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New Method for Reducing Evaporation Losses in Dams, Large Stagnant Water, and Agricultural Water Management

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Abstract

This study evaluates two research methods to mitigate water evaporation in arid regions with high temperatures and sparse rainfall. The first method assesses evaporation control using locally available date palm yarn (SEES) as a floating cover for water bodies. The second method investigates the effect of SEES laid under ploughed ground to enhance soil moisture retention. Evaporation from water surfaces was measured using two identical evaporation pan—one covered with date palm yarn and the other left open—over two months. Results indicate a 7.5% reduction in evaporation for the covered pool compared to the open one. The floating SEES cover provided shade, reduced direct solar exposure, and conserved more water for irrigation. Additionally, SEES placed under ploughed soil retained moisture, increasing soil water content and plant root absorption. Chemical analysis revealed that SEES contains beneficial compounds that enhance soil wettability and nutrient retention. This method provides a low-cost, sustainable, and eco-friendly solution for reducing water loss in agriculture and water reservoirs.

Keywords: SEES, Evaporation Control, Water Management, Date Palm Yarn, Soil Moisture Retention

Introduction

Water is one of the most vital resources on Earth, covering approximately 70% of the planet's surface. While oceans account for nearly 95% of the total water, the remaining portion is distributed among lakes, reservoirs, rivers, ponds, and soil moisture. Reservoirs play a crucial role in water storage for irrigation and domestic use, as well as in mitigating the effects of dust storms. However, in arid regions, evaporation poses a significant challenge, leading to substantial water loss.

In southeastern Iran, particularly in Baluchistan region, evaporation can result in the loss of up to 50% of stored water, especially between May and September. This loss exacerbates existing water scarcity issues, as evaporated water is effectively removed from the local hydrological system. The rate of evaporation is influenced by several factors, including the surface area of the water body, where larger reservoirs experience greater losses. Higher temperatures accelerate the movement of water molecules, increasing their kinetic energy and enhancing the transition from liquid to vapor. Wind speed also plays a crucial role, as strong winds disrupt the equilibrium at the water surface, carrying away moisture and intensifying evaporation. Additionally, humidity levels affect the process—drier air absorbs moisture more readily, whereas high humidity slows down evaporation.

According to the kinetic theory of evaporation, water molecules are in continuous random motion. Some molecules, possessing sufficient kinetic energy, overcome intermolecular forces and transition into the gaseous phase. These principles highlight the importance of controlling environmental conditions to minimize water loss from reservoirs in arid regions.

Various methods have been explored to suppress evaporation, including chemical surface films, continuous plastic covers, suspended shading systems, and modular floating elements [1].

This study aims to develop a practical, environmentally friendly, and cost-effective method for reducing evaporation losses by using Phoenix dactylifera (date palm) fibers and leaves as a natural cover on water reservoirs. In addition to mitigating water loss, this approach may enhance soil moisture retention in cultivated lands. The research was conducted in Saravan city, southeastern

Iran, over a six-month period in 2019, evaluating the effectiveness of date palm leaves in suppressing evaporation [2].

The date palm (Phoenix dactylifera) has been cultivated for centuries, with its exact origin likely tracing back to the Middle East, the Fertile Crescent, and North Africa. It has played a significant economic role in agriculture, with various cultivars adapted for commercial farming. Given its widespread availability and sustainability, date palm leaves present a promising, natural solution for evaporation control in water-scarce regions [3].

Materials and Methods

Experimental Setup

This study was conducted in Saravan, southeastern Iran, from June 25 to August 24, 2019, during the peak of the hot and arid season. The primary objective was to evaluate the effectiveness of natural evaporation suppression methods using locally available date palm materials [4].

Three Class A evaporation pans, conforming to U.S. standards (120.1 cm in diameter and 25.5 cm in height), were used for the experiment. The pans were arranged in an open, unshaded environment to ensure uniform exposure to sunlight and wind. A 10 cm wooden platform elevated each pan to minimize heat exchange with the ground surface. The experimental setup included the following conditions:

- **Pan A:** Covered with a woven mat made from date palm fronds (4.2 mm thick).
- **Pan B:** Covered with a mat composed of date palm fibers (5 mm thick).
- **Pan C (Control):** Left uncovered to measure natural evaporation rates.

