/m², and the maximum compressive stress was found to be within permissible limits. For the full tank condition, wall thicknesses were varied with depth, and hoop tension was calculated based on IS:3370 Part IV. Required steel reinforcement was determined, and appropriate bar spacing and diameter were proposed to satisfy structural requirements. The concrete tensile stress was checked and found to be well within allowable limits.

A pump was designed for irrigating 100 hectares of maize. Given the duty of 2295.8 ha/cumec and a pump efficiency of 48%, the required discharge was calculated, resulting in a work output of 346.08 kg.m/sec. The horsepower requirement was 4.61 HP, and with the given efficiency, the input power was approximately 10 HP.

For the irrigation canal design, with a discharge of 45 cumec, a longitudinal slope of 1:9000, and side slopes of 5:4 (H:V), the channel cross-section was designed using Manning's equation. With a Manning's coefficient of 0.015, the flow depth was determined to be 4.42 m, and the base width 11.05 m, leading to a trapezoidal cross-section suitable for the design discharge.

From the results, it was evident that millet is a more water-efficient crop compared to maize, making it suitable for drought-prone or water-scarce regions. Millets also provide better nutritional value, being rich in proteins, dietary fiber, vitamins (B3, B6, B9), zinc, and antioxidants like flavonoids and lignans. In contrast, maize is higher in carbohydrates and contains essential minerals such as calcium, iron, and zinc but is comparatively lower in protein. Thus, promoting millet cultivation not only aids water conservation but also enhances nutritional security.

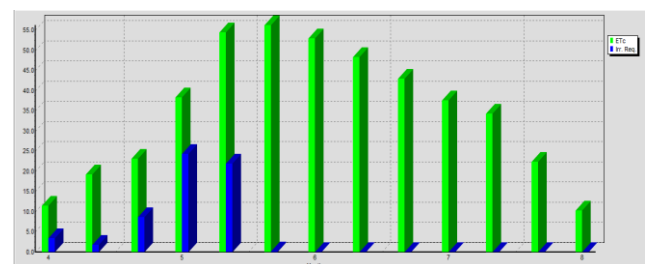


Figure 3. Water Requirement of Maize

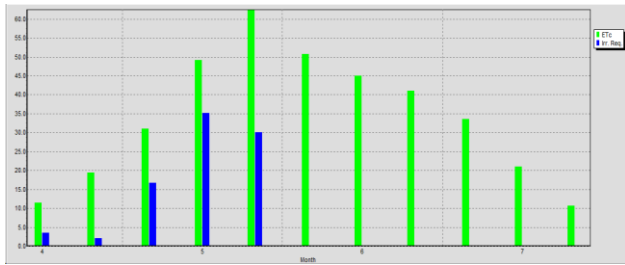


Figure 4. Water Requirement of Millete

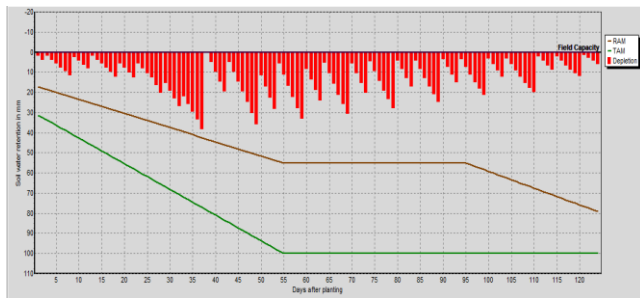


Figure 5. Irrigation scheduling graph of maize

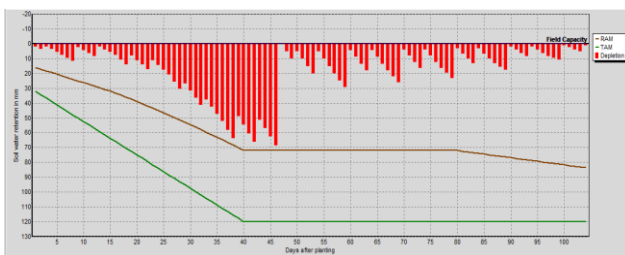


Figure 6. Irrigation scheduling graph of Millete

Based on the analysis conducted using CROPWAT for the Koraput district, it was found that the crop water requirement for conventionally grown crops such as maize is significantly higher compared to millets. This highlights the need to adopt more water-efficient cropping systems in drought-prone regions like Koraput. Millets, being C_4 crops, are highly efficient in utilizing carbon dioxide and are known for their resilience under harsh climatic conditions. They can sustain grain and fodder production even during prolonged droughts and high temperatures. As a result, promoting millet cultivation in this region presents a sustainable and climate-resilient agricultural solution. Additionally, to support crop water demand during hot and dry periods, the development of a lift irrigation system comprising a weir, intake well, storage tank, and pump has been proposed. This system would help supplement irrigation requirements and ensure water availability during critical crop growth stages.

