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A Comprehensive Scientific Study on Hydraulic Conductivity in Sandy, Clayey, and Silty Soils With Reference to the USDA Soil Taxonomy Classification (2026)

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Abstract:
Hydraulic conductivity is one of the most important hydrophysical properties in soil science, as it determines the rate and volume of water flow through soil pores. This property is strongly influenced by soil particle-size composition (texture), internal structure, organic matter content, and degree of water saturation. Hydraulic conductivity values vary widely among different soil types: sandy soils record the highest values due to their large pore size, whereas clayey soils record the lowest values due to their fine particles and compaction. Silty soils occupy an intermediate position between the two. This study examines saturated and unsaturated hydraulic conductivity in sandy, clayey, and silty soils, reviews the American classification of these soils according to the USDA Soil Taxonomy system at the suborder level, reviews previous studies conducted on related soil properties in Libya, analyzes results derived from recent scientific studies, and concludes with practical recommendations of benefit to the agricultural, hydrological, and environmental sectors.

Keywords: Hydraulic conductivity, Soil hydrophysical properties, Soil texture, Saturated and unsaturated flow, USDA Soil Taxonomy, Libya.

دراسة علمية شاملة عن الهيدروليكية الموصلية (النفاذية) في الأتربة الرملية والطينية والطميية مع الإشارة إلى تصنيف التربة وفقاً لإدارة الزراعة الأمريكية *(USDA)* (2026)

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الملخص
تُعد الموصلية الهيدروليكية من أهم الخصائص الهيدروفيزيائية للتربة في علم التربة، إذ تُحدد معدل وحجم تدفق المياه خلال مسامات التربة. وتتأثر هذه الخاصية بشدة بتركيب حجم حبيبات التربة (القوام)، والبنية الداخلية، ومحتوى المادة العضوية، ودرجة التشبع المائي. وتتفاوت قيم الموصلية الهيدروليكية تفاوتًا كبيرًا بين أنواع التربة المختلفة؛ إذ تسجل الترب الرملية أعلى القيم نظرًا لكبر حجم مساماتها، في حين تسجل الترب الطينية أدنى القيم بسبب دقة حبيباتها وتماسكها، بينما تحتل الترب الطميية (الغرينية) موقعًا وسطًا بين النوعين. وتتناول هذه الدراسة الموصلية الهيدروليكية المشبعة وغير المشبعة في الترب الرملية والطينية والطميية، وتستعرض التصنيف الأمريكي لهذه الترب وفق نظام التصنيف الأمريكي للتربة (USDA Soil Taxonomy) على مستوى الرتبة الفرعية (Suborder)، كما تستعرض الدراسات السابقة التي أُجريت على

الخصائص المرتبطة بالتربة في ليبيا، وتحلل النتائج المستخلصة من الدراسات العلمية الحديثة، وتخلص إلى توصيات عملية تفيد القطاعات الزراعية والهيدرولوجية والبيئية.

الكلمات المفتاحية: الموصلية الهيدروليكية، الخصائص الهيدروفيزيائية للتربة، قوام التربة، المشبعة وغير المشبعة، تصنيف التربة(USDA) ، ليبيا.

1. Introduction

Hydraulic conductivity is a coefficient expressing the ease with which water flows through soil or porous rock under the influence of a hydraulic gradient. This coefficient is widely used in the design of irrigation and drainage systems, groundwater modeling, estimation of crop water requirements, and assessment of groundwater contamination risk. Its importance is also evident in understanding the dynamics of water percolation and the study of pollutant movement through soil.

In agricultural and hydrological studies, the distinction between saturated hydraulic conductivity (Ksat) and unsaturated hydraulic conductivity (K(θ)) is fundamental. The former is measured when soils are completely filled with water, while the latter changes with variation in soil moisture content. The textural properties of soil (soil texture) and its structure are the governing factors in determining the value of hydraulic conductivity.

This study provides a comprehensive scientific review of hydraulic conductivity in the three principal soil types — sandy, clayey, and silty — along with a detailed review of the precise American classification of each according to the USDA Soil Taxonomy system, in addition to a dedicated review of previous Libyan studies addressing related soil hydrophysical properties.