Figure 1: shows the woven fiber, and fiber of date palm

Figure 2: show the date frond and woven frond

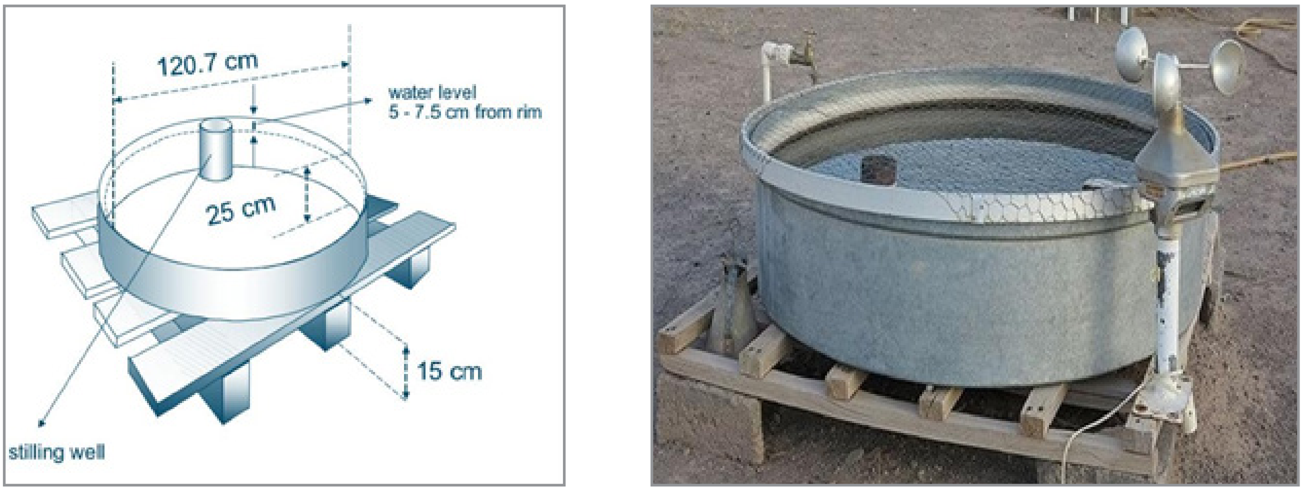

Figure 3: show the Evaporation Pan

To monitor environmental factors influencing evaporation, a weather station was installed near the experimental site. The station continuously recorded key meteorological parameters, including air temperature, relative humidity, wind speed, and atmospheric pressure [5-8].

Water levels in each pan were measured weekly using a fixed-point gauge to ensure precision. Any variation due to rainfall was accounted for by draining excess water, and if the water level dropped below 25.4 mm, refilling was conducted to maintain consistent experimental conditions [9].

Please reviw and rewrite"Materials and Methods". Attention: I have add some forumla which i think they are not placed correctly base on the methodloly , I have also extra detail,

Experimental Design

This study employed an experimental survey research approach to monitor evaporation rates over a two-month period from June 25 to August 24, 2019, the hottest and driest season in Saravan, southeastern Iran [10]. Evaporation was measured weekly by recording changes in water levels every Friday.

Three U.S. standard Class A evaporation pans (120.1 cm in diameter, 25.5 cm in height) were used, each subjected to different surface conditions to evaluate their impact on evaporation reduction:

- **Pan A:** Covered with a double-layer date palm frond mat (4.2 mm thick).
- **Pan B:** Covered with a date palm fiber mat (5 mm thick).
- **Pan C (Control):** Left uncovered to allow direct exposure to sunlight, wind, and temperature fluctuations [11-14].

The date palm frond and fiber mats used as shaded covers were sourced from local agricultural waste materials, making them an environmentally friendly byproduct available in Saravan [15].

Experimental Setup and Sample Collection

Each evaporation pan was elevated on a 10 cm wooden platform to ensure stability and accurate measurement conditions. The pans were placed in an open, unshaded area, minimizing external interference [16-18].

