Sultanate of Oman
Ministry of Education
Al Batinah North Governorate
Hind bint Al-Muhallab Basic
Education School (Grades 5–10)

The Effect of Soil Capillarity on Water Retention in Arid Environments

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Table of Contents

Abstract

With the increasing scarcity of water in arid environments due to low rainfall and the continuous depletion of water resources, the agricultural sector faces major challenges related to the limited ability of soil to retain water and its rapid exposure to dryness. This negatively affects crop productivity and threatens the sustainability of agricultural systems. In this context, soil capillarity plays a crucial role as a key physical property that directly influences the movement of water within soil pores and its ability to retain moisture over extended periods.

This study aims to investigate the effect of soil capillarity on water retention in arid environments by examining the pore structure of different soil types, analyzing water-movement behavior through them, and evaluating their capacity to reduce water loss caused by evaporation or deep percolation. The research also seeks to explore the relationship between soil structure and capillary action, and its impact on improving irrigation efficiency and supporting sustainable agriculture in water-scarce regions.

The study evaluates the potential of soils with enhanced capillary characteristics as a sustainable environmental solution for increasing water-retention capacity and mitigating the effects of drought, through addressing the following research questions:

1. What is the effect of soil capillarity on water movement and retention in arid environments?
2. How does soil pore structure contribute to improving water-retention efficiency and reducing water loss?
3. To what extent do variations in soil capillarity influence soil properties and plant growth under the same conditions?

To answer the research questions, the study was conducted in two main stages, with a focus on examining the role of soil capillarity in water movement and retention under arid environmental conditions.

First Stage, An interview was conducted with an agricultural engineer to gain insights into soils that exhibit a layered structure similar to layered soil . In addition, a field inspection was carried out at Wadi Al-Hilti Dam in the Wilayat of Sohar, where the geological and structural composition of the soil in the dam basin was examined. Particular attention was given to identifying clay blocks, sandy cracks, and pore spaces that enhance water movement through capillary action and improve the soil's ability to retain moisture.

Second Stage, The practical component of the study involved planting two groups of marigold seedlings. The first group was planted in a pot containing an engineered soil model designed to simulate a layered structure that enhances capillary water retention, while the second group was planted in conventional agricultural soil from the school garden. Both pots were subjected to the same environmental conditions in terms of irrigation and sunlight exposure, and plant growth was monitored for **42 days**. Soil properties — including permeability, salinity, pH, electrical conductivity, and moisture — were measured periodically using **GLOBE Program Protocols** (Soil, Land Cover, and Water Protocols).

The results demonstrated that the soil with enhanced capillary structure — similar to layered soil — exhibited a higher capacity for water retention and required less frequent irrigation compared to conventional soil. It also showed greater efficiency in reducing salinity buildup and improving root aeration and water distribution across sandy layers, which contributed to improved plant growth and better resilience under arid environmental conditions.

Key Terms

Dams: Engineered structures constructed to store or regulate the flow of water, leading to the formation of reservoirs that help reduce flooding and support water supplies used for irrigation, agriculture, drinking, power generation, and other purposes (Al-Thariyah, 2022).

Soil Properties: The physical and chemical characteristics that distinguish one soil type from another — such as color, cohesion, moisture content, and porosity — and that directly influence water movement and retention within the soil (Abdullah, 2010).

Soil Permeability: The ability of soil to allow water and air to pass through its pores. It is a key factor affecting water movement and retention efficiency and varies according to soil structure and particle composition (Al-Khatib, 2016).

Infiltration Rate Test: A test used to measure the rate at which water infiltrates through the soil in order to determine its hydrological properties and its capacity to retain water and reduce deep percolation losses (Al-Khatib, 2016).

Soil Capillarity (Capillary Action in Soil): A physical property that depends on pore size and the bonding between soil particles, allowing water to move vertically or laterally through the soil without relying on gravity, as a result of surface tension and adhesive forces. Capillarity plays a major role in moisture retention in upper soil layers, particularly in arid environments (Hillel, 1998).

Marigold Plant: A flowering plant belonging to the Asteraceae family, characterized by its bright yellow-to-orange blossoms. It is commonly used as an ornamental plant and as an experimental species in agricultural studies due to its sensitivity to soil and moisture variations (Al-Najjar, 2012).

Introduction and Literature Review

The Sultanate of Oman faces significant challenges in maintaining a sustainable supply of freshwater due to its arid climate and low rainfall, which directly affects the agricultural sector, particularly in areas that rely heavily on groundwater resources that are continuously depleted. Under these environmental conditions, there is an urgent need for innovative scientific approaches that enhance water-use efficiency and reduce water loss in agricultural systems (Al-Masar, 2020).

Soil plays a fundamental role in agricultural sustainability, as its ability to retain and supply water to plant roots is strongly influenced by its physical properties—especially soil pore structure and capillarity, which enable water movement through fine pores and allow moisture to be retained in the upper soil layers for longer periods. This property becomes particularly important in arid environments, where it can help reduce evaporation and minimize deep percolation losses that do not benefit plant growth.

In this context, the present study investigates the effect of soil capillarity on water retention in arid environments by employing a layered soil model similar to layered soil and comparing it with conventional agricultural soil in terms of moisture-retention efficiency and plant growth performance. The study aims to explore how enhancing capillary behavior in soil can contribute to improving water-use efficiency and reducing irrigation demand, thereby supporting more sustainable agricultural practices in water-scarce regions.

Research Methods

The data for this study were collected using two main approaches: a scientific interview and an experimental study, with the aim of examining the effect of soil capillarity on water retention in arid environments.

1. Scientific Interview

An interview was conducted with agricultural engineer Nasser Al-Hinai from Sultan Qaboos University. The interview focused on understanding the physical and structural characteristics of soil, particularly the role of pore structure and layered composition in capillary water movement, and how these properties influence moisture retention and reduce water loss when compared with conventional agricultural soil.

