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Article

The Impact of Agricultural Land Use on Some Chemical Properties of Desert Soils in the Holy Karbala Governorate

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Abstract: This study investigates the impact of agricultural land use on the chemical properties of desert soils in the Holy Karbala Governorate, Iraq. Despite the extensive use of desert soils for agriculture, little is known about how these practices affect soil chemistry in this region, creating a critical knowledge gap. The research employed a comparative analysis between cultivated and uncultivated lands across six pedons, analyzing key soil parameters such as pH, electrical conductivity, organic matter, and nutrient content. The findings reveal significant alterations in soil chemistry due to agricultural activities, including decreased soil pH and electrical conductivity, increased organic matter and cation exchange capacity, and variable nutrient content. These results underscore the need for sustainable land management practices to maintain soil health and productivity, which is vital for long-term agricultural success in arid environments.

Keywords: Land Use, Desert Soils, Chemical Properties of Desert Soils.

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1. Introduction

Desert soils are found on all continents, with their properties and formation conditions promoting the buildup of soluble salts, gypsum, and carbonates, which are abundant in hot desert soils. Most of these locations consist of aeolian deposits from former eras, as well as old formations of marine and fluvial sediments from rivers and valleys passing through these regions (Khormali & Monger, 2020).

Desert soils are characterized by low organic matter due to the restricted and degrading natural flora under hot environmental conditions and insufficient rainfall, resulting in the absence of leaching processes (Ali & Alwan, 2013). Despite the dry climate, desert soils operate as moisture reservoirs, holding moisture through deposited clays and salts instead of humus seen in temperate and cold locations (Zhao et al., 2013). Vegetation cover plays an essential impact in affecting soil chemical characteristics, particularly nutrient content. Studies have indicated that forest soils have increased organic matter, accessible phosphorus, and nitrogen levels, especially near tree trunks compared to locations distant from root zones, demonstrating the impact of vegetation on soil chemical characteristics (Campbell et al., 1988).

There is a difference in soil qualities around plant roots compared to locations far from them. Research indicates that differences in organic matter and nutrient content between these areas are due to factors such as reduced soil pH, formation of chelate complexes by acids secreted by plant roots, increased mineral weathering, and enhanced organic matter decomposition (Dieffenbach & Matzner, 2000).

Changes in agricultural land use and management practices can influence soil qualities, which are necessary for sustainable crop production. Changes in agricultural land use impact soil nutrient efficiency in a farming area in China, revealing that land use and agricultural management techniques significantly affect soil organic carbon, total nitrogen, and accessible and total phosphorus in the surface soil (0-25 cm). These components decrease with increasing soil depth, with orchards and vegetable fields having higher soil nutrient levels than other agricultural land uses (Chen et al., 2011).

Agricultural methods alter soil chemical and physical properties through crop rotation over 20 years, resulting in lower exchangeable sodium percentage (ESP) and soil EC, as well as reduced calcium carbonate ($CaCO_3$) concentration due to leaching processes. Soil cation and anion content also decreased due to tillage and irrigation techniques and crop depletion. The study also indicated an increase in CEC, phosphorus, potassium, sulfur, and organic matter in soils from cultivated areas due to constant organic and chemical fertilizer treatments across the cultivation period (Abu Aideh, 2015). Li et al. (2021) found that reclaiming desert lands for various agricultural applications has a substantial impact on soil chemical characteristics, increasing bacterial diversity, organic carbon, total nitrogen, and total phosphorus in the soil following reclamation.

Al-Wazzan and Aati (2022) observed that soil organic matter content was closely related to land use, decreasing in uncultivated lands while increasing in cultivated lands, particularly in greenhouses, alfalfa fields, and pomegranate orchards, due to continuous additions of animal manure (humus) and soil conditioners, increasing soil organic matter values. Ibrahim et al. (2023) underlined the necessity of studying the impact of land use types and topographic locations on soil physical and chemical parameters for sustainable soil management. Their study on analyzing soil physical and chemical qualities under different land uses indicated that most soil parameters were lower in cultivated fields, emphasizing the necessity for soil fertility management to sustain agriculture in these locations. These attributes included soil pH, EC, and levels of exchangeable calcium, magnesium, and salt under agricultural usage compared to uncultivated fields. Desert areas of the Holy Karbala Governorate are significant because they are uncultivated, unexploited lands suited for raising various crops and vegetables. Given the importance of these lands and their wide area in Karbala, this study intends to produce a database for these soils by studying the impact of agricultural use on some chemical properties to build sustainable management plans fit for these properties.