Evaporation rates were measured in millimeters per day (mm/day), per week (mm/week), and per month (mm/month). The recorded parameters included:

- Evaporation rate (measured by changes in water level).
- Environmental factors, such as temperature, wind speed, and humidity, monitored using a weather station [19-22].

To maintain uniform conditions, each pan was initially filled with approximately 250 mm of water and refilled when necessary to compensate for evaporation losses [23].

Measurement Procedure

The experiment was conducted in Saravan, with all measurements taken every Saturday at 5:00 PM. Water levels in each pan were recorded using a fixed ruler mounted on a stand to ensure stiffness and repeatability. The water was allowed to evaporate over a 24-hour period, enabling the assessment of evaporation rate variations under different conditions [24].

Measuring Evaporation

Evaporation loss (EL) was calculated using the pan coefficient method, as described by Cooley (1983):

- $EL = K_{pan} \times E_{pan}$ Where:
- EL = Estimated evaporation loss (mm)
- E_{pan} = Observed evaporation from the pan (mm)
- K_{pan} = Pan coefficient (typically 0.7 for Class A evaporation pans)

This coefficient accounts for differences between pan evaporation and actual open-water evaporation. Weekly evaporation values were determined by recording changes in water levels while ensuring that evaporation was the primary cause of water loss, preventing external disturbances [25-29].

This methodological approach allowed for a direct comparison of the evaporation rates under different surface conditions, providing insights into the effectiveness of date palm materials in reducing water loss under extreme climatic conditions [30].

Additionally, the following equation was used to estimate lake evaporation, as per Mayer (1982) and BIS (1992):

Where:
- *EL* = Lake evaporation in mm/day
- *Km* = Coefficient (0.36 for large deep waters, 0.50 for small, shallow waters)
- *ew* = Saturated vapor pressure at the water surface temperature (mm of mercury)
- *ea* = Actual vapor pressure of overlying air at a specified height (mm of mercury)
- *u*9 = Mean monthly wind velocity at about 9m above ground

The saturated vapor pressure was determined using the following equation:

$$e_w = 4.584 \times \exp(\frac{17.27 \times t}{237.3 + t})$$

Where t is the water surface temperature in degree Celsius Wind speed was calculated as:

$$\mu_h = C \times h^{(\frac{1}{7})}$$

And relative humidity was given by:

$$\frac{e_a}{e_w} = Relative\ Humidity$$

Water loss = Evaporation intensity × Area

Y = −0.006X5 + 0.157X4 + 1.537X3 + 5.302X2 − 3.832X + 12.02+

Where:
Y=Validated values Y= Predicted values

The pan coefficient for ISI modified Class A evaporation pans is typically between 0.70 and 0.60, with evaporation rates ranging from 4-5 mm/day for these pans and 10 mm/day for lake evaporation. The coefficient ratio is about 0.8 for transitional months [31, 32].

Floating Date Palm Mats Experiment

To further examine evaporation control, woven date palm leaf and date palm fiber mats of 2m × 3m were floated on top of two pans separately. The evaporation rate was monitored and compared with the undisturbed open pan (Control Pan C) to evaluate their effectiveness in reducing evaporation [33].

Evaporation Reduction Performance

Weekly evaporation rates were recorded and analyzed under varying environmental conditions, as shown in Table 1. Key meteorological parameters, including temperature, wind velocity, and relative humidity, were monitored to assess their influence on evaporation rates [34-36].

Table 1: Environmental conditions of the study area

Date	Temperature (°C)	Wind Velocity (km/h)	Relative Humidity (%)	K	Rainfall (mm)
25/05/2019	42	24	33	0.65	-
02/06/2019	44	17	32	0.65	-
09/06/2019	46	21	34	0.65	-
16/06/2019	48	18	35.5	0.65	-
23/06/2019	45	19	34	0.65	-
30/06/2019	46	23	34	0.65	-
06/07/2019	44	27	34	0.65	-
13/07/2019	44	19	32	0.65	-
20/07/2019	45	17	30	0.65	-
27/07/2019	46	20	33	0.65	-
04/08/2019	45	23	34	0.65	-
11/08/2019	45	26	33	0.65	-
18/08/2019	42	25	32	0.65	-

The measured evaporation rates for the three experimental setups—control pan (A), date-palm leaf mat pan (B), and date-palm mat fiber pan (C)—are summarized in Table 2.