2. Hydraulic Conductivity — Theoretical Foundations

2.1 Darcy's Law

The French scientist Henry Darcy formulated his famous law in 1856, which remains the mathematical foundation of water movement in soil. This law states that the rate of water flow through a given cross-section of soil is directly proportional to the hydraulic gradient and the soil's hydraulic conductivity coefficient. It is expressed by the following mathematical formula:

$$Q = K \cdot A \cdot (\Delta H / \Delta L)$$

Where: Q = flow rate (m^3/s), K = hydraulic conductivity coefficient (m/s), A = cross-sectional area (m^2), ΔH = hydraulic head difference (m), ΔL = distance in the direction of flow (m). Darcy's Law applies under conditions of linear flow and within the range of low Reynolds numbers ($Re < 1$), meaning the flow must be laminar.

2.2 Saturated Hydraulic Conductivity (Ksat)

Saturated hydraulic conductivity represents the state in which all soil pores are filled with water. Ksat depends heavily on pore size distribution and pore geometry. Researchers estimate Ksat using several field and laboratory methods, most notably:

- Constant Head Method: used for highly permeable soils such as sandy soils.
- Falling Head Method: used for low-permeability soils such as clayey soils.
- Field Auger Hole Method: a direct field measurement reflecting natural soil conditions.
- Inverse Auger Hole Method: used in arid regions where the groundwater table is deep.

2.3 Unsaturated Hydraulic Conductivity K(θ)

Unsaturated hydraulic conductivity varies with soil moisture content (θ). At full saturation, K(θ) equals the Ksat value, and it decreases sharply as moisture content declines. This dependency is modeled using several mathematical models, most notably:

- Brooks & Corey model (1964): assumes a power-law relationship between conductivity and moisture content.
- Van Genuchten model (1980): a widely used model based on an S-shaped conductivity curve, employed in most modern hydrological modeling programs.

- Mualem-Van Genuchten model: combines the Van Genuchten model with Mualem's theory to derive the unsaturated hydraulic conductivity equation based on the water retention curve.

3. Sandy Soils

3.1 Textural and Structural Properties

Sandy soils are characterized by a high proportion of large-diameter particles (0.05–2 mm) according to USDA classification. These soils possess a wide macropore system that leads to high water flow rates. The sand fraction typically ranges between 70% and 100% of the total soil particle mass. They are also characterized by low water storage capacity, low organic matter content, and weak ability to retain nutrients.

3.2 Hydraulic Conductivity Values in Sandy Soils

Table (1): *Saturated hydraulic conductivity values in sandy soils (Rawls et al., 1982; Saxton & Rawls, 2006)*

Texture	Ksat (cm/hr)	Ksat (mm/hr)	Classification
Sand	> 21.0	> 210	Very High
Loamy Sand	6.0 – 21.0	60 – 210	High
Sandy Loam	2.5 – 6.0	25 – 60	Medium–High

3.3 American Classification of Sandy Soils (USDA Soil Taxonomy – Suborder)

Sandy soils are classified within the USDA Soil Taxonomy system under several orders, most notably the Entisols order (the order comprising recently formed soils). At the suborder level, sandy soils are divided as follows:

- Psamments: the suborder most directly associated with sandy soils. These soils possess a coarse sandy texture throughout most of the profile. They are characterized by an absence of clear structural development and occur in numerous regions worldwide, from deserts to coastal lands.
- Orthents: a suborder within Entisols comprising soils that do not belong to other suborders, which may be sandy in certain areas.
- Fluvents: floodplain soils that may be sandy in texture, formed from recent river flood deposits.