2. Experimental Study

An experiment was conducted using two groups of marigold seedlings planted in two different soil types:

- a layered soil structure designed to enhance capillary behavior and water-retention capacity, and
- conventional agricultural soil for comparison.

Throughout the experiment, several soil properties were measured — including permeability, salinity, moisture content, and pH — in addition to monitoring plant growth over specific time intervals, in order to analyze the influence of soil capillarity on moisture behavior and water availability around plant roots.

Research Procedures

The research was organized and implemented according to the following steps:

1. **Information Collection:** The required data were collected from books available in the Learning Resource Center and through online information sources.
2. **Research Planning:** A comprehensive research plan was developed, including the identification of objectives and the timeline for implementation.
3. **Conducting the Interview:** An interview was conducted with Agricultural Engineer Nasser Al-Hinai from Sultan Qaboos University to obtain specialized insights on Layered soil and its impacts.
4. **Engineering the Layered soil Model:** A Layered soil sample was engineered with precise specifications to serve as a core component of the experiment.
5. **Protocol Identification:** Appropriate protocols for implementing the study were determined based on scientific and environmental standards.
6. **Selection of Tools and Instruments:** The necessary devices and instruments were selected for conducting the experiment, including a pH meter, a salinity and conductivity meter, a measuring tape, and a soil-moisture sensor.
7. **Conducting the Experiment:** An experimental research approach was adopted to study the effect of two soil types on the growth of marigold seedlings, while monitoring environmental and soil characteristics.
8. **Data Collection:** The data and results obtained from the experiment were collected, organized into clear and accurate tables, and represented graphically.
9. **Data Entry:** The collected data were entered into the official GLOBE Program website for monitoring and analysis.

10. **Data Analysis:** The results were analyzed and discussed, with graphical representations used to illustrate the findings.
11. **Conclusions and Recommendations:** The main research findings were extracted, and appropriate recommendations were proposed to support the effective use of Layered soil .

Research Plan and Implementation Timeline

No.	Student Name	Task	Date of Implementation
1	Mira Omar Al-Yhyai	Selection of the research topic	October 2025
2	Mira Omar Al-Yhyai Fadwa Saif Al-Issaei	Collecting information about the research topic from various sources	October 2025
3	Mira Omar Al-Yhyai Fadwa Saif Al-Issaei	Conducting an interview with Engineer Nasser Al-Hinai	October 2025
4	Mira Omar Al-Yhyai Fadwa Saif Al-Issaei	Collecting soil and water samples for protocol application	November 2025 — December 2025 — January 2026
5	Mira Omar Al-Yhyai Fadwa Saif Al-Issaei	Observing the results, recording them, and entering the data on the website	November 2025 — December 2025
6	Mira Omar Al-Yhyai Fadwa Saif Al-Issaei	Writing the research report and interpreting the results	January 2026

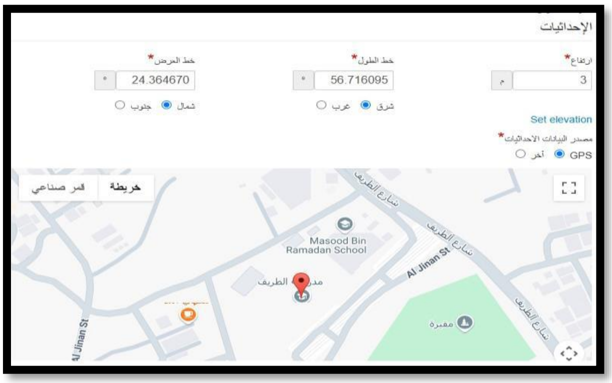
Table 1: Research Implementation Steps

The table (1) illustrates the steps of implementing the research plan, beginning with the selection of the research topic, followed by the collection of relevant information and data through interviews, in addition to conducting the experiment, which included taking soil samples to study their properties using GLOBE program instruments. The results were then documented, analyzed, and discussed.

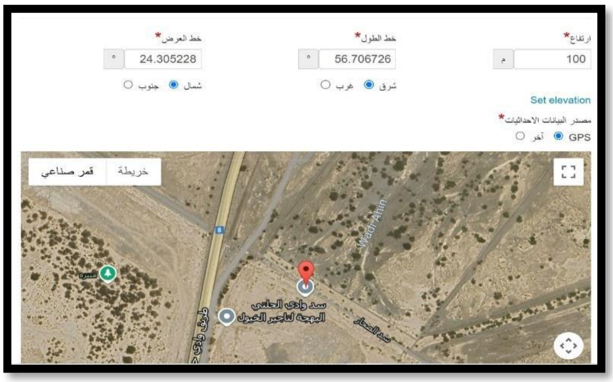
Study Location

The study was conducted in the Wilayat of Sohar, located in the North Al Batinah Governorate, which is characterized by a hot and relatively humid climate, making it a suitable environment for examining soil behavior and water retention in arid conditions. A field visit was carried out to Wadi Al-Hilti Dam in Sohar to investigate the characteristics of the soil within the dam reservoir, study its layered and porous structure, and analyze its influence on water movement and moisture retention within the specific geological context of the site.

In addition, the practical component of the study was implemented within the school campus, where an experimental soil model was prepared to simulate the layered structure observed at the dam site, with the aim of comparing the effect of this soil structure on plant growth relative to conventional agricultural soil. Reference coordinates for both the dam site and the experimental site were accurately recorded using a **GPS** device to ensure precise documentation, and the collected data were entered into the official **GLOBE** platform for environmental monitoring and analytical processing.



