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Research article

Effect of cotton, maize, and sesame cultivation on soil depletion and a comparison of its effect on chemical properties

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ABSTRACT

The study site was selected within the greenhouses at the University of Mosul in Nineveh Governorate, northern Iraq. Cotton and sesame seeds were sown on June 3, 2025, while maize seeds were sown on July 3, 2025. The cotton and sesame crops were harvested on November 10, 2025, and the maize was harvested on December 5, 2025. Soil samples were collected from the topsoil (0-30) cm at the study sites, with three replicates per site, after the harvest. DAP fertilizer (0:46:18) and urea fertilizer (46%) were used to fertilize the cotton, maize, and sesame soils to increase crop productivity and to determine effecting of intercropping on soil fertility. A sprinkler irrigation system was installed on the greenhouses to spray the crops using water from the Tigris River. The results showed that the soil acidity in all the soils studied was neutral, slightly inclined towards alkalinity, ranging from (7.20) in the maize soil to (7.35) in the cotton soil. soil electrical conductivity degree, it ranged from (0.50 dS m^{-1}) in the maize soil to (0.75 dS m^{-1}) in the sesame soil. Therefore, all the soils of the study sites are considered good in terms of electrical conductivity and safe for all cultivated crops. This is reflected in the good concentration of cations and anions in the soil and is safe for cultivation. The results obtained a clear difference in soil depletion degree among the studied crops after the end of the experiment and the harvest of the (cotton, maize, and sesame) crops. It was found that cotton had the highest stressing effect on the soil, followed by maize, while sesame had the least effect on nitrogen and phosphorus. The nitrogen percentage ranged between (21.6, 36.3, 91.0) mg kg^{-1} for the soils of cotton, maize, and sesame crops respectively, while phosphorus percentage ranged between (31.5, 38.0, 45.0) mg kg^{-1} for cotton, maize, and sesame crops soils respectively.

1. Introduction

Soil is one of the most important natural resources upon which agricultural production depends, as it represents the living medium that provides the physical support and nutrient reserves necessary for plant growth and productivity. With the increasing global demand for food due to population growth, agricultural systems have moved towards intensive farming and the cultivation of high-yield

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crops that are highly depleting and stressful on the soil. This has led to increased pressure on soil resources and accelerated rates of soil degradation (Ullah et al., 2018).

Soil depletion is defined as the gradual decrease in its nutrient content due to continuous absorption by crops without adequate replenishment, especially by soil-stressing crops (Baligar *et al*., 2001). This leads to a deterioration of the soil's physical, chemical, and biological properties (Dobermann, 2007). Agricultural crops vary considerably in their impact on soil fertility depending on several factors, most notably their nutritional requirements, the length of the growing season, nutrient uptake efficiency, and the nature of their root system. Therefore, field crops are classified as either exhaustive crops or relatively conservative crops, according to the extent of their nutrient depletion (El-nagggar *et al*., 2012).

Crops such as cotton (Gossypium spp.) and maize (Zea mays L.) are among the most important economic crops globally, but they are also known for their high nutrient consumption, particularly of nitrogen, phosphorus, and potassium (Fageria *et al*.,2011). Numerous studies have shown that these crops absorb large quantities of nutrients from the soil to achieve high yields, leading to a depletion of soil nutrient stores over time (Liu and Li, 2014). In a recent study, (Djaman *et al*., 2025) demonstrated that continuous cultivation of cotton-maize crops over a long period resulted in a significant depletion of soil fertility and a deterioration of its chemical properties, despite the application of conventional fertilization programs, highlighting the severe impact of these crops on the soil. Recent studies also show that maize is a crop with high demand for nutrients, as its high productivity is associated with increased absorption of macronutrients, which leads to accelerated soil depletion, especially in intensive farming systems. On the other hand, cotton is characterized by a long growing season and a deep root system (Johnston and Poulton,2018), which enables it to absorb nutrients from different layers of soil, but at the same time it increases the severity of its depletion (Zhang *et al*., 2024). In contrast, some oilseed crops, such as sesame (Sesamum indicum L.), are classified as low-input crops, characterized by their ability to grow in challenging environmental conditions and relatively low nutritional requirements compared to other field crops, particularly in arid and semi-arid soils. Given the increasing environmental challenges, including soil degradation and climate change, the importance of developing sustainable agricultural strategies based on a thorough understanding of the impact of different crops on soil fertility is paramount. Selecting appropriate crops within a crop rotation can significantly contribute to reducing soil depletion and improving its long-term productivity (Murrell *et al* ., 2021).