Table (2): *American suborder classification of sandy soils (Soil Survey Staff, 2022)*

Suborder	Key Characteristics	Geographic Distribution
Quartzipsamments	Coarse sand > 90% quartz, very high permeability, Ksat > 150 mm/hr	Coasts, sandy deserts, North Africa, Arabian Peninsula
Ustipsamments	Arid to semi-arid environment, low water reserve, Ksat: 80–180 mm/hr	Mediterranean regions, arid plateaus
Aquipsamments	Temporary influence of groundwater, high porosity, Ksat: 60–150 mm/hr	Floodplains, low-lying coastal areas
Torripsamments	Very arid desert soils, no distinct horizon, Ksat > 200 mm/hr	Tropical and subtropical deserts

4. Clayey Soils

4.1 Textural and Structural Properties

Clayey soils are characterized by a high proportion of very fine particles (diameter < 0.002 mm) known as clay. These particles possess an extremely high specific surface area, reaching up to 800 m^2/g in the case of montmorillonite clay. This results in a high capacity to retain water and nutrients, though it significantly restricts water movement. Clayey soils record the lowest saturated hydraulic conductivity values among the different soil types, making them a natural barrier to pollutant seepage.

From a hydrological perspective, clay shrink-swell cycles during dry and wet seasons contribute to the formation of a macropore network that can produce rapid preferential flow, temporarily elevating the apparent hydraulic conductivity of the soil.

4.2 Hydraulic Conductivity Values in Clayey Soils

Table (3): Saturated hydraulic conductivity values in clayey soils (Rawls et al., 1982; Saxton & Rawls, 2006)

Texture	Ksat (cm/hr)	Ksat (mm/hr)	Classification
Clay	< 0.06	< 0.6	Very Low
Clay Loam	0.06 – 0.20	0.6 – 2.0	Very Low
Silty Clay	0.02 – 0.10	0.2 – 1.0	Very Low
Silty Clay Loam	0.10 – 0.40	1.0 – 4.0	Low
Sandy Clay Loam	0.30 – 1.20	3.0 – 12.0	Low–Medium

4.3 American Classification of Clayey Soils (USDA Soil Taxonomy – Suborder)

Clayey soils belong mainly to the Vertisols order (characterized by shrinking and swelling) and the Alfisols order, and occasionally Mollisols. The following presents the suborders most closely associated with clayey soils:

Table (4): *American suborder classification of clayey soils (Soil Survey Staff, 2022; FAO, 2015)*

Order	Suborder	Hydrological Characteristics	Geographic Distribution
Vertisols	Usterts	Very low Ksat (< 1 mm/hr), wide seasonal cracks producing preferential flow	Semi-arid regions: India, Sudan, Australia
Vertisols	Aquerts	Seasonal water deposition, Ksat < 0.5 mm/hr, periodic saturation	Swampy areas and riverbanks
Vertisols	Uderts	Humid climate, Ksat 0.1–2 mm/hr, well-developed clayey B horizon	Tropical and subtropical regions
Alfisols	Udalfs	Low–medium Ksat (1–10 mm/hr), argillic Bt horizon	Eastern United States, Western Europe
Alfisols	Ustalfs	Ksat 0.5–5 mm/hr, alternating dry/wet climate	West Africa, India

5. Silty Soils

5.1 Textural and Structural Properties

Silty soils are characterized by the dominance of silt particles with diameters ranging between 0.002 and 0.05 mm according to USDA classification. Hydraulic conductivity values in silty soils occupy an intermediate position between sandy and clayey soils. One of the most notable features of silty soils is their tendency to form a surface crust upon exposure to raindrop impact, which considerably reduces the infiltration rate. They are also characterized by relatively lower structural stability and higher susceptibility to compaction.

Silty soils are among the most fertile soil types in terms of nutrient content and moisture retention capacity. They are widely distributed across floodplains, river estuaries, and areas with wind-deposited sediments (loess deposits). Loess in Central Europe, Central Asia, and North America is described as among the most studied and productive silty soils.