The Layered soil Pattern Discovered in the



The Layered soil Pattern Discovered in the

Wadi Al-Hilty Dam Basin During Drought

Wadi Al-Hilty Dam Basin During Rainfall

Identification of the Protocols Used in the Study

In this study, the Water Protocol will be used to measure the pH, salinity, and electrical conductivity of the water source used for irrigation. The Soil Protocol will be applied to determine soil pH using a pH meter, and to measure soil salinity and conductivity using a salinity and conductivity meter, in addition to using a soil-moisture sensor to measure soil moisture. The Land Cover Protocol will also be used to observe the general appearance and condition of the seedlings.

Identification of the Instruments and Tools Required for Conducting the Study

Several instruments will be used to measure soil properties as well as plant characteristics. Table (2) presents the most important of these instruments and their respective uses.

No.	Device	Image	Use
1	pH Meter (Soil Acidity Meter)		Measuring soil acidity (pH)
2	Salinity and Conductivity Meter		Measuring soil salinity
3	Measuring Tape		Measuring lengths
4	Soil Moisture Sensor		Measuring soil moisture
5	Dissolved Oxygen Meter		Measuring the amount of dissolved oxygen

Table 2: Instruments and Tools Required for Conducting the Study

Data Collection and Analysis

First: Interview with Engineer Nasser Al-Hinai (College of Agriculture – Sultan Qaboos University)

A scientific interview was conducted with Agricultural Engineer Nasser Al-Hinai, a graduate of the College of Agriculture at Sultan Qaboos University, with the aim of gaining insight into the characteristics of certain soil formations that develop in flood-affected and dam-reservoir environments, and understanding how their layered structure influences water movement and retention through soil capillarity.

The engineer explained that research conducted at Sultan Qaboos University — under the supervision of Professor Saeed Al-Ismaeeli — has documented a specific soil pattern that forms in wadi and dam environments. This soil consists of low-permeability clay blocks separated by sandy cracks or layers with relatively higher permeability. The development of this soil structure occurs through a sequence of natural processes, including:

1. **Accumulation of floodwater** within the reservoir, carrying sediment and suspended particles.
2. **Deposition of sand within cracks and larger pore spaces** as water velocity decreases.

3. **Deposition of fine clay particles above the sandy layers**, forming a more cohesive clay layer.
4. **Evaporation of water and drying of the clay layer**, leading to shrinkage and cracking.
5. **Expansion of cracks due to thermal and climatic effects**, allowing moisture redistribution within the soil.
6. **Repetition of these processes with successive floods**, resulting in the gradual buildup of alternating clay and sand layers over time.

This description indicates that such soils exhibit **a** higher capacity for retaining water within clay matrices, while the sandy cracks act as pathways that facilitate water and air movement through capillary action. This makes the soil a significant case study for understanding moisture behavior and water-retention dynamics in arid environments.

The Layered Soil Pattern Observed in the Wadi Al-Khoud Dam Basin

Second: Field Visit to Wadi Al-Hilty Dam in the Wilayat of Sohar

A field visit was carried out to Wadi Al-Hilti Dam in the Wilayat of Sohar with the aim of studying the characteristics of the soil within the dam reservoir and examining the clay and sandy formations resulting from repeated sedimentation processes caused by seasonal floods. The visit focused on analyzing the layered soil structure, cracks, and pore spaces, and investigating their role in water movement and retention within the environmental and hydrological conditions of the site.

One of the Layered Soil Patterns Observed at Wadi Al-Hilti Dam

Third: Practical Application Using GLOBE Program Protocols

1. Construction of a Layered Soil Model for the Experimental Study

Samples of sandy and clayey soil were collected from the basin area of Wadi Al-Hilti Dam in the Wilayat of Sohar. The soil layers were then arranged inside the planting pot in order to simulate the natural sediment-induced layering observed in dam environments. A highly permeable sand layer was placed at the bottom, followed by a less-permeable clay layer on top.

A plastic mold was used to create longitudinal voids within the clay layer to represent natural cracks and pore channels, which were then filled with sandy soil. An additional sand layer was added above the clay layer, and the process was repeated to obtain a stratified pattern that allows the study of water movement and retention through soil capillarity.

This model was prepared for use in the experimental phase to examine the effect of soil layering on plant growth, using **GLOBE Program protocols** to monitor seedling development and analyze moisture behavior within the soil, and to compare the results with those observed in conventional agricultural soil under the same conditions.

This model was prepared to study the impact of Layered soil on plant growth using the GLOBE Program protocols, whereby plants will be cultivated in this soil and their development monitored, while analyzing the influence of its unique properties — such as its ability to retain water — and comparing it with conventional soil.

1 Fabrication of the Plastic Model

2 Placing the Clay Soil and Filling the Cracks with Sandy Soil

3 Removing the Plastic Mold

4 Layered Soil Model — Ready for Experimentation

2. Properties of the Water Used for Irrigating the Seedlings (Well Water)

The water source available at the school was used for irrigating the seedlings. Samples of this water were collected and tested using the appropriate measuring instruments, and the results were recorded as shown in Table (3) below.

Water Properties	Values
Electrical Conductivity (µS/cm)	686
Salinity (ppm)	431
pH	7.5
Dissolved Oxygen	6

Table 3: Properties of the Water Used for Irrigating the Seedlings (Well Water)

Table (3) presents the properties of the water in terms of electrical conductivity, salinity, and pH. Three readings were taken in order to calculate the average and obtain accurate data.

Measuring Dissolved Oxygen Levels

Measuring Salinity and Electrical

3. Properties of the Layered Soil Compared with Conventional Agricultural Soil

Marigold seedlings were planted in two pots, with six seedlings placed in each pot and kept at a similar height and growth stage. The first pot contained a layered soil structure that was engineered to simulate sediment-induced soil layering in arid environments, while the second pot contained conventional agricultural soil taken from the school garden for comparison.