2. Materials and Methods

Location and Area

The study area is located in the desert, within the administrative boundaries of the Ain Al-Tamr district, west of Karbala Governorate. It is about 50 kilometers from the center of Karbala Governorate. Anbar Governorate borders the area to the rest of the sides while the administrative limits of Al- Hurr district mark it to the east. The estimated area is around 364,000 dunams. Map number (1) and the satellite image reveal the geographical coordinates of the study region as (32° 42′ 3′) North, (32° 7′ 47′), (43° 8′ 11′), (43° 44′ 27′), East (Figure 1).

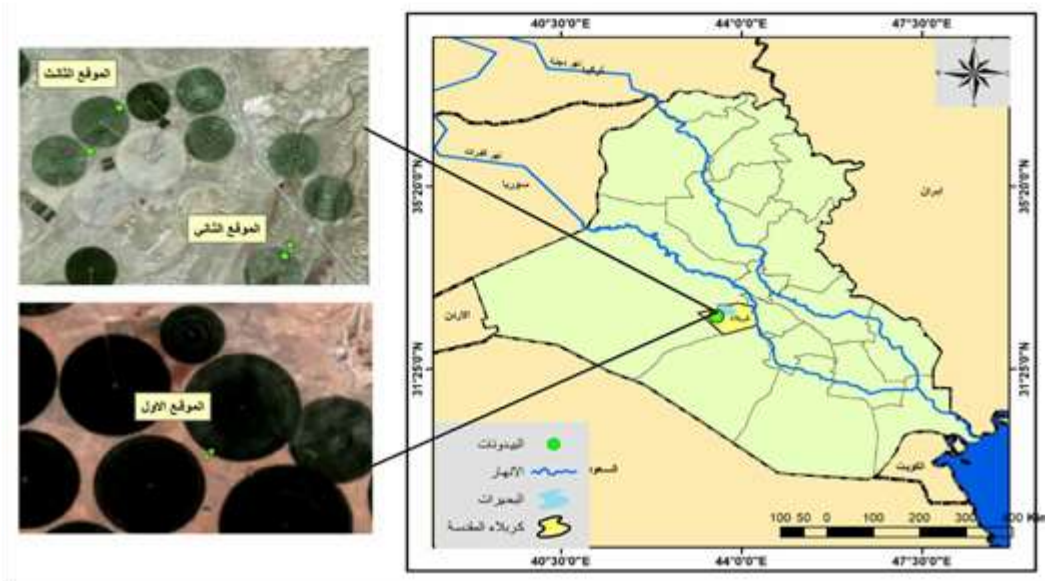

Figure 1: illustrates Map No. 1 and the satellite image of the locations of the study pedons.

Preliminary Procedures

At this stage, information and data about the study area were collected, and maps and previous studies were prepared. The Karbala Agriculture Directorate was consulted to determine the study area characterized by agriculture. The desert area in Ain Al-Tamr district was selected as a representative area for desert soils used for agricultural purposes in Karbala Governorate.

Field Procedures:

Several field trips to the research area were successfully carried out using information provided from the Karbala Governorate's Agriculture Directorate. Information obtained from local farmers who used the same agricultural practices in terms of tillage and irrigation methods, such as central pivot systems, and planted the same crops was also considered. The following points were considered when determining the positions of the pedons:

1. Choosing pedon positions in agriculturally used areas based on their duration of use, with a preference for areas that have been used for a long time.
2. Selecting pedons from unused (uncultivated) land.
3. Selecting pedon locations in both used and unoccupied regions that are generally near together within the same site to guarantee that the pedons represent the same soils.

The following places were determined, including six pedons:

- First Site: Located in the desert, district 20, Al-Jazeera, 4 kilometers southwest of Al-Ukhaidir Fort, with pedon No. 1 in agriculturally used land for six years and pedon No. 2 in uncultivated territory.
- Second Site: Located in the desert area, district 20, Al-Jazeera, 7 kilometers south of Ain Al-Tamr center, with pedon No. 3 in agriculturally used land for ten years and pedon No. 4 in uncultivated ground.
- Third Site: Located in the desert area, district 20, Al-Jazeera, 5 kilometers south of Ain Al-Tamr center, with pedon No. 5 in agriculturally used land for twelve years and pedon No. 6 in uncultivated ground.