5.2 Hydraulic Conductivity Values in Silty Soils

Table (5): *Saturated hydraulic conductivity values in silty soils (Rawls et al., 1982; Saxton & Rawls, 2006)*

Texture	Ksat (cm/hr)	Ksat (mm/hr)	Classification
Silt	0.60 – 2.00	6.0 – 20.0	Medium
Silt Loam	0.40 – 1.50	4.0 – 15.0	Medium
Loam	0.50 – 2.50	5.0 – 25.0	Medium

5.3 American Classification of Silty Soils (USDA Soil Taxonomy – Suborder)

Silty soils are associated with several American classification orders depending on their formation conditions and properties. Inceptisols, Mollisols, and Entisols (Fluvents) are among the most common orders for silty soils:

Table (6): *American suborder classification of silty soils (Soil Survey Staff, 2022; NRCS, 2019)*

Order	Suborder	Hydrological Characteristics	Geographic Distribution
Inceptisols	Udepts	Medium Ksat (5–20 mm/hr), good structure, moderate horizon development	North America, Europe, Southeast Asia
Inceptisols	Aquepts	Low–medium Ksat (2–10 mm/hr), seasonal saturation	Floodplains, wetlands
Mollisols	Ustolls	Ksat 5–25 mm/hr, high organic content, dark Ah horizon	Great Plains of the USA, Eurasia
Mollisols	Udolls	Ksat 8–30 mm/hr, temperate humid climate, high fertility	American Corn Belt, Central Europe
Entisols	Fluvents	Ksat 3–20 mm/hr, recent deposits, cross-bedding	River plains, major river deltas

6. Comprehensive Comparative Table of Hydraulic Conductivity in the Three Soil Types

Table (7): *Comprehensive comparison of hydraulic conductivity properties in the three soil types*

Property	Sandy Soils	Silty Soils	Clayey Soils	Source
Ksat (mm/hr)	> 25	4 – 25	< 4	Rawls et al. (1982)
Particle Size	0.05–2 mm	0.002–0.05 mm	< 0.002 mm	USDA NRCS
Total Porosity %	35–50%	40–55%	50–60%	Brady & Weil (2017)
Macroporosity %	High (20–40%)	Low (5–15%)	Very Low (<5%)	Hillel (2004)
Water Retention Capacity	Low	High	Very High	Saxton & Rawls (2006)
Cracking Potential	None	Low	High (esp. Vertisols)	FAO (2015)
Erosion Risk	Low	High	Low–Medium	Morgan (2005)
Dominant Classification Order	Entisols (Psamments)	Inceptisols/Mollisols	Vertisols/Alfisols	Soil Survey Staff (2022)

7. Previous Studies in Libya

Although dedicated laboratory measurements of saturated and unsaturated hydraulic conductivity remain limited in the Libyan scientific literature, a substantial body of research has addressed closely related soil hydrophysical properties — infiltration rate, soil texture, bulk density, and aggregate stability — primarily in the Al-Jabal Al-Akhdar (Green Mountain) region of northeastern Libya. These studies provide an important local reference base that can be connected to the international USDA Soil Taxonomy framework discussed in this study.

7.1 Studies on Soil Physical Properties and Infiltration

Abagandura, Nasr and Moumen (2017) investigated the influence of tillage practices on soil physical properties and maize growth and yield in Jabal Al-Akhdar, Libya, showing that tillage method exerted a measurable effect on bulk density and related physical properties that govern water movement through the soil profile.

Habel (2013) examined the role of climate on aggregate stability and soil erodibility in selected soils of Al-Jabal Al-Akhdar, finding that aggregate stability — a property closely linked to macropore continuity and therefore to hydraulic conductivity — varied with local climatic conditions across the study sites.

A study published in the Journal of Marine Science and Environmental Technologies (2020) on soil erodibility and land degradation in the Al-Jabal Al-Akhdar region reported a strong relationship between final infiltration rate and soil erodibility, with a correlation coefficient of approximately 0.68 between infiltration rate and the erodibility indicators examined.

Alsanousi and colleagues (2024), publishing in the Journal of Forestry Research and Technology (Forest Science and Technology), investigated physicochemical soil characteristics across 56 sample plots at varying elevations and slope aspects in the Al-Jabal Al-Akhdar forest. The study found that clay content decreased and sand content increased with elevation, while available water capacity increased with altitude on the northern slope; the region was shown to encompass five USDA soil orders — Entisols, Aridisols, Alfisols, Vertisols, and Mollisols — directly relevant to the American classification framework discussed in Sections 3–5 of this study.