Table 2: Evaporation performance of different treatments

Control Pan A (mm)	Date-Palm leaf Mat Pan B (mm)	Date Palmmat Fiber Pan C (mm)	Evaporation Pan A (mm/day)	Evaporation Pan B (mm/day)	Evaporation Pan C (mm/day)
250	250	250	35.75	11.7	7.8
195	232	238	16.25	9.1	7.8
170	218	226	11.7	9.1	7.8
152	204	214	98.8	10.4	5.2
136	188	206	11.7	11.05	8.45
118	171	193	13	9.75	7.8
98	156	181	63.7	101.4	7.15
62	137	170	20.15	16.25	110.5
31	112	159	16.9	10.4	7.15
5	96	148	3.25	10.4	7.15
0	80	137	0	9.1	5.2
0	66	129	0	15.6	7.15
0	42	118	0	27.3	

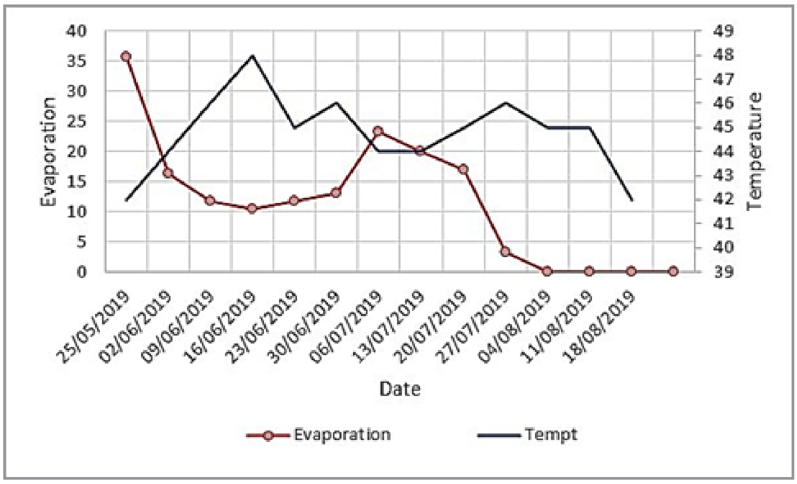

Figure 4: shows the evaporation rates of Pan A(open) in relation to environmental temperature.

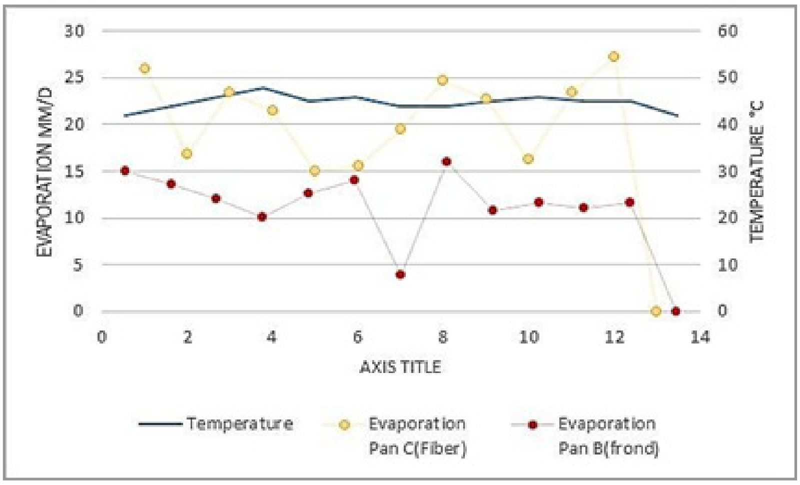

Figure 5: shows the evaporation rates of Pan C (fiber) and Pan B (frond) in relation to environmental temperature.