Objective of this study: To compare the effects of cotton, maize, and sesame cultivation on soil fertility depletion through assessing nutrient uptake and soil nutrient loss, with the aim of identifying the most depleting crops and promoting sustainable cropping systems that reduce soil degradation.

2. Materials and Methods

2.1 Study site

The study site was chosen within the greenhouses inside the University of Mosul in Nineveh Governorate, northern Iraq. Cotton and sesame seeds were planted on 3/6/2025, while maize seeds were planted on 3/7/2025. The cotton and sesame crops were harvested on 10/11/2025, and the maize crop was harvested on 5/12/2025. The cultivation took place in three greenhouses belonging to the Dry Agriculture Center at the University of Mosul, adjacent to each other. Soil samples were collected from the surface layer (0-30 cm) of the soils at the study sites, with three replicates for each site within the geographical location (36º2305.83N 43º0806.96E). After the samples arrived at the laboratory, they were air-dried and then ground using a wooden mallet. They were sieved through a sieve with openings of (2 mm) and stored inside plastic containers to prepare them for various laboratory analyses and studies.

2.2 Laboratory Analyses

Chemical and physical analyses were performed on soil samples in the Soil Science and Water Resources Laboratories – Dry land Agriculture Center – University of Mosul. The degree of reactivity was measured using a pH meter, and electrical conductivity using an EC meter. The cations of calcium and magnesium were determined by titration with Ethylendiaminetraacetic acid (0.01) M, and soluble sodium and potassium using a flame photometer. Chloride ions were determined by titration with silver nitrate (0.01 M) , and carbonates and bicarbonates by titration with dilute sulfuric acid (0.01 M), while sulfates were determined by precipitation using barium chloride. Soil texture was measured using a hydrometer, and apparent density by the paraffin wax method. Soil organic matter was calculated by wet oxidation using potassium dichromate (1M), and calcium carbonate by titration with a 1M NaOH solution. method as shown in Tables (1) according to the methods mentioned in Salem and Ali (2017).

Table 1. Some physical and chemical properties of the study soil samples

Crop type	$CaCO_3$	O.M	ρb	Clay	Silt	Sand	Textuer
	%		$Mg\ m^{-3}$		$gm\ kg^{-1}$		
Sesame crop	15	39	1.3	529.5	235.0	235.5	clay
Cotton crop	14	41	1.3	529.5	260.0	210.5	clay
Maize crop	13	38	1.2	454.5	285.0	260.6	clay

2.3 Fertilization

DAP fertilizer was used at a ratio of (0:46:18) and urea fertilizer at a ratio of (46%) to fertilize cotton, maize, and sesame fields to increase crop productivity.

2.4 Irrigation

A sprinkler irrigation system was used, installed on greenhouses, to spray the crops. Water from the Tigris River was used for irrigation, and its chemical composition is shown according to the methods described in Salem and Ali (2017), Table (2).

Table .2. Chemical analysis of Tigris River water used in the irrigation process

Classes	EC $dS\ m^{-1}$	pH	SAR
C_2-S_1	0.63	7.4	0.30
	Soluble ion ($meq\ l^{-1}$)		

Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	Cl^{-}	CO_3^{-2}	HCO_3^{-1}	SO_4^{-2}
0.52	0.05	3.60	2.20	1.50	Nil	3.77	1.10

3. Results and Discussion

The results, as shown in Table (3) and Figure (1) indicate that the soil acidity in all the studied soils was neutral, slightly alkaline, ranging from (7.20) in the maize soil to (7.35) in the cotton soil. This is the degree of alkalinity characteristic of calcareous Iraqi soils (Alhadede *et al.*, 2025). The electrical conductivity of the studied soils ranged from (0.50 $dS\ m^{-1}$) in the maize soil to (0.75 $dS\ m^{-1}$) in the sesame greenhouse soil. Therefore, all the soils in the studied sites are considered to have good electrical conductivity and are safe for all the cultivated crops. This is reflected in the concentration of the main cations and anions (sodium, potassium, calcium, magnesium, chlorides, bicarbonates, and sulfates), which contribute to salt formation in the soil solution. Their concentrations were low and within safe levels. For crop cultivation, where the cultivated crops do not need these elements in high concentrations, with the exception of potassium, which is available in the soils but suffers from the fixation process in the well-known alkaline calcareous soils. Therefore, reducing the concentration of the mentioned cations and anions at a good and safe concentration reduces the concentration of soluble salts in the soil solution, thus making it possible to study the depletion of nitrogen and phosphorus elements by cultivated crops (Smith *et al.*, 2025).