6. CONCLUSION

Millets also offer notable nutritional and environmental advantages. Their low glycaemic index, attributed to a high content of complex carbohydrates and low levels of simple sugars, makes them particularly beneficial for individuals with diabetes. Moreover, studies have shown that millet consumption may contribute to improved cardiovascular health by increasing good cholesterol and reducing triglycerides. Agriculturally, millets thrive in rain-fed areas with marginal soil fertility, unlike water-intensive crops such as rice and wheat. An ICRISAT study suggests that a single rice plant requires about 2.5 times more water than a millet plant. This significant difference reinforces the recommendation to promote millet cultivation in water-scarce regions. Given their low-fat content, high dietary fibre, and ability to grow under minimal inputs, millets emerge as a sustainable and nutrition-rich crop for addressing food and water security challenges in regions like Koraput.

REFERENCES

- Abozeid, G., El-Belasy, A. M., & Shehata, S. M. (2014). Simulation of flow over weirs with bottom pipes (Case study: Bahr Hassan Wasef Weir). *JES. Journal of Engineering Sciences*, 42(4), 891-904.
- Anjana, M. V., & Baliga, L. (2021). Comparative study on the design of elevated circular concrete water tank.
- Bhende, A. A., & Jamale, P. B. (2022). Comparative analysis of different shapes of underground water tank. *International Journal of Modern Developments in Engineering and Science*, 1(5), 19-21.
- Dave, R., Patel, R., & Vyas, P. (2017). Design and seismic analysis of ground supported water tank. *Kalpa Publications in Civil Engineering*, 1, 1-6.
- Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2019). Crop water requirements and irrigation schedules for some major crops in Southern Iraq. *Water*, 11(4), 756.
- Gang, M. G., Yun, C. J., & Jeon, G. Y. (2015). Weir design for ungauged watersheds of developing countries. *Magazine of the Korean Society of Agricultural Engineers*, 57(1), 73-80.
- Geressu, R. T., Tarekegn, T. H., & Demissie, E. A. (2023). Optimised multi-objective design of weir structures. *Proceedings of the Institution of Civil Engineers - Water Management*, 1-13.
- Hassan, I. M., Abozeid, G., & Shehata, S. M. (2010). Hydraulic of clear and submerged overfall weirs with bottom circular openings. *Journal of Faculty of Engineering, Ain Shams University*, 1, 115-119.
- Kannan, B. (2021). Estimation of crop water requirement for sugarcane in Coimbatore district using FAO CROPWAT. *Madras Agricultural Journal*, 108.
- Memon, A. V., & Jamsa, S. (2018). Crop water requirement and irrigation scheduling of soybean and tomato crop using CROPWAT 8.0. *International Research Journal of Engineering and Technology*, 5(9), 669-671.

- Mhamunkar, S., Satkar, M., Pulaskar, D., Khairnar, N., Sharan, R., & Shaikh, R. (2011). Design and analysis of overhead water tank at Phule Nagar, Ambernath. Population, 4106.
- Mosisa, G. (2024). Structural performance evaluation of diversion weir structure: Case study of Basaka small scale irrigation scheme, Oromia, Ethiopia. American Journal of Civil Engineering, 12(1), 27-31.
- Nazir, S., & Kumar, A. (2022). Design and analysis of circular overhead Intze water tank by STAAD Pro V8i SS6 software. International Journal of Innovative Research in Engineering & Management, 9(2), 393-402.
- Ranjan, A., Denis, D. M., Sherring, A., Kumar, M., Singh, V., & Masih, S. (2023). Water requirements of wheat crops in a small watershed by using CROPWAT. International Journal of Environmental and Climate Change, 13(2), 126-133.
- Sethaputra, S., Kuntiyawichai, K., Plernkamon, V., & Sawaengphet, J. (2017). Sizing of a small irrigation weir. Engineering & Applied Science Research, 44(3).
- Surendran, U., Sushanth, C. M., Mammen, G., & Joseph, E. J. (2015). Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India. Aquatic Procedia, 4, 1211-1219.
- T. Mulugeta & W. Tadesse. (2022). Assessment of irrigation scheme failure factors: A case study on Marza irrigation scheme Fogera, Amhara, Ethiopia. Water Conservation Science and Engineering, 465-474.
- Wagh, K. K., Ghuge, A. K., Gaidhane, D. N., & Gandhe, G. R. (2021). Design and analysis of underground water tank by using STAAD Pro. International Research Journal of Engineering and Technology, 8(4), 4527-4532.