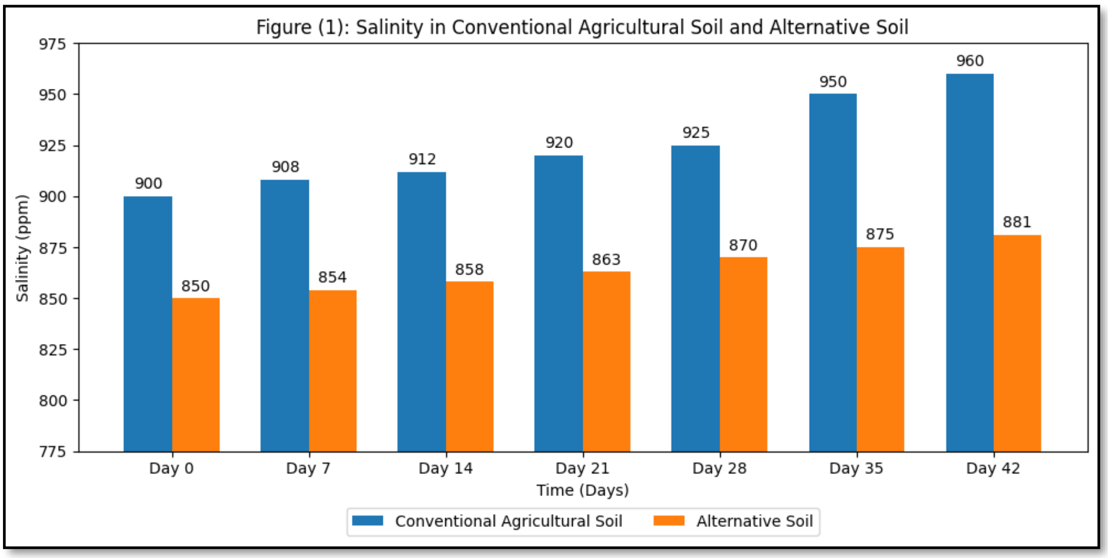
Soil samples from both pots were tested prior to planting and then monitored weekly over a period of **42 days** using specialized measuring instruments. The average readings were recorded to ensure accurate and reliable comparative results.

Measuring Soil pH, Salinity, and Electrical Conductivity

The results are presented in Table (4), in addition to the graphs that illustrate the average variations in salinity, moisture, and pH levels throughout the study period.

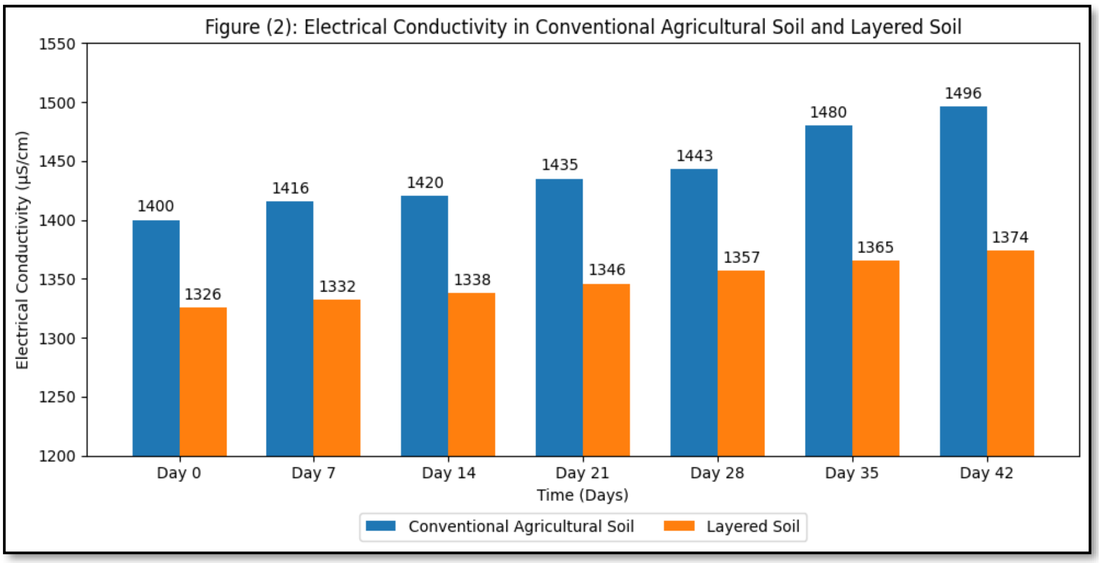
Time Period (Days)	Property	Conventional Agricultural Soil	Layered Soil
Day 0	Salinity (ppm)	900	850
	Electrical Conductivity (µS/cm)	1400	1326
	pH	7.4	7.4
Day 7	Salinity (ppm)	908	854
	Electrical Conductivity (µS/cm)	1416	1332
	pH	7.3	7.35
Day 14	Salinity (ppm)	912	858
	Electrical Conductivity (µS/cm)	1420	1338
	pH	7.2	7.3
Day 21	Salinity (ppm)	920	863
	Electrical Conductivity (µS/cm)	1435	1346
	pH	7.1	7.25
Day 28	Salinity (ppm)	925	870
	Electrical Conductivity (µS/cm)	1443	1357
	pH	7.0	7.2
Day 35	Salinity (ppm)	950	875
	Electrical Conductivity (µS/cm)	1480	1365
	pH	6.8	7.15
Day 42	Salinity (ppm)	960	881
	Electrical Conductivity (µS/cm)	1496	1374
	pH	6.6	7.1

Table 4: Properties of Conventional Agricultural Soil and Layered Soil



The results shown in Figure (1) indicate that salinity levels in conventional agricultural soil initially started at approximately **900 ppm**, while the values were slightly lower in the layered soil, beginning at about **850 ppm**. Over time, salinity increased gradually in both soils; however, the rate of increase was higher in the conventional soil, reaching approximately **960 ppm after 42 days**, compared to **881 ppm** in the layered soil.