The results obtained in this study indicate a clear variation in the degree of soil depletion among the studied crops after the end of the experiment and harvesting of cotton, maize, and sesame. Cotton was found to have the highest depletion effect on the soil, followed by maize, while sesame had the lowest effect on nitrogen and phosphorus. The percentage values of nitrogen ranged between (21.6, 36.3, and 91.0) for cotton, maize, and sesame soils, respectively, while the percentage of phosphorus ranged between (31.5, 38.0, and 45.0) for cotton, maize, and sesame soils, respectively. Cotton and maize are more depleting of nitrogen and phosphorus than sesame due to their higher nutritional requirements associated with producing a large biomass and a longer growth period. They require high amounts of nitrogen to form proteins and chlorophyll and support intensive vegetative growth, which leads to a rapid and intensive withdrawal of mineral nitrogen from the soil. This withdrawal often exceeds the rate of its replacement by chemical fertilizers or the decomposition of organic fertilizers (Snyder,2017). They also require large amounts of phosphorus for its vital role in energy transfer (ATP) and the formation of roots and seeds, especially in the early stages of growth. This leads to the depletion of available phosphorus in the soil, especially since phosphorus is a relatively immobile element and is quickly converted into unavailable forms. The severity of the deficiency increases, especially with repeated cultivation of these crops. Sesame, on the other hand, is characterized by higher efficiency in using both nitrogen and phosphorus and its ability to grow under less fertile conditions (Stewart et al.,2005). Furthermore, its actual requirements for these two elements are significantly lower, making it less impactful on depleting soil stores of these nutrients. This was confirmed by Brady and Weil (2017) and Fageria (2007), who indicated that high-yielding crops are associated with increased N and P consumption compared to lower-demand crops(Vitousek *et al* .,2009). These findings are corroborated by several previous studies that confirmed the varying capacities of field crops to absorb and draw nutrients and their long-term impact on soil fertility (Djaman et al., 2025). Results are also consistent with the findings of Zhang *et al.* (2024) and Ullah et al. (2018), who noted that maize is a high-demand crop for macronutrients (N, P, K), and that intensive cultivation leads to lower soil levels of these elements, especially with high yields. Zhao *et al*. (2022) also indicated that cotton farming systems directly affect soil dynamics. Phosphorus, a limited element in the soil, increases the likelihood of long-term soil fertility degradation. Furthermore, studies by Fixen *et al*. (2014) confirmed that intensive production systems relying on high-yield crops such as maize and cotton are often associated with increased nutrient depletion rates unless balanced and sustainable fertilization programs are implemented.

Table 3. The concentration of dissolved ions in the soil samples of the study4. Conclusion

No.	Crop type	pH	EC dS m^{-1}	N	P	K^{+}	Mg^{+2}	Na^{+}	Ca^{+2}	Cl^{-}	HCO_3^{-}	SO_4^{-2}
				mg kg^{-1}				meq l^{-1}				
1	Sesame crop	7.30	0.75	91.0	45.0	0.3	2.3	1.3	3.7	3.4	2.5	1.9
2	Maize crop	7.20	0.50	36.3	38.0	0.4	1.5	0.6	2.7	1.7	2.1	0.9
3	Cotton crop	7.35	0.57	21.6	31.5	0.4	2.4	0.7	2.8	2.1	2.3	0.7

