



ISSN 2790 – 5985

eISSN 2790 – 5993

Agriculture College – Wasit University

Dijlah Journal of  
Agricultural Sciences

Dijlah J. Agric. Sci., 5(2):77-84, 2026

## Application of Nanotechnology for Improving physical properties of Degraded soils

Zahraa Khaled Kamel Al-Salihi

Department of Soil and Water Resources Sciences, College of Agricultural, University of Wasit, Wasit, Iraq.

Corresponding author: [Zakameel@uowasit.edu.iq](mailto:Zakameel@uowasit.edu.iq)

### Abstract:

This study aimed to study the effects of nanotechnology on improving the physical properties of degraded soil in Dhi Qar Governorate, which faces environmental challenges such as high salt content, water shortage, and deterioration of the physical structure of the soil. Emphasis has been placed on the use of nano-materials such as nano-silica and nano-clay, improving bulk density, permeability, water conductivity and water-holding capacity of soil .

Preliminary results show that nanomaterials contribute significantly to enhancing soil structural cohesion, increasing in-situ capacity, reducing permeability in sandy soil, and improving pore distribution. In addition, the use of nanotechnology has improved water use efficiency and reduced degradation caused by corrosion or erosion. The study recommends broader application of nanotechnology in affected areas in Iraq, with a focus on conducting long-term field studies to ensure effectiveness and environmental sustainability. Technology is a promising tool for achieving sustainability of agriculture and water resources in the face of increasing environmental challenges.

**Keywords:** *Nanotechnology, degraded soil, sustainability techniques, soil improvement, water-holding capacity, nanoparticles.*

Received:22/2/2026

Accepted:17/3/2026

Published:1/4/2026

### 1. Introduction:

The phenomenon of soil degradation is undoubtedly one of the most pressing environmental problems in the world. As a result of various degradation processes around the world (Ranjani et al., 2021). Soil erosion and land resource degradation are 2 issues of great concern in many countries. Land degradation has become the most serious threat to global security, as it is increasingly threatening food production, food security and natural resource conservation, especially to the poor and vulnerable in arid regions of developing countries in Africa and Asia, thus seriously threatening people. Life, soils and landscapes (Nightingale & Richmond, 2022). Soil degradation is the loss of inherent physical, chemical or biological properties of soil due to natural or human processes, which can lead to the reduction or disappearance of important ecosystems (Muhammad Israr et al., 2020). Thus, the main causes of soil degradation are: erosion, decomposition of organic matter, loss of biodiversity, compaction, sealing, point and spread source pollution, contamination, and salinization (Hillel, 2010).

Nanoscience has become the forefront of the most exciting and important fields in the field of physics and other sciences. It has also given great hope for the scientific revolution in the near future. These revolutions have changed the direction of science for many applications, and nanoscience represents the fifth generation of technological development (Daraio & Jin, 2012). Nanoscience is a unit for measuring the length of very small things that can only be seen with an electron microscope, such as a unit cell or bacteria, because it is not interested in a specific science, but it also specializes in materials science and links these sciences to physics such as chemistry, physics, and bioengineering, and these sciences have many People interested in studying the properties of matter at the nanoscale. It represents branches and subfields (Aegerter & Mennig, 2013); (Milea et al., 2011).

**Importance of the research:** How can nanotechnology contribute to improving soil properties and improving agricultural land productivity?

## **2. Research objectives:**

- 1- Study the effects of nanotechnology on improving deteriorated physical properties.
- 2-Identifying nanomaterials suitable for soil use.
- 3-Evaluating the effect of nanotechnology application on the physical properties of soil.
- 4-Study the effects of nanotechnology to improve the soil's ability to retain moisture and reduce compaction.

## **2.2. Materials and methods:**

### **1) Field studies:**

The study area was selected in Dhi Qar Governorate (Shatrah District), which suffers from soil degradation due to lack of water resources and high soil salinity. Shatrah District is an Iraqi district in Dhi Qar Governorate in southern Iraq. It has an area of 5,044 square kilometers and a population of 899,192 people (2016). Its coordinates are 31°24'N 46°18'E (Al-Mayah & Al-Tmemy, 2024).

## **2) Collecting soil samples:**

Areas were chosen that represent the typical soil of the region, such as areas near the river. Sampling tools such as scoops, tubes or collection bags, locators, and sterile instrument tools were collected. The samples were collected from two different depths: first, the surface depth was taken from 15-30 cm root zone, second, the subsurface were taken from 50 -100 cm depth. These two holes were considered representation different locations in the study area.