This difference suggests that the layered soil structure enhances capillary water movement and salt redistribution**,** which helps reduce salt accumulation in the root zone. In contrast, conventional soil tends to retain higher salt concentrations due to limited internal water distribution.



With respect to **electrical conductivity**, the initial readings were approximately **1400 µS/cm** in the conventional agricultural soil and about **1326 µS/cm** in the layered soil, as shown in Figure (2). Over time, electrical conductivity continued to increase in both soils due to the gradual accumulation of dissolved salts; however, the rate of increase was higher in the conventional soil, reaching approximately **1496 µS/cm after 42 days**, compared to **1374 µS/cm** in the layered soil over the same period.

This difference indicates that **the layered soil structure promotes more effective capillary-driven redistribution of water and salts**, which reduces salt accumulation in the root zone. In contrast, conventional soil tends to retain higher salt concentrations, potentially limiting the plant's ability to absorb water and nutrients.

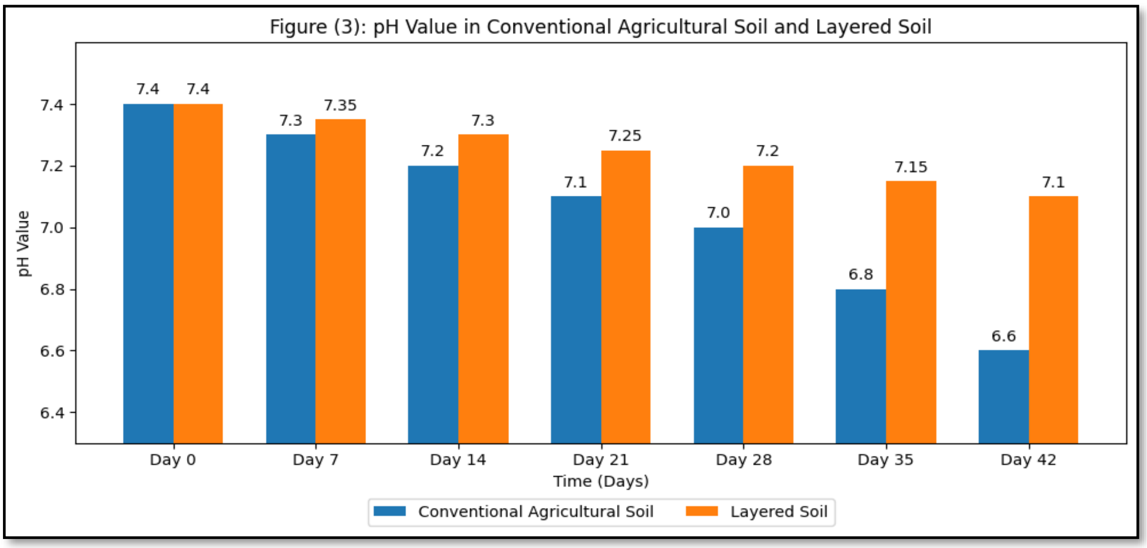


Figure (3) shows that the mean pH value initially started at **7.4** in both soils. However, in the conventional agricultural soil, the pH gradually decreased to approximately **6.6** after 42 days, indicating an increased influence of chemical processes within the soil as a result of salt accumulation and changes in soil–water interactions.

In contrast, the layered soil exhibited only a slight decline in pH, stabilizing at around **7.1** by the end of the study period, which reflects **a greater ability to maintain chemical balance within the soil matrix**.

This difference suggests that **capillary-driven water movement within the layered soil structure contributes to a more stable root-zone environment**, thereby enhancing nutrient availability and supporting healthier plant growth compared to conventional soil.

4. Permeability

The infiltration rate test was used as an indicator of soil permeability and water movement**.** An equal amount of water was added to each pot, and the time required for the water to drain from the surface was measured.

The results showed that water required approximately **23 minutes** to drain in the conventional agricultural soil, whereas the drainage time in the layered soil was shorter, at about **15 minutes**. This indicates that the layered soil structure facilitates more efficient water transmission through fine pores and vertical pathways, supported by capillary action, compared with the relatively uniform structure of conventional soil.

Flooding with an Equal Amount of Water

After 15 Minutes

5. Moisture Retntion

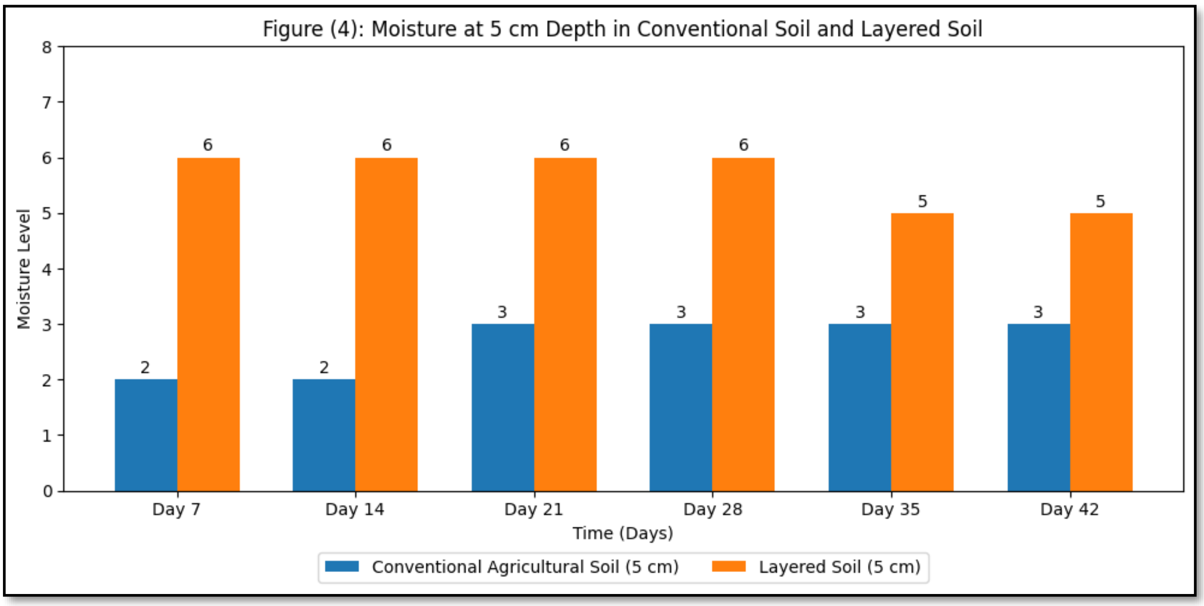
The seedlings were irrigated with equal amounts of water at a rate of once every seven days in order to ensure uniform irrigation conditions for both soil types. The moisture level in each pot was measured prior to every irrigation event.