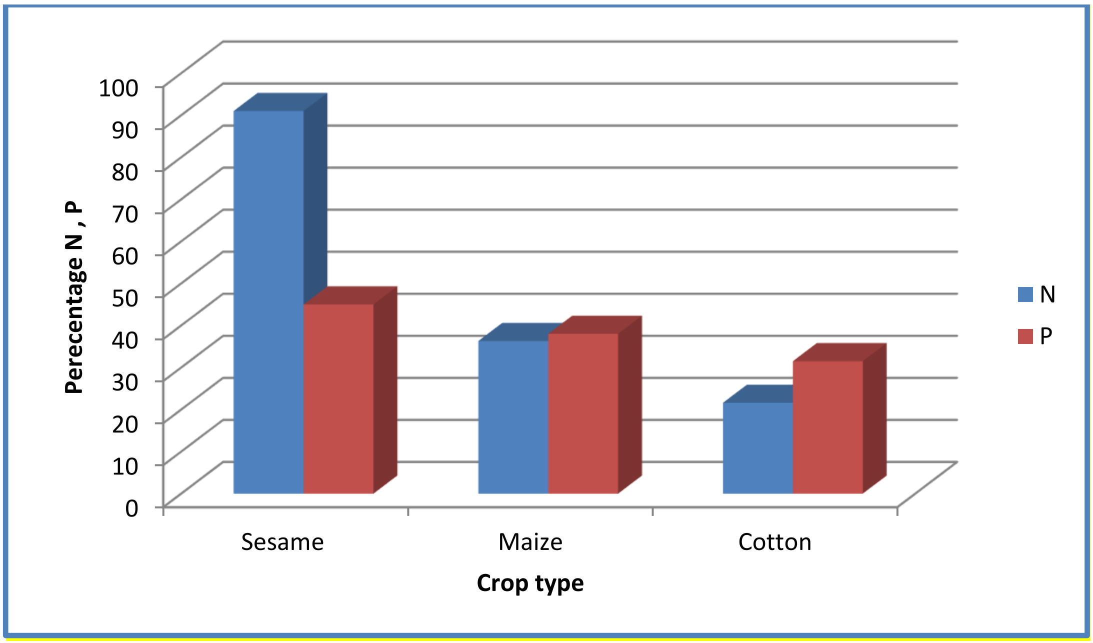

Figure 1. Relationship between nitrogen and phosphorus ratios in cotton, maize, and sesame crops.

Based on the above, it can be said that the difference in soil depletion between these crops is mainly related to their growth requirements, productivity, and nutrient use efficiency. The importance of adopting balanced crop rotations that include less depleting crops such as sesame, along with the application of integrated soil management strategies, including the use of organic fertilizers and soil amendments, is highlighted. This is crucial for reducing soil fertility degradation and achieving sustainable agricultural production, a point also confirmed by the studies of Tilman *et al*. (2002) and Bationo *et al*. (2007).

4. Conclusion

1- Cotton and maize cause higher soil depletion compared to sesame.
2- There is a significant decrease in nitrogen content due to high vegetative growth.
3- Available phosphorus is reduced due to increased uptake.
4- Calcareous soils increase phosphorus fixation, reducing its availability, especially with maize and cotton cultivation.

5. Recommendations

1- Adopt a balanced fertilization system to compensate for nitrogen and phosphorus depletion, particularly with cotton and maize.
2- Include sesame in crop rotation to reduce soil depletion.
3- Improve phosphorus utilization efficiency by adding slow-release fertilizers.
4- Use organic matter (humic, fulvic, biochar) to increase nutrient availability.

References

Alhadede, A. A., Alhadidi, K. E. N., & Al-Khafagi, Q. D. E. (2025). Effect of ionic strength on the dissolution and precipitation of carbonate minerals and the nature of ionic species from some calcareous soil. Journal of Global Innovations in Agricultural Sciences, 13(2), 699–705. https://doi.org/10.22194/JGIAS/25.1546

Baligar, V. C., Fageria, N. K., & He, Z. L. (2001). Nutrient use efficiency in plants. Communications in Soil Science and Plant Analysis, 32(7–8), 921–950. https://doi.org/10.1081/CSS-100104098

Bationo, A., Waswa, B., Kihara, J., & Kimetu, J. (2007). Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities. Nutrient Cycling in Agroecosystems, 76(1), 3–16. https://doi.org/10.1007/s10705-005-4736-9

Djaman, K., Irmak, S., & Futakuchi, K. (2025). Regenerating productivity after soil fertility depletion in a 20-year cotton–maize rotation. Plant and Soil. https://doi.org/10.1007/s10705-025-10429-1