7.2 Studies on Land Degradation and Soil Management

Aburas (2009), in a doctoral study conducted at the University of Newcastle upon Tyne, assessed soil erodibility in relation to soil degradation and land use across Mediterranean Libya, establishing baseline relationships between soil physical degradation and land management practices still referenced in subsequent Libyan soil studies.

A study published by the Journal of Misurata University for Agricultural Sciences compared the effect of topography and land use on soil erosion rates across the Marawa, Al-Masaylaba–Madur Al-Zaitoun, and Al-Qadida areas of Al-Jabal Al-Akhdar, measuring soil texture, bulk density, moisture content, and field infiltration rate across twenty-four slopes; the study concluded that Mollisols in the region held greater agricultural investment potential than the co-occurring Aridisols, given their more favorable physical and hydrological properties.

A further assessment of soil management and its role in reducing land degradation in the southern part of Al-Jabal Al-Akhdar documented detailed morphological descriptions of clay-silt textured soils in the region, including structural and consistency properties that directly influence local infiltration behavior.

7.3 Relevance to This Study

Collectively, the Libyan literature confirms two patterns consistent with the international findings reviewed in this study: first, that soil texture and structure remain the dominant controls on infiltration and inferred hydraulic conductivity across Libyan soils, mirroring the sand–silt–clay gradient documented in Sections 3 through 6; and second, that the Al-Jabal Al-Akhdar region alone spans at least five USDA soil orders, underscoring the practical value of applying the USDA Soil Taxonomy suborder-level classification — as presented in this study

— to Libyan soils. This also reinforces this study's Research Recommendation (Section 9.2) that further dedicated Ksat measurement campaigns, using standard methods such as the Constant Head and Falling Head methods described in Section 2.2, be undertaken across representative Libyan soil types to close the current data gap and enable direct comparison with the international USDA reference values presented herein.

8. Results and Discussion

8.1 Patterns of Hydraulic Conductivity and Their Interpretation

The results of the reviewed studies revealed a wide and clear variation in saturated hydraulic conductivity (Ksat) values among the three soil types. The most notable findings can be summarized in the following points:

First: Sandy soils — Pure sandy soils record the highest Ksat values, generally exceeding 210 mm/hr, and in some coarse pure sand deposits can reach more than 500 mm/hr. This is mainly attributed to the size of the macropores and their relatively high density. Ksat values decrease markedly with the addition of finer particles (as in the transition from Sand to Loamy Sand), confirming the pivotal role of pore size distribution.

Second: Silty soils — Silty soils record medium Ksat values ranging between 4 and 25 mm/hr in most cases. These soils are notable in that Ksat is strongly affected by field treatments (such as tillage and compaction), potentially declining by 50–80% due to mechanical pressure. Some studies indicate that organic fractions in these soils improve their structure and increase soil aggregate stability, positively reflecting on Ksat.

Third: Clayey soils — Clayey soils record the lowest values, with Ksat generally falling below 1 mm/hr, and in the case of pure clay it may drop below 0.1 mm/hr. Notably, however, some clayey soils, especially Vertisols, display relatively high initial infiltration rates in the field due to seasonal shrinkage cracks that provide rapid flow pathways. This apparent contradiction between laboratory and field measurements makes measuring Ksat in these soils particularly complex.

8.2 Effect of Management and Environmental Factors on Hydraulic Conductivity

Studies have shown that organic matter is one of the most important factors influencing the improvement of hydraulic conductivity in clayey and silty soils, as it enhances soil aggregate stability and reduces the risk of pore clogging. Similarly, the use of conservation tillage techniques contributes to maintaining soil structure and limiting the deterioration of hydraulic conductivity. In contrast, excessive flood irrigation practices in some clayey soils have led to compaction of subsurface soil layers and a reduction in Ksat by rates reaching 60% compared to uncompacted soil (Ferreras et al., 2000).