## **3) Preparation of nanomaterials:**

A. Nano-silica and nano-clay (Khaleel and sukkar,2019).

Chemical method: Natural silica, such as sand, is dissolved in a strong alkaline solution (sodium hydroxide), and a strong acid, such as sulfuric acid, is used to precipitate silica nanoparticles.

Physical method: grinding silica using advanced ball mill until the particle size reaches nano. Application: Nano silica is used to increase soil properties in terms of compressive strength and water absorption capacity, in addition to reducing permeability.

B- Preparation of nano-clay

Preparation steps: Natural clay mixed with fume silica nanoparticles. Use a mechanical stirrer to break up large masses and evenly distribute nanoparticles to mix materials intensively for a long time. Application: Silica clay is used to improve the structural properties of soil and make it more homogeneous and feasible in agricultural and engineering projects.

## **4) Processing applications:**

A- Applying nanomaterials to soil samples: Nanomaterials (nano silica and nano clay) were added to the soil samples at different concentrations (1% and 2%). These concentrations were sprayed to ensure uniform distribution of the nanomaterials and the materials were mixed well with the soil. Then, changes in soil physical properties were monitored after treatment.

B- Monitoring changes in the physical properties of the soil:

After adding nanomaterials, changes in soil physical properties were measured. measurement:

Density It has been reported that adding nanomaterials leads to an increase in soil density, which indicates improved cohesion of soil particles. Permeability The treated samples showed a significant reduction in soil permeability, indicating the ability of nanomaterials to reduce water infiltration. Water holding capacity the soil's water holding capacity was measured and the treated

samples showed a significant increase in this capacity. Water conductivity The soil's ability to conduct water was measured, and the treated samples showed a noticeable increase in this ability. The samples were examined in one of the laboratories of Dhi Qar University.

**Statistical analysis:** SPSS and Minitab: These are the main tools used in statistical analysis to measure the effect of nanomaterials on the physical properties of soil. These programs provide tools for testing hypotheses, calculating the mean and standard deviation, and analyzing variance (El-Sharkawy et al., 2024).

### 3. Results and discussion:

Data were collected on the physical properties of the soil before and after treatment with nanomaterials. Four main properties were measured: bulk density, permeability, water holding capacity, and water conductivity. Different concentrations of nanomaterials were determined and their effect on the sample was tested.

#### 1) Bulk density:

The weight of the soil in a given volume. This density increases with increasing pressure and also increases with increasing depth. It is known as dry bulk density. It is calculated by dividing the weight of dry soil by the total volume of soil. The volume of soil includes the combined volume of solids and pores that It contains air and water, and this measuremsoil .

Table (1) shows the bulk density concentrations before and after adding nanomaterials.

Processing type	Bulk density (g/cm <sup>3</sup> )	Change relative to the original soil
Native soil	1.34	-
Nano Silica (1%)	1.41	+5.22%
Nano Silica (2%)	1.45	+8.21%
Nano clay (1%)	1.38	+2.98%
Nano clay (2%)	1.42	+5.97%

The results showed that adding nanomaterials (nano-silica and nano-clay) to the soil significantly increased the density and improved the cohesion of soil particles. Silica nanoparticles have a greater effect on bulk density compared to clay nanoparticles, possibly due to the more favorable properties of increased cross-linking and reduced voids.

In both cases, increasing the concentration resulted in further improvement, but the increase in density was more pronounced for the silica nanoparticles.

In (1%) nano-silica: bulk density: 1.41 g/cm<sup>3</sup>. The result was +5.22% When adding (2%) nano-silica: the bulk density was: 1.45 g/cm<sup>3</sup>. Then it became +8.21% When the proportion of silica nanoparticles increased from 1% to 2%, the bulk density increased further. The significant improvement in density may be a result of improved bonding between soil particles thanks to the

physical and chemical properties of silica nanoparticles (e.g. increased interparticle space filling and improved cohesion).

When nano clay was added at a rate of (1%): the bulk density was: 1.38 g/cm<sup>3</sup>. Then it changed until the percentage became: +2.98%. When adding nano clay (2%): the bulk density was: 1.42 g/cm<sup>3</sup>. The percentage became +5.97%. The effect of Nano clay is less compared to Nano silica, as it resulted in a smaller increase in bulk density.