- The control pan (A) exhibited the highest evaporation rate.
- The date-palm mat fiber pan (C) demonstrated the highest evaporation reduction, with a peak reduction of 75.00%, significantly outperforming the other methods.
- The date-palm leaf mat pan (B) also effectively reduced evaporation, with reductions reaching 57.61% in some cases, confirming the effectiveness of SEES materials in mitigating water loss [37].
- In most scenarios, date-palm mat fiber (C) showed greater evaporation reduction than date-palm leaf mat (B), making it the more effective material for evaporation control.
- However, in certain environmental conditions, negative reduction percentages were observed, indicating that factors such as temperature, humidity, and material absorption characteristics could influence evaporation dynamics [38-40].

Effect of SEES on Soil Moisture Retention

Soil moisture retention was analyzed by comparing fields treated with ploughed-in SEES to untreated control fields. The results showed a 9.3% increase in soil moisture content in SEES- treated areas, suggesting a notable improvement in water conservation. This finding supports the hypothesis that organic-based surface covers enhance soil water retention by reducing direct evaporation losses [41].

Reduction in Evaporation Using Date-Palm Leaf Mat (Pan B) and Date-Palm Mat Fiber (Pan C)

The effectiveness of date-palm-based materials in reducing evaporation was assessed by comparing the percentage reduction in evaporation for Pan B and Pan C relative to the control Pan

The results demonstrated that:

- Date-Palm Mat Fiber (Pan C) consistently exhibited the highest evaporation reduction, with reductions of up to 75.00% in some trials.
- Date-Palm Leaf Mat (Pan B) achieved moderate reductions, with a maximum of 57.61% in optimal conditions.
- In several instances, both materials reduced evaporation rates by 44% to 69%, highlighting their significant contribution to water conservation.
- Anomalies were observed in certain conditions where evaporation rates in Pan B and Pan C exceeded those in the control pan, leading to negative reduction percentages. This suggests that under specific environmental factors, such as high humidity or material absorption properties, evaporation suppression may be less effective or even reversed [42].
- Despite these variations, the overall trend confirmed that natural palm-based materials substantially reduce evaporation, with date-palm mat fiber proving to be the most effective option.

Comparison with Existing Literature

The evaporation reduction performance observed in this study aligns with findings from previous research:

- Al-Hassoun et al. (2009) reported a 63% reduction in evaporation using floating palm fronds as a cover, indicating the potential of palm-based materials in arid conditions.
- Craig et al. (2007) demonstrated that physical shading structures significantly lower evaporation rates by minimizing solar radiation exposure.
- Recent studies on nature-based evaporation control methods highlight that organic surface covers not only conserve water but also contribute to soil temperature regulation and moisture retention [43].

Implications for Water Management in Arid Regions

The findings of this study provide valuable insights into sustainable water conservation strategies for arid and semi-arid regions. The integration of date-palm-based covers in irrigation and reservoir management can significantly reduce evaporation losses, improving water availability for agricultural and domestic use. Additionally, applying these techniques in large- scale water storage systems could enhance long-term water sustainability in drought-prone areas.

Conclusion

Water scarcity is a critical challenge in arid regions, where low precipitation and high evaporation rates significantly reduce available water resources. This study aimed to highlight the importance of water conservation in such environments and demonstrated an effective, low-cost, and sustainable method for reducing evaporation losses [44].

The results confirm that utilizing waste materials from date palm trees, such as fibers and leaves, can effectively decrease evaporation rates while also contributing to agricultural water conservation. This method not only enhances water availability for irrigation and dam storage but also supports crop production by retaining soil moisture. Compared to conventional evaporation suppression techniques, such as chemical films, plastic covers, and floating modules, the use of date-palm waste is an environmentally friendly and cost-effective alternative. Unlike synthetic materials that degrade under high temperatures and potentially introduce pollutants into water bodies, natural palm-based materials preserve water quality and offer a sustainable solution tailored to the local environment.

Additionally, this approach promotes effective waste management by repurposing agricultural byproducts that would otherwise be discarded. By integrating this technique into water conservation strategies, communities in arid regions can achieve dual benefits—minimizing water loss and enhancing sustainability. Future research should explore long-term performance, large-scale application, and the potential combination of this method with other water conservation strategies to optimize its effectiveness in diverse environmental conditions.

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