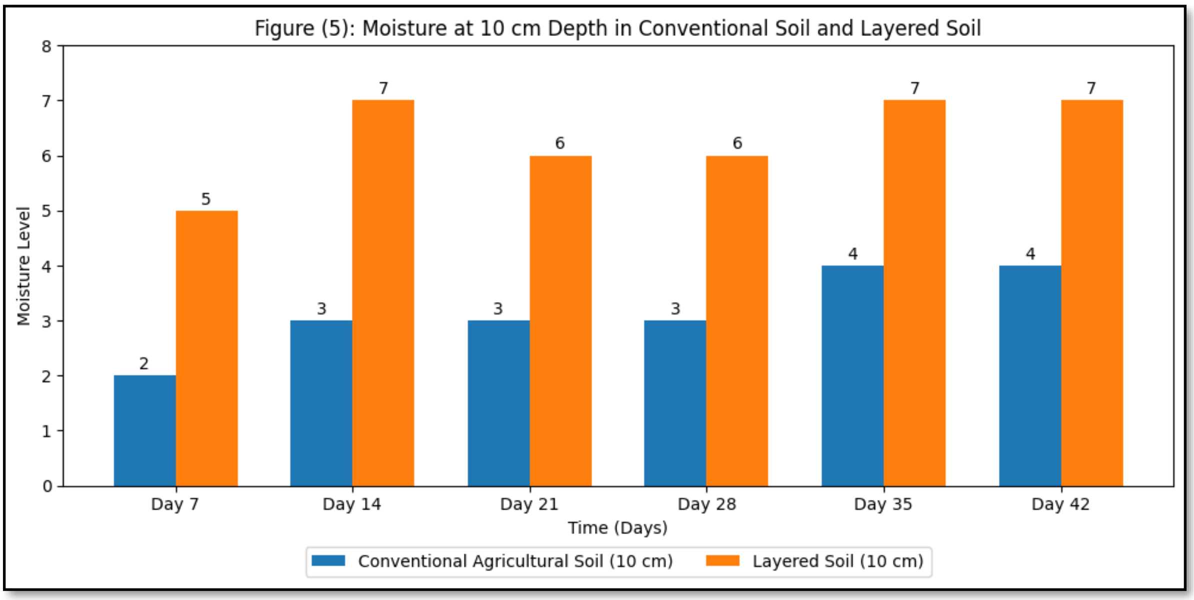
Measuring Soil Moisture Levels

Soil moisture was measured weekly before irrigation using a moisture meter calibrated on a scale from (0–10), and the readings were recorded in Table (5) in order to compare the ability of each soil type to retain water throughout the experiment period. Values in the range (1–3) indicate dry soil, while values (4–6) represent moderately moist soil, and values (7–10) indicate highly moist soil. The results were as follows:

Time Period (Days)	Conventional Soil (5 cm)	Layered Soil (5 cm)	Conventional Soil (10 cm)	Layered Soil (10 cm)
Day 7	5	7	6	8
Day 14	4	6	5	7
Day 21	4	6	5	7
Day 28	4	6	5	7
Day 35	3	5	4	6
Day 42	3	5	4	6

Table 5: Average Soil Moisture Readings in Conventional Agricultural Soil and Layered soil





Figures (4) and (5) show that the layered soil exhibited a higher capacity for moisture retention compared with the conventional agricultural soil. At the beginning of the experiment (Day 7), moisture levels in the layered soil were higher at both depths (5 cm and 10 cm) and continued to remain stable or gradually increase until Day 42.

In contrast, the conventional soil showed a progressive decline in moisture levels over time, indicating its limited ability to retain water within the surface and subsurface layers.