As the proportion of Nano clay increased from 1% to 2%, the density improved, but at a lower rate than that of Nano silica, perhaps because differences in the structural composition of Nano clay affected the degree of cohesion and voids between soil particles compared to silica.

## 2) Permeability:

Soil permeability is a property that determines the ability of soil to transport liquid (such as water) through the pores between particles. Permeability is affected by soil properties such as particle size, grain distribution, organic content, and pore voids.

Table (2) shows the permeate concentrations before and after adding nanomaterials.

Processing type	Transmittance(cm/min)	Change relative to the original soil
Native soil	0.45	-
Nano Silica (1%)	0.35	-22.22%
Nano Silica (2%)	0.30	-33.33%
Nano clay (1%)	0.40	-11.11%
Nano clay (2%)	0.33	-26.67%

The results showed when adding (1%) of nano silica to a permeability ratio of: 0.35 cm/min. It led to a ratio of -22.22% When adding (2%) of nano silica: the permeability was: 0.30 cm/min. The percentage became -33.33%. The addition of 1% and 2% silica nanoparticles resulted in a significant decrease in transmittance, with a larger percentage (2%) being more effective.

This reduction can be explained by filling the pores between soil particles with silica nanoparticles, which reduces the size of the permeable pores and increases the resistance of the soil to fluid seepage. When adding nano clay (1%): the permeability was: 0.40 cm/min. Then it became -11.11% When adding nano clay (2%): the permeability was: 0.33 cm/min. It became -26.67% The addition of nanoclay reduced the permeability, but the rate was lower than that of nano-silica. At 2%, the impact was greater compared to 1% (11.11% decrease) (26.67% decrease).

This effect is due to the ability of nanoclay to improve intermolecular aggregation, but to a lesser extent than nanosilica due to the different properties of the material.

Silica nanoparticles: They are more effective at reducing permeability (such as dams and reservoirs), making them a better choice in applications requiring low-permeability soils. As for

nano-clay: it has a mild effect and can be useful if its purpose is not to significantly reduce permeability.

### 3) Water-holding capacity:

The water-holding capacity of soil (soil moisture holding capacity) is the inherent ability of soil to store water between particles in pore spaces for use by plants. This property depends on factors such as grain size, organic matter percentage, and pore distribution Choudhary et al., 2021.

Table (3) shows soil water retention concentrations before and after adding nanomaterials.

Processing type	Water holding capacity (%)	Change relative to the original soil
Native soil	19.2	-
Nano Silica (1%)	22.5	+17.19%
Nano Silica (2%)	25.4	+32.29%
Nano clay (1%)	20.8	+8.33%
Nano clay (2%)	23.1	+20.31%

When adding 1% nano silica, the results showed that the water retention capacity: 22.5%. The percentage has increased to +17.19% When adding nano silica (2%): the water retention capacity was: 25.4%. The percentage became +32.29% The addition of 1% and 2% of silica nanoparticles increased the water holding capacity of the soil, and the increase was greater at 2%. The significant improvement in water holding capacity is due to the effect of silica nanoparticles to improve intermolecular cohesion and increase water-containing micropores. When adding 1% nano clay, the water retention capacity was 20.8%. Until it became +8.33% As for adding (2%) nano-clay, the water retention capacity was: 23.1%. The percentage became +20.31%

Nanoclay improved the soil's ability to hold less water than nano silica. When 2% nanoclay was added, the increase was larger (20.31%), reflecting increased efficacy with increasing concentration.

Nano silica can be used to dramatically increase water retention, which is beneficial in sand or dry soil. Nano clay provides moderate improvement and is more suitable for soils with average properties. Both materials contribute to improving water retention capacity by strengthening the porous structure and improving pore distribution.

### 4) Water conductivity:

A physical property that expresses the ability of the soil to allow water to pass through it. It is a very important property in the fields of agriculture, water management, and civil engineering, and it affects the distribution of water in the soil, drainage processes, as well as groundwater recharge (Altafi Dadgar et al., 2020).

Table (4) shows the soil water conductivity concentrations before and after adding nanomaterials.

Processing type	Water conductivity (cm/min)	Change relative to the original soil
Native soil	0.48	-
Nano Silica (1%)	0.40	-24.22%
Nano Silica (2%)	0.39	-38.39%
Nano clay (1%)	0.42	-13.15%
Nano clay (2%)	0.35	-28.69%

Nano-silica: The results of the statistical analysis showed a noticeable improvement in reducing the water conductivity (i.e. reducing the permeability) with increasing concentration. When nano-silica was added at a rate of 1%, the conductivity decreased to 0.40 cm/min (-24.22%), when the concentration was increased to 2%, It decreased to 0.39 cm/min (-38.39%).