After determining the pedon sites, the coordinates were recorded using a GPS device. The pedons were exposed in November 2023, and their horizons were morphologically classified using the parameters outlined in the United States Soil Survey Manual (Soil Survey Division Staff, 1993). Soil samples weighing 2 kg were collected from each horizon, tagged, and stored in plastic bags for chemical analysis. The soils of the pedons were classified at the sub-group level by Soil Survey Staff (2014).

Laboratory Procedures

After collecting soil samples from each horizon, they were transported to the laboratory and air-dried before being manually crushed with a wooden hammer to preserve the mineral morphology. The samples were then sieved through a 2 mm screen and stored in plastic containers. The samples were labeled and delivered to the lab for chemical analysis.

Chemical Analysis

Soil Reaction (pH): The soil reaction was determined in a 1:1 soil-water extract using a pH meter, as described by Page et al. (1982).

Electrical Conductivity (EC): The electrical conductivity was measured with an EC meter according to the method described by Page et al. (1982).

Cation Exchange Capacity (CEC): The cation exchange capacity was evaluated using the method proposed by Richards (1954).

Organic Matter (OM): The percentage of organic matter was calculated using the wet oxidation method of Walkley and Black, as described by Jackson (1958).

Calcium Carbonate (Calcite): The calcium carbonate concentration was determined using the method outlined by Richards (1954).

Gypsum (Calcium Sulfate Dihydrate): The calcium sulfate dihydrate concentration was determined using the method outlined by Richards (1954).

Available Nitrogen: Black (1965) described the Kjeldahl method for estimating soil nitrogen availability.

Available Phosphorus: Page et al. (1982) described the Olsen method for estimating soil phosphorus availability.

- Available Potassium: The available potassium was determined using a flame photometer and the method given by Jackson (1958).

3. Results and Discussion

Soil Reaction (pH)

The soil pH measurements for the soil horizons of the pedons in the study region, as given in (Table 1) , revealed that the soil response values were from neutral to slightly alkaline, ranging from 7.54 to 8.36. The pH value was the highest in the second horizon soil of pedon No. 6 in the uncultivated area at the third site, and the lowest in the third horizon soil of pedon No. 5 in the cultivated lands. These results agreed with the results of Al-Ghazali (2018) and Al-Khuzaie (2018).

These results demonstrate the impact of agricultural land use and field practices on soil pH values, as there was a significant decrease in pH values in the pedon soil, particularly in the surface horizons of the cultivated lands at the second and third sites, when compared to pH values in the pedon soil in the uncultivated lands of the same sites.

This is due to increased organic matter content in the soil caused by the decomposition of crop wastes and root exudates, as well as increased soil microbial activity and acid secretion. Furthermore, ammonium-based fertilizers with acidic effects, such as urea, which is widely used by desert farmers, contributed to lower pH levels. Furthermore, irrigation techniques contribute to a reduction in carbonate mineral values in the soil's higher strata. In the first site, the pH values of the cultivated areas were slightly higher than those of the uncultivated lands. This could be because the water used to irrigate crops in this site's cultivated fields is greater in salinity and pH than the well water utilized in the other two sites.