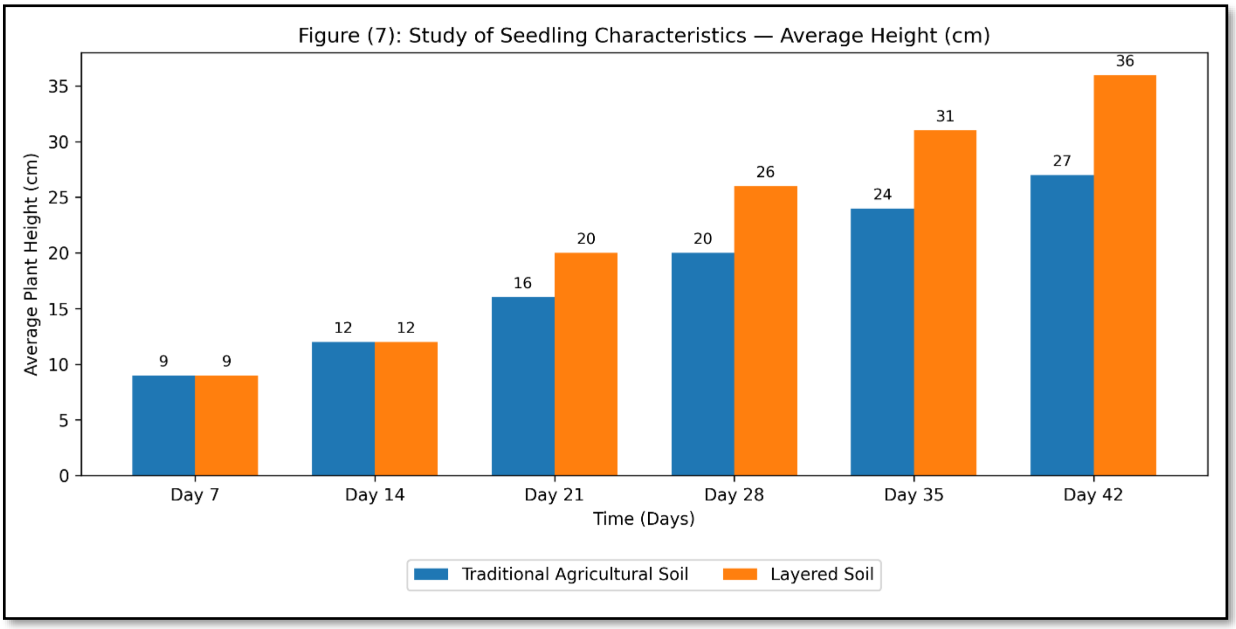
These findings suggest that the layered soil structure enhances capillary water movement and supports longer moisture storage within fine soil pores, whereas conventional soil loses moisture more rapidly.

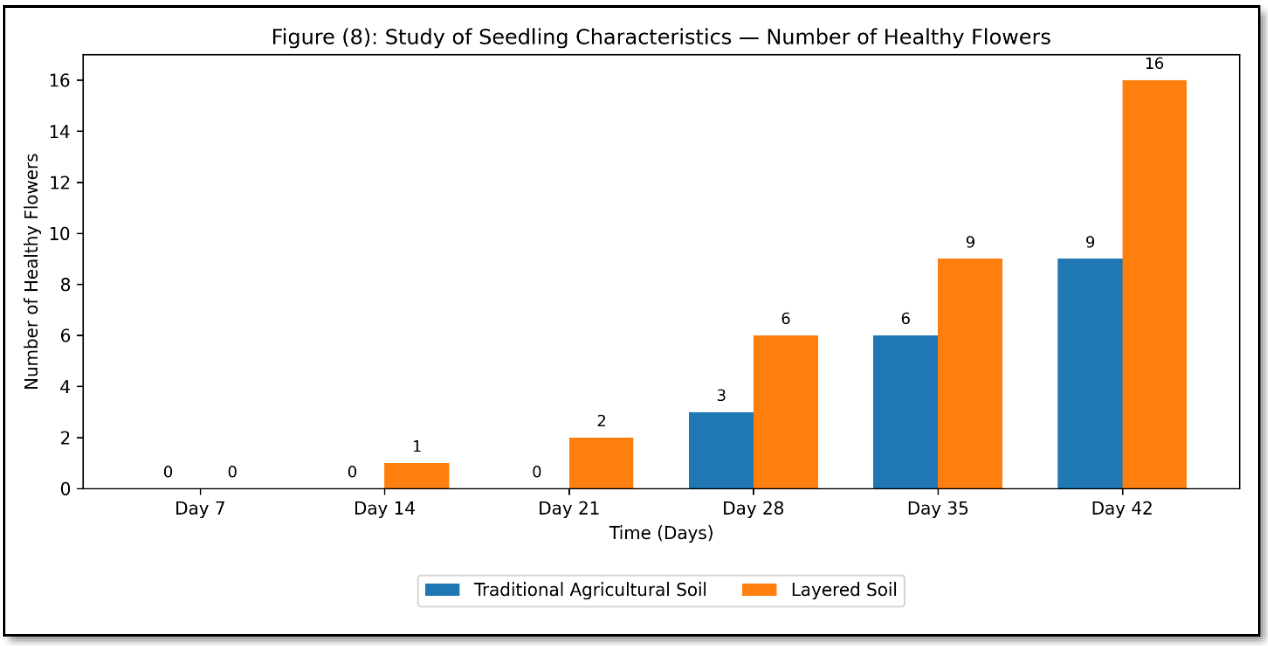
6. Observation of the General Appearance of Seedlings over 42 Days of Planting

The general appearance of the marigold seedlings grown in both soil types was monitored over a period of **42 days** through periodic visual observation, recording changes in growth, leaf color, stem strength, and overall plant vigor. The results are summarized in Table (6)**.**

Time Period	Parameter	Traditional Agricultural Soil	Layered Soil
Day 7	Average plant height (cm)	9	9
	Number of healthy flowers	0	0
Day 14	Average plant height (cm)	12	12
	Number of healthy flowers	0	1
Day 21	Average plant height (cm)	16	20
	Number of healthy flowers	0	2
Day 28	Average plant height (cm)	20	26
	Number of healthy flowers	3	6
Day 35	Average plant height (cm)	24	31
	Number of healthy flowers	6	9
Day 42	Average plant height (cm)	27	36
	Number of healthy flowers	9	16

Table (6): Study of Seedling Characteristics





Figures (7) and (8) show that the layered soil outperformed the traditional agricultural soil in terms of plant growth and flower production. During the first and second weeks, plant height was equal in both soil types; however, over time, plant growth in the layered soil increased steadily, reaching 36 cm on Day 42, compared to 27 cm in the traditional agricultural soil.