8.3 Overall Quantitative Result

Based on the ROSETTA database (Schaap et al., 2001) and the equations of Saxton & Rawls (2006), saturated hydraulic conductivity among the three soil types can be ranked as follows:

Sandy soils: Ksat = 6 – 500 mm/hr | Silty soils: Ksat = 2 – 25 mm/hr | Clayey soils: Ksat = 0.01 – 4 mm/hr

The ratio between the most permeable sandy soil and the least permeable clayey soil is estimated to exceed 50,000:1, reflecting the enormous variation in water movement behavior among these soils.

9. Conclusions and Recommendations

9.1 Key Conclusions

- Soil texture fundamentally controls saturated hydraulic conductivity values by determining pore size and its volumetric distribution.
- Sandy soils (Psamments in the American classification) record the highest values and are the most affected by minor changes in particle distribution.

- Clayey soils (Vertisols, Alfisols) are characterized by the phenomenon of preferential flow through shrinkage cracks, making laboratory measurements less representative of actual field conditions.
- Silty soils (Inceptisols, Mollisols, Fluvents) represent the optimal agricultural choice in terms of the balance between hydraulic conductivity, moisture retention, and fertility.
- The Mualem-Van Genuchten model is considered the most accurate for describing unsaturated hydraulic conductivity across different soil types and is widely used in modeling programs.
- Libyan soil studies, concentrated mainly in Al-Jabal Al-Akhdar, confirm the same texture-driven infiltration patterns identified internationally, while highlighting a clear need for dedicated Ksat measurement studies at the national level.

9.2 Recommendations

- Recommendation for agricultural authorities: it is necessary to adopt field Ksat measurements alongside laboratory measurements to capture the effect of cracks and macropores in clayey soils.
- Environmental recommendation: it is necessary to avoid constructing landfills over sandy soils without adequate liners, given their high Ksat and the risk of pollutant seepage.
- Recommendation for engineers: apply conservation soil management techniques and avoid mechanical compaction of silty soils to preserve Ksat values and ensure agricultural productivity.
- Research recommendation: conduct comparative studies using the USDA Soil Taxonomy classification for local soils in the Arab region, to determine their hydraulic properties and relate them to the international classification system.
- Technical recommendation: employ modern mathematical models (HYDRUS-1D/2D, SWAP) in the hydrological modeling of the three soil types as decision-support tools for irrigation management.
- National recommendation: expand direct Ksat measurement campaigns (constant head, falling head, and field auger hole methods) across Libyan regions beyond Al-Jabal Al-Akhdar, to build a national reference database comparable to the international ROSETTA and USDA datasets referenced in this study.

References

- Abagandura, G. O., Nasr, G. E.-D. M., & Moumen, N. M. (2017). Influence of tillage practices on soil physical properties and growth and yield of maize in Jabal Al Akhdar, Libya. *Open Journal of Soil Science*, *7*(6), 118–132.
- Aburas, M. M. (2009). *Assessment of soil erodibility in relation to soil degradation and land use in Mediterranean Libya* [Doctoral dissertation, University of Newcastle Upon Tyne].
- Alsanousi, A. et al. (2024). Investigating soil properties on the north and south slopes at different elevations in Al-Jabal Al-Akhdar, Libya. *Forest Science and Technology*, 286–299.
- Assessment of soil erodibility in relation to land degradation, Al-Jabal Al-Akhdar, Libya. (2020). *Journal of Marine Science and Environmental Technologies*, *6*(1).
- Brady, N. C., & Weil, R. R. (2017). *The nature and properties of soils* (15th ed.). Pearson Education.
- Brooks, R. H., & Corey, A. T. (1964). *Hydraulic properties of porous media* (Hydrology Paper No. 3). Colorado State University.
- Clapp, R. B., & Hornberger, G. M. (1978). Empirical equations for some soil hydraulic properties. *Water Resources Research*, *14*(4), 601–604.
- Darcy, H. (2004). *Les fontaines publiques de la ville de Dijon* (P. Bobeck, Trans.). Kendall Hunt Publishing. (Original work published 1856)
- Effect of topography and land use on soil erosion rates in Al-Jabal Al-Akhdar, Libya. (n.d.). *Journal of Misurata University for Agricultural Sciences*.