Table 1. Chemical Properties of Soils in the Study Area

Pedon	Land use	Horizon	Depth cm	pH	EC ds m^{-1}	CEC meg 100g	Gypsum gm kg^{-1}	Carbonats gm kg^{-1}	O.M gm kg^{-1}
P1	Cultivated land	Ap	0 - 18	7.81	2.22	6.55	81.3	331.98	43.51
		B_{k1}	18 - 40	8.09	2.2	6.03	96.3	401.96	11.73
		B_{k2}	40 - 58	8.16	2.28	7.57	88.8	421.58	13.67
		B_{k3}	58 - 90	7.99	2.22	7.73	61.4	398.68	13.78
		C_k	90 - 120	7.93	2.17	6.48	82	207.28	7.52
P2	Uncultivated land	A	0 - 20	8.24	2.1	6.02	61.3	425.24	7.19
		B_{ky1}	20 - 50	8	2.16	8.06	132	385.32	5.82
		B_{ky2}	50 - 70	7.6	2.29	6.02	143.5	380.78	4.91
		C_{ky1}	70 - 90	7.6	2.22	7.88	141	184.56	8.25
		C_{ky2}	90 - 112	8.13	2.03	6.66	182	196.62	9.51
P3	Cultivated land	Ap	0 - 19	7.56	2.8	11.31	54	370.38	16.99
		B_{k1}	19 - 55	8.04	2.4	11.33	65.5	435.98	14.07
		B_{k2}	55 - -85	7.99	2.2	7.76	67.6	397.26	11.31
		C_k	85 - 120	7.66	2.29	9.65	72.1	334.68	9.83
P4	Uncultivated land	A	0 - 17	8.07	2.6	11.09	105.6	352.22	15.21
		B_{ky}	17 - 63	8.12	3.4	7.83	162.5	225.82	6.27
		B_k	63 - 93	7.96	2.57	7.76	72	359.36	1.18
		C_{ky}	93 - 120	7.97	2.6	2.05	68	174.06	11.23
P5	Cultivated land	Ap	0 - 20	7.72	2.65	10.33	41.5	352.42	11.08
		B_{k1}	20 - 65	7.89	2.95	15.25	21	461.18	10.97
		B_{k2}	65 - 95	7.54	2.8	11.62	32	417.06	9.44
		C_k	95 - 120	7.95	3.02	10.3	26	180.46	9.19
P6	Uncultivated land	A	0 - 10	7.84	2.25	9.96	152	434.62	8.97
		B_{ky1}	10.- 48	8.36	3.63	6.24	132.6	371.5	7.57
		B_{ky2}	48 - 88	8.28	4.12	9.82	127.8	357.58	10.83
		B_{ky3}	88 - 110	8.21	5.46	13.91	173.3	371.12	9.85

Electrical Conductivity of Soil (EC)

Table (1) shows chemical measurements of pedons in the research area, with electrical conductivity values ranging from 5.46 to 2.03 ds.m^{-1}. The lowest value was recorded in the lower horizon of pedon number (2) in uncultivated soils within the first site, and the greatest value was in the lower horizon of pedon number (6) in uncultivated soils within the third site of the research region. These results are consistent with the results of Al-Khazai (2018).

The results also revealed the impact of agricultural land use on electrical conductivity values, with pedons in cultivated lands in the second and third sites having lower electrical conductivity rates than those in uncultivated lands from the same sites. This is due to irrigation water flushing salts, particularly because sandy soil improves the effectiveness of salt leaching. Furthermore, plants, particularly salt-tolerant crops, contribute to salinity reduction by draining salts, and the presence of crop residues on the soil surface after harvest in summer causes a fall in soil temperature, reducing evaporation and accumulated salt content. This is consistent with Abu Aideh (2015).

Regarding cation exchange capacity (CEC) of the soil

The chemical measurement results of the pedons in the research region, as given in Table (1), revealed that the cation exchange capacity values ranged from (15.25 - 2.05) milli equivalents per 100 g soil. These values vary between pedons and within horizons of the same pedon, indicating soil quality, fine fraction content (clay and silt), organic matter concentration, and the opposing behavior of carbonate minerals. These values are low for several reasons, including the prevalence of sand over silt and clay fractions, which is consistent with Al-Rifai's (2000) results in the Western Desert region. Another reason is the high content of calcium carbonate minerals in the study area's soil, which is inversely related to cation exchange capacity because carbonate minerals coat fine soil particles (clay and silt), which are important for increasing cation exchange capacity values by reducing specific surface area, as stated by Al-Azzawi (2006).

The results also showed that agricultural land use had an effect on cation exchange capacity values, with an increase in cation exchange capacity rates, particularly in the upper horizons of pedons located in cultivated lands in the second and third sites, when compared to rates in pedons located in uncultivated lands from the same sites. This is linked to plants increasing soil organic matter concentration, as reported by Qi et al. (2015). Furthermore, crop irrigation activities in these soils flush and diminish calcium carbonate and sulfate minerals, particularly in upper strata of the soil surface, which did not occur in pedons from uncultivated areas.