The layered soil also initiated flower production earlier, starting from Day 14, and the number of healthy flowers increased to 16 by Day 42. In contrast, flower production in the traditional agricultural soil began on Day 21 and reached a total of 9 flowers by the end of the experimental period.

Planting Marigold Seedlings

After 42 days

7.Data Entry Documentation

Documentation of Data Entry on the GLOBE Website (www.globe.gov)

Results Analysis and Discussion

The results presented in Table (4) and Figures (1, 2, and 3) indicate that the layered soil is more sustainable and suitable for agricultural use compared with conventional agricultural soil. The layered soil demonstrated a clear ability to reduce salt accumulation over time, thereby minimizing the negative effects of salinity on plant growth. In addition, the rate of increase in electrical conductivity was lower, reflecting the soil's effectiveness in limiting salt concentration and improving salt redistribution within the soil profile.

Furthermore, the layered soil maintained a more stable pH level throughout the experimental period, which enhances the availability and absorption of essential nutrients by plants.

Permeability test results also show that the layered soil exhibits improved permeability compared with conventional agricultural soil. The presence of sand-rich pathways facilitated faster water movement, which enhanced water-use efficiency and supported sustainable plant growth under arid conditions.

The results presented in Table (5) and Figures (4 and 5) demonstrate that the layered soil retained moisture for longer periods at both shallow and deeper layers. This characteristic improved the plant's ability to utilize stored moisture during dry periods. In contrast, moisture levels in conventional agricultural soil declined more rapidly, indicating a continuous need for frequent irrigation to maintain adequate water availability.

Based on the findings shown in Table (6) and Figures (7 and 8), it can be concluded that the layered soil significantly enhanced plant growth and increased flower productivity compared with conventional agricultural soil. The layered soil consistently produced a higher number of healthy flowers throughout the experimental period, indicating its effectiveness in improving plant growing conditions and overall productivity**.**

These findings lead to the following answers to the research questions:

Answer to the First Research Question:

According to the interview with Engineer Nasser Al-Hinai, layered soil is formed through the deposition of sand within cracks and the accumulation of clay layers resulting from repeated flooding events. This process enhances soil structural stability and positively influences water movement within the soil profile. The layered soil consists of low-permeability clay blocks separated by highly permeable sandy pathways, which contribute to reducing soil salinity and increasing moisture retention. These characteristics support sustainable agricultural practices, particularly in saline or drought-prone environments.

Answer to the Second Research Question:

The structure of layered soil affects water retention and water-use efficiency in agriculture due to its composition of low-permeability clay blocks and highly permeable sandy pathways. While the clay blocks retain water for extended periods, the sandy pathways enable rapid drainage and balanced redistribution of water within the soil profile. This interaction reduces water loss and improves irrigation efficiency, particularly in environments characterized by climatic variability. In addition, capillary action within the fine clay matrix facilitates the upward movement and redistribution of moisture from wetter zones to drier layers, thereby enhancing overall soil water availability and supporting plant growth under arid conditions.

Answer to the Third Research Question:

Marigold plants exhibited better growth performance in layered soil due to the balanced distribution of water through sand-rich pathways and the soil's ability to retain moisture within clay layers. This structure enhanced water availability to plant roots, thereby supporting healthier growth and higher productivity. In contrast, plants grown in conventional agricultural soil faced limitations in moisture retention, which led to rapid drying of surface layers and resulted in reduced growth performance.

Conclusion

This study was successfully completed using both the interview method and practical experimentation based on the GLOBE Program protocols. Through this study, a layered soil model was developed and compared with conventional agricultural soil in the cultivation of marigold seedlings. The findings revealed that the layered soil offers a significant agricultural advantage, as it demonstrated a clear ability to reduce irrigation water consumption compared with conventional agricultural soil.

The layered soil also showed an effective capacity to reduce salinity levels, making it more suitable for plants that are sensitive to saline conditions. In addition, the layered soil improved root aeration and enhanced the distribution of water across sand-rich layers, which promoted plant growth and supported its sustainability under harsh environmental conditions.

Commercial Applications of Layered soil

Layered soil can be utilized commercially in several fields, particularly in sustainable agriculture within arid or high-salinity regions, where it contributes to improving crop growth and productivity. In addition, layered soil can be integrated with smart irrigation systems to enhance water-use efficiency and optimize irrigation practices. It can also be marketed to research centers and universities for further study and application in modern agricultural research.

Moreover, layered soil represents a promising solution for urban agriculture, especially in rooftop farming or polluted areas, due to its ability to improve soil conditions and increase agricultural productivity in urban environments.

Acknowledgment

We would like to express our sincere thanks and appreciation to Engineer Nasser Al-Hinai for his valuable contribution to the development of the research idea and for his assistance in constructing the layered soil model. We also extend our gratitude to Dr. Hilal Al-Shaibi for his support and guidance during the preparation and writing of this research.

Our thanks are likewise extended to Ms. Asmaa Al-Alawi, the supervising teacher, for her continuous supervision of the project and for providing some of the equipment required to carry out the study.

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GLOBE Badges

I AM A GLOBE RESEARCHER

This badge is earned because the study was conducted using official GLOBE Program protocols for soil, water, and land cover, with systematic data collection, analysis, and documentation in accordance with GLOBE scientific standards.

I AM A PROBLEM SOLVER

This badge is earned because the study addresses a real environmental challenge related to water scarcity and soil salinity in arid environments by proposing and experimentally validating a soil model that improves water retention and reduces irrigation demand

I AM A COLLABORATOR

This badge is earned because the study was conducted through collaboration with a STEM professional and under academic supervision, integrating expert input, guidance, and cooperative effort throughout the research process.