Nano clay: The results of statistical analysis showed an improvement in reducing conductivity. But to a lesser extent compared to nano-silica, when adding nano-clay at a rate of 1%, the conductivity decreased to 0.42 cm/min (-13.15%), and at a concentration of 2%, it decreased to 0.35 cm/min (-28.69%). The results showed that adding nanomaterials, especially nano-silica, reduces the soil's ability to permeate water. This improvement is considered positive because it enhances the soil's ability to retain water, which is essential for improving the sustainability of agriculture in degraded areas.

#### 4. Conclusions:

Nanomaterials such as nano-silica and nano-clay have proven effective in enhancing the properties of degraded soil by improving its structure and reducing the effects of degradation. The current results indicate the possibility of generalizing the use of nanotechnology to other areas suffering from soil degradation in Iraq and supporting agricultural development on a large scale. Nanotechnology helps restore the environmental balance of the soil by reducing the negative effects of human activity and environmental factors. The use of nanomaterials improves aeration within the soil by increases the bulk density, which enhances root growth and increases the effectiveness of nutrients and water absorption. Nanomaterials helped reduce the variation between different parts of the soil and make the physical properties of the soil more stable.

#### Reference:

- 1) Aegerter, M. A., & Mennig, M. (2013). *Sol-gel technologies for glass producers and users*. Springer.
- 2) Al-Mayah, W. T., & Al-Tmemy, W. B. (2024). Use of remote sensing, GIS, and regression analysis in monitoring water quality of Al-Gharraf River, southern Iraq. *Middle East Research Journal of Biological Sciences*, 4(4), 96–112. <https://doi.org/10.36348/merjbs.2024.v04i04.002>

- 3) Altafi Dadgar, M., Nakhaei, M., Porhemmat, J., Eliasi, B., & Biswas, A. (2020). Potential groundwater recharge from deep drainage of irrigation water. *Science of the Total Environment*, 716, 137105. <https://doi.org/10.1016/j.scitotenv.2020.137105>
- 4) Daraio, C., & Jin, S. (2012). Synthesis and patterning methods for nanostructures useful for biological applications (pp. 27–44). [https://doi.org/10.1007/978-0-387-31296-5\\_2](https://doi.org/10.1007/978-0-387-31296-5_2)
- 5) El-Sharkawy, M., Alotaibi, M. O., Li, J., Mahmoud, E., Ghoneim, A. M., Ramadan, M. S., & Shabana, M. (2024). Effect of nano-zinc oxide, rice straw compost, and gypsum on wheat (*Triticum aestivum* L.) yield and soil quality in saline–sodic soil. *Nanomaterials*, 14(17), 1450. <https://doi.org/10.3390/nano14171450>
- 6) Hillel, D. (2010). Dirt: The erosion of civilization. *Vadose Zone Journal*, 9(2), 507–508. <https://doi.org/10.2136/vzj2009.0145br>
- 7) Milea, C. A., Bogatu, C., & Duță, A. (2011). The influence of parameters in silica sol-gel process. *Bulletin of the Transilvania University of Braşov, Series I: Engineering Sciences*, 4(53).
- 8) Muhammad Israr, F., Ali, F., Ullah, A., Ur Rehman, S., Nawaz, A., Iqbal, R., Ullah, S., Zeb, U., & Noreen, Z. (2020). Immunochromatographic test and third generation ELISA for elucidating the existence and risk factors of anti-HCV antibodies among blood donors from Swabi, Pakistan. *Abasyn Journal of Life Sciences*, 138–144. <https://doi.org/10.34091/AJLS.3.2.13>
- 9) Nightingale, E., & Richmond, C. (2022). Reclaiming land, identity and mental wellness in Biigtigong Nishnaabeg territory. *International Journal of Environmental Research and Public Health*, 19(12), 7285. <https://doi.org/10.3390/ijerph19127285>
- 10) Ranjani, M., Veerasingam, S., Venkatachalapathy, R., Mugilarasan, M., Bagaev, A., Mukhanov, V., & Vethamony, P. (2021). Assessment of potential ecological risk of microplastics in the coastal sediments of India: A meta-analysis. *Marine Pollution Bulletin*, 163, 111969. <https://doi.org/10.1016/j.marpolbul.2021.111969>