Dobermann, A. (2007). Nutrient use efficiency—Measurement and management. In IFA International Workshop on Fertilizer Best Management Practices. International Fertilizer Industry Association. https://www.fertilizer.org/resource/nutrient-use-efficiency-measurement-and-management/

El-Naggar, A., Hassan, M., & Ahmed, S. (2021). Nutrient uptake and productivity of sesame (Sesamum indicum L.) under different fertilization regimes. Arabian Journal of Geosciences, 14, 1234. https://doi.org/10.1007/s12517-021-07229-6

Fageria, N. K. (2007). Yield physiology of rice and maize under different nutrient management systems. Journal of Plant Nutrition, 30(6), 843–859. https://doi.org/10.1080/01904160701358002

Fageria, N. K., Baligar, V. C., & Jones, C. A. (2011). Growth and Mineral Nutrition of Field Crops (3rd ed.). CRC Press. https://doi.org/10.1201/b10160

Fixen, P. E., Johnston, A. M., & Bruulsema, T. W. (2014). The role of fertilizers in sustaining food security and protecting the environment. Nutrient Cycling in Agroecosystems, 99(1–3), 1–18. https://doi.org/10.1007/s10705-014-9620-4

Johnston, A. E., & Poulton, P. R. (2018). The importance of long-term experiments in agriculture: Their management to ensure continued crop production and soil fertility. European Journal of Soil Science, 69(1), 113–125. https://doi.org/10.1111/ejss.12521

Liu, Q., Wang, J., & Li, H. (2019). Nitrogen use efficiency in maize and cotton under different management practices. Field Crops Research, 241, 107565. https://doi.org/10.1016/j.fcr.2019.107565

Marschner, P. (2012). Marschner's Mineral Nutrition of Higher Plants (3rd ed.). Academic Press.

Murrell, T. S., Mikkelsen, R. L., Sulewski, G., Norton, R., & Thompson, M. L. (2021). Improving nutrient use efficiency in cropping systems. Agronomy Journal, 113(1), 1–14. https://doi.org/10.1002/agj2.20472

Salem, S. J., & Ali, N. S. (2017). Directory of chemical analyzes of soil, water, plants, and fertilizers. Ministry of Higher Education and Scientific Research, College of Agriculture, University of Baghdad (in Arabic), 407 pp. https://core.ac.uk/download/pdf/185619949

Smith, P., Johnson, D., & Clark, M. (2025). Improving soil health and nutrient management in maize systems. Field Crops Research. https://doi.org/10.1016/j.fcr.2025.109090

Snyder, C. S. (2017). Enhanced nitrogen fertilizer technologies support the "4R" concept to optimize crop production and minimize environmental losses. Soil Research, 55(6), 463–472. https://doi.org/10.1071/SR16335

Stewart, W. M., Dibb, D. W., Johnston, A. E., & Smyth, T. J. (2005). The contribution of commercial fertilizer nutrients to food production. Agronomy Journal, 97(1), 1–6. https://doi.org/10.2134/agronj2005.0001

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature, 418(6898), 671–677. https://doi.org/10.1038/nature01014

Ullah, S., Anwar, S., Rehman, M., & Khan, S. (2018). Nutrient uptake and soil fertility changes under maize-based cropping systems. Soil and Tillage Research, 180, 132–140. https://doi.org/10.1016/j.still.2018.03.010

Vitousek, P. M., Naylor, R., Crews, T., David, M. B., Drinkwater, L. E., Holland, E., Johnes, P. J., Katzenberger, J., Martinelli, L. A., Matson, P. A., Nziguheba, G., Ojima, D., Palm, C. A., Robertson, G. P., Sanchez, P. A., Townsend, A. R., & Zhang, F. S. (2009). Nutrient imbalances in agricultural development. Science, 324(5934), 1519–1520. https://doi.org/10.1126/science.1170261

Zhang, Y., Liu, X., & Chen, F. (2024). Plant nutrient removal in maize systems and its impact on soil fertility. Agronomy, 14(3), 456. https://doi.org/10.3390/agronomy14030456

Zhao, C., Zhang, R., & Sun, Q. (2022). Phosphorus dynamics in cotton–maize intercropping systems. Applied Soil Ecology, 176, 104503. https://doi.org/10.1016/j.apsoil.2022.104503