Organic Matter in Soil (O.M)

Table (1) shows the chemical measurement results of the pedons in the research region, which indicated that organic matter values ranged from (43.51 - 1.18 g kg^{-1}). The lowest organic matter value was recorded in the lower horizon of pedon number (4) in uncultivated soils at the second site, whereas the highest organic matter value was recorded in the surface layer of pedon number (1) in cultivated soils at the study's first site. Pedons in cultivated fields showed a reduction in organic matter concentration with depth, which was attributed to the root system depth of densely planted crops in these soils, particularly wheat, which farmers in this region planted at high densities. Pedons in uncultivated lands had higher organic matter content in lower horizons than in surface horizons due to the presence of deep-rooted desert plant species that spread their roots in lower horizons in search of moisture, as reported by Al-Ghanmi (2017) and Al-Shammari (2020). The soil organic matter content in the research pedons is generally low, with variations both horizontally and vertically within the study pedons. This drop in organic matter concentration is due to the region's prevalent meteorological circumstances, which include drought and high temperatures, which accelerate organic matter decomposition and oxidation, as well as a sparse plant cover.

However, agricultural use had an effect on organic matter content values, resulting in an increase in organic matter content rates, particularly in surface horizons of pedons located in cultivated lands at all sites, as compared to rates in pedons located in uncultivated lands at the same sites. This is due to plants increasing soil organic matter content, as crop leftovers from roots, stems, and leaves make up a large portion of plant weight. The residual roots in the soil after any crop might be 4 tons or more per hectare, and these residues degrade by soil organisms, increasing soil organic matter content, according to Qi et al. (2015).

Calcium Carbonate (Ck)

Table (1) shows that the soil in the research area is calcareous, with a calcium carbonate content ranging from (461.18 - 174.06) g kg^{-1}. The lowest calcium carbonate value was recorded in (Cky) from pedon number (4) in uncultivated soils within the second site, while the greatest calcium carbonate value was reported in horizon (Bk1) of pedon number (5) in cultivated soils within the third site of the study region. These results are compatible with Al-Ghazali (2018).

The results also revealed that the dominating pattern of calcium carbonate mineral distribution in the research area's pedons found in cultivated areas is a rise in sub-surface horizons as opposed to surface horizons. This highlights the importance of agricultural use and associated irrigation and fertilization processes in dissolving and leaching calcium carbonate minerals, redistributing them in subsurface horizons. This activity also accelerates decalcification and calcium carbonate formation processes, which are readily visible in cultivated soils, particularly given the prevalence of sand, which improves water percolation and efficiency in leaching salts, including calcium carbonate minerals. Furthermore, high-density crop residues after harvest limit evaporation in the summer by lowering soil temperature, which reduces salt deposition on the soil surface. Soil microorganisms also contribute to crop residue decomposition, and their organic acids lower soil pH near root hairs, causing dissolution of soil calcium carbonate minerals and reducing their presence in the rhizosphere layer while increasing their presence in calcification layers, which is consistent with the results of Abd et al. (2017) results.

Gypsum

Table (1) shows that the calcium sulfate concentration of the pedons in the research region ranged from 182 to 21 g kg^{-1}. The lowest calcium sulfate value was found in (Bk1) of pedon number (5) in cultivated soils at the third site, while the greatest calcium sulfate value was found in horizon (Cky2) of pedon number (2) in uncultivated soils at the first site of the study.

In general, surface horizons had lower gypsum concentration than sub-surface horizons in all pedons studied, with the exception of pedon number (5). The lower gypsum content in the sub-surface horizon (Bk1) compared to the surface horizon is due to the higher calcium carbonate content in this horizon, which lowers the solubility of gypsum. This is because this horizon has the highest concentration of calcium carbonate minerals.

Table 2. Fertility Characteristics of Pedon Soils Study.