- Ferreras, L., García, E., Toresani, S., Fernández, E., & Gorini, R. (2000). Effect of organic amendments on some physical, chemical and biological properties in a horticultural soil. *Bioresource Technology*, *75*(1), 9–16.
- Food and Agriculture Organization. (2015). *World reference base for soil resources 2014, update 2015: International soil classification system for naming soils and creating legends for soil maps* (World Soil Resources Reports No. 106). FAO.
- Habel, A. Y. (2013). The role of climate on the aggregate stability and soil erodibility of selected El-Jabal Al-Akhdar soils-Libya. *Alexandria Journal of Agricultural Research*, *58*, 261–271.
- Hillel, D. (2004). *Introduction to environmental soil physics*. Elsevier Academic Press.
- Morgan, R. P. C. (2005). *Soil erosion and conservation* (3rd ed.). Blackwell Publishing.
- Mualem, Y. (1976). A new model for predicting the hydraulic conductivity of unsaturated porous media. *Water Resources Research*, *12*(3), 513–522.
- Natural Resources Conservation Service. (2019). *Keys to soil taxonomy* (12th ed.). United States Department of Agriculture.
- Rawls, W. J., Brakensiek, D. L., & Saxton, K. E. (1982). Estimation of soil water properties. *Transactions of the American Society of Agricultural Engineers*, *25*(5), 1316–1320, 1328.
- Saxton, K. E., & Rawls, W. J. (2006). Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Science Society of America Journal*, *70*(5), 1569–1578.
- Schaap, M. G., Leij, F. J., & van Genuchten, M. Th. (2001). ROSETTA: A computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. *Journal of Hydrology*, *251*(3–4), 163–176.
- Šimůnek, J., Šejna, M., & van Genuchten, M. Th. (2016). *HYDRUS-1D software package for simulating the one-dimensional movement of water, heat, and multiple solutes in variably-saturated media* (Version 4.xx). University of California.
- Soil Survey Staff. (2022). *Keys to soil taxonomy* (13th ed.). USDA Natural Resources Conservation Service.
- van Genuchten, M. Th. (1980). A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Science Society of America Journal*, *44*(5), 892–898.
- Warrick, A. W. (2002). *Soil physics companion*. CRC Press.
- Zhang, Z. F. (2010). Soil water retention and relative permeability for conditions from oven-dry to full saturation. *Vadose Zone Journal*, *9*(2), 145–156.
- California Bearing Ratio (CBR) Value for Expansive Soil Subgrade Stabilized Using Brick Dust-Lime Mixtures . (2026). *Albahit Journal of Applied Sciences*, *5*(2), 54-63. https://doi.org/10.65419/albahit.v5i2.136
- Fadwa Ibrahim Salem Elagori. (2026). The Relationship between Land Surface Temperature and Soil Moisture in the Ecosystem of the Region – An Applied Study Based on Data from Shahat Station for the Period 1981–2024. Journal of Libyan Academy Bani Walid, 2(1), 961–977. https://doi.org/10.61952/jlabw.v2i1.484
- Jamal. S. M. Taher, Awad M. Mohamad, & Shukri. M. Elsbia. (2026). Soil pH Dynamics in a Calcareous Soil as Influenced by Organic and Sulfur Amendments under Different Irrigation Water Qualities. Journal of Libyan Academy Bani Walid, 2(1), 11–17. https://doi.org/10.61952/jlabw.v2i1.385
- Mohamed Saleh Alamin Hassan, Ibrahim Abobaker Ali Langer, & Omar Imsiry Omar. (2026). The Impact of Climatic Factors on Desertification Acceleration in Southwestern Libya: A Field Study of) Murzuq and Ubar(. Journal of Libyan Academy Bani Walid, 2(1), 114–126. https://doi.org/10.61952/jlabw.v2i1.423

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.