Location	Pedon	Land use	Horizon	Depth cm	N mg Kg^{-1}	P mg Kg^{-1}	K mg Kg^{-1}
Location 1	P1	Cultivated land	Ap	0 - 18	11.2	9.782	162.13
			B_{k1}	18 - 40			
	P2	Uncultivated land	A	0 - 20	8.4	0.391	219.01
			B_{ky1}	20 - 50			
Location 2	P3	Cultivated land	Ap	0 - 19	16.1	4.14	338.7
			B_{k1}	19 - 55			
	P4	Uncultivated land	A	0 - 17	14.7	0.184	720.71
			B_{ky}	17 - 63			
Location 3	P5	Cultivated land	Ap	0 - 20	14.35	0.182	303.05
			B_{k1}	20 - 65			
	P6	Uncultivated land	A	0 - 10	10.5	0.068	185.9
			B_{ky1}	10.- 48			

Available Phosphorus

The fertility measurements of pedon soils in the research region, as shown in Table (2), revealed accessible phosphorus levels ranging from 9.782 to 0.068 mg kg-1. The lowest available phosphorus value was discovered in pedon soil number (6) in uncultivated fields at the third location. In contrast, the highest available phosphorus value was found in pedon soil number (1) in farmed fields inside the first study site.

The data also revealed how agricultural land use influences the quantity of available phosphorus in soil. This was confirmed by an increase in accessible phosphorus content in the surface strata of pedon soils discovered inside cultivated lands across all sites, as compared to pedon soils in uncultivated lands from the same locations. This effect is attributed to farmers' agricultural practices, particularly the use of phosphorus-containing fertilizers such as Diammonium Phosphate (DAP), as well as the role of plants and crop residues in increasing soil organic matter and essential plant nutrients such as nitrogen and phosphorous. This outcomes is consistent with the results of Bait al-Mal (2010) and Qi et al. (2015).

Overall, available phosphorus content levels in the research area's soils declined, particularly in the soils at the second and third locations. This drop could be attributable to the fact that the first and second sites were not cultivated the season prior to the production of this study, whereas the first site had been used for agriculture the previous season. As a result of this usage, phosphorus fertilizers are sensitive to adsorption and precipitation by carbonate minerals in alkaline calcareous soils. As shown in the soils of the research region, adsorption and precipitation processes intensify with time, resulting in phosphorus that is no longer accessible and eventually precipitates as calcium phosphate.

Available Potassium

The fertility measurements of pedon soils in the research region, as shown in Table (2), revealed that accessible potassium levels ranged between 720.71 and 185.9 mg kg-1. The lowest accessible potassium value was identified in pedon soil number (6) in uncultivated lands within the third site, while the maximum value was discovered in pedon soil number (4) in uncultivated lands within the second site of the study region.

The study also found that the content of accessible potassium in pedon soils in the study area varied, with all pedons within cultivated lands having a lower potassium content than pedon soils inside uncultivated areas from the same sites. This drop is due to the agricultural practices used by the majority of farmers in the region, particularly in fertilization operations, where they utilize foliar potassium fertilizers by spraying crops with this type of fertilizer, such as Potassium Sulfate. This liquid foliar fertilizer is used to spray plant leaves in accordance with advice from wheat crop development engineers in this region to improve potassium fertilizer efficiency. Furthermore, some farmers use only nitrogen (urea) and phosphorus (DAP) fertilizers, resulting in a decrease of accessible potassium in the soils of the study area's farmed areas. As a result, agricultural usage had an inverse influence on the available potassium content in pedon soils in the research area's cultivated lands.

Furthermore, there was heterogeneity in the level of available potassium in pedon soils within uncultivated areas, with a decrease in available potassium content observed in the third site, particularly in pedon soil number (6), as compared to pedon soil number (4). The cause for these declines could be a rise in soil reaction values as well as an increase in calcium carbonates and calcium sulfates in pedon (6), both of which are calcium sources in these soils. Calcium and available potassium have an inverse relationship, which means that increasing the calcium concentration reduces the available potassium content in the soil.

4. Conclusion

The study results indicated that there is an agricultural impact on the chemical characteristics of pedon soils in the study area, resulting in a drop in soil pH and electrical conductivity (EC) in pedon soils within cultivated areas at the first and second sites. Conversely, pH and EC values increased in pedon soils within cultivated areas at the first site. The results also revealed an agricultural impact on soil organic matter content and cation exchange capacity by an increase in organic matter content and cation exchange capacity values in pedon soils located inside cultivated fields throughout research sites. The study also demonstrated an agricultural impact on NPK values, with a considerable rise in soil content of accessible nitrogen and phosphorus in pedon soils inside cultivated lands, while soil potassium content dropped in pedon soils within cultivated lands of the study region.

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