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# DIAGNOSTIC SPECIFICS OF THE CHEMICAL ELEMENTAL COMPOSITION OF THE MEADOW-GRAY SOILS IN THE MUGHAN STEPPE, AZERBAIJAN

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## SUMMARY

Under consistent soil utilization and anthropogenic influence, variations occur within the genetic horizons of the soil profile. In this context, the investigations based on structural and mineralogical processes of the gray soil formation are highly pertinent in the Sabirabad region, Azerbaijan. Soil scientists are diligent with conducting in-depth studies of the soils within the republic, ensuring their proper utilization. The following study aimed to comparatively analyze the long-term mineralogical processes under anthropogenic influence and soil exploitation in the Kura and Araz lowlands, Azerbaijan. In this zone, the arable soil analysis enables the assessment of their conditions, identification of the factors involved in the formation of the mineral composition, and assessment of the variations that occur as a result of irrigation and long-term fertilizer use. The soils' elemental composition provides valuable insights into the soil formation processes, as the land's genetic horizons exhibited distinct variations regarding this. Irrigation of meadow-gray soils has induced disparities both in mineral composition and the structural state of soils. In these grounds, determining the chemical elements, such as calcium (Ca), iron (Fe), potassium (K), titanium (Ti), manganese (Mn), copper (Cu), strontium (Sr), vanadium (V), zirconium (Zr), chromium (Cr), and bromine (Br), was successful through spectrometric analysis.

**Keywords:** Gray soils, soil genetic horizons, anthropogenic influence, soil compaction, elemental composition, minerals, soil genesis, humus

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**Key findings:** The soils' elemental study revealed variations in the mineralogical composition of gray soils in the Sabirabad region, Azerbaijan. Morphological and mineralogical analyses indicate clay mineral accumulation at intermediate depths, which likely contributed to the soils' compaction. The mineralogical composition provides a solid base for using appropriate agricultural techniques, particularly under changing climate conditions.

## INTRODUCTION

Climate change, which has accelerated in the 21st century, is a widely acknowledged challenging environmental issue by the scientific community in the present era. Generally, climate change affects agricultural conditions and economic activities across the climate zones, with particularly pronounced effects in the southern regions. This phenomenon inevitably causes unexpected variations in the structure and physical properties of soils. As a result, the southern territories and arid regions emerged to be especially vulnerable to climate change, warranting focused attention and study (Saakbaeva *et al.,* 2014).

A number of adverse agrophysical properties of meadow-gray soils, such as high density, compactness, water resistance, and significant swelling upon moisture absorption, necessitate particular attention during soil utilization and planting of various crops. Anthropogenic soil formation with various directions and intensity appears in the classification of soil profile genetic horizons (Lebedeeva *et al.,* 2005).

Salinity and gray soils' compaction in these regions provide a sound basis to account for a considerable decrease in the fertility of meadow-gray soils. These soils seemed to be ecologically fragile due to the arid climate, sparse vegetation cover, and sizable soil degradation occurring due to soil erosion, salinization, and compaction, exacerbated by enhanced anthropogenic pressure (Opekunov *et al.,* 2022).

The contemporary alluvial deposits have a predominantly clay and loamy material composition, including sandy and sandy-loam layers. In these soil depositions, the silt fractions exhibited a marked difference in color. Therefore, it is also crucial to note that the formation of Mughan Steppe soils is from alluvial deposits of the Kura and Araz rivers. However, the deposits of the Araz are reddish, while those of the Kura are gray-brown. Based on these distinguishing features, categorizing the deposits of the Kura and Araz can result in two distinct geographical groups.

The research based on mineralogical composition of the compact soils and their significance in soil formation in arid zones holds greater practical importance. In these areas, the parent rocks' composition and properties and their weathering products, as well as redisposition processes, inherit the soils with minimal variations due to a limited impact of soil formation processes. This considerably elaborates the essence of the soil formation, with a significant impact on the chemical and structural-sorption properties of soils in this region, particularly the soils with poor organic matter content. Therefore, the mineralogical studies play a crucial role, including the comprehensive analysis of the mineralogical composition, chemical, and structural-sorption properties of soils, depending on the soil genesis and composition of soil-forming rocks, the features of their transformation during soil formation, as well as intensive use of soils in irrigated agriculture.

The presented research sought to analyze the mineralogical and chemical composition of meadow-gray soils in the Mughan Steppe and investigate the considerable variations in soil compaction and mineral composition due to irrigation systems (Mustafayev, 2012, 2015, and 2020). Most countries impose strict restrictions on the amount of mineral and organic fertilizers applied to soils, as over fertilization is a prevalent issue in agricultural practices (Shpanev *et al*., 2021; Semenov *et al.,* 2023). This phenomenon poses significant risks, including reduced agricultural productivity, loss of biodiversity in natural ecosystems, and other adverse environmental impacts.

**MATERIALS AND METHODS**

The relevant study centered on the determination of unique characteristics of the soil cover, with the insufficient research carried out on soils of these zones in Azerbaijan. In this context, the collection of soil samples came from the gray soils of the District Sabirabad, specifically from long-irrigated lands, focusing on soil compaction. The morphological and mineralogical composition analyses of soils ensued, with X-ray images obtained using an S8 Tiger roentgen diffractometer.

The analysis of the elemental composition of soil and sedimentary rocks provides crucial information for soil-chemical, geochemical, and ecological studies. The soil chemical elements' composition and concentration directly influence the crop plant nutrition and the progression of soil-forming processes. Additionally, the probe of toxic elements is vital for understanding the sources and mechanisms of chemical soil pollution. The X-ray fluorescence analysis (XFA) method is particularly effective for studying those soil parameters. The elemental composition at varying soil depths when analyzed used the Elvax Prospector 3 apparatus. Quantitative analysis of the soil samples was successful through the fundamental parameters method (FPA) with empirical calibration.

In assessing the elemental composition of the soil, the measuring units of the Elvax Prospector 3 spectrometer gained connectivity to an external computer. For computers operating on Windows 10, installing the Microsoft Mobile Device Center software was necessary. The mathematical processing of the data proceeded by using descriptive statistics in the Excel program. For more advanced statistical analysis of the obtained data, the study utilized the Statistica 120 software package (StatSoft).

The latest research continued over the past five years at the Institute of Soil Science and Agrochemistry, Baku, Azerbaijan, which aimed to describe the mineral composition of soils in the primary soil types of the Mugan Steppe. This includes the meadow-gray soils of the region, particularly focusing on the compaction of the irrigated soil layer. The spectrometer employs a method for determining the elemental composition through characteristic (fluorescent) X-ray analysis, which involves the examination of various atoms in soil samples using a digital X-ray emitter.

**RESULTS AND DISCUSSION**

The soil cover characteristics were a diverse range of types and agronomic properties in the region of District Sabirabad, Azerbaijan. In agricultural zones, the soils' primary composition was low-humus gray, light-gray, and relatively fertile meadow-gray varieties, along with meadow saline, solonetzic, and alluvial-meadow soils (Ahmadova, 2010). The insufficient use of organic fertilizers and the long-term cultivation of row crops across several zones have resulted in a decline in soil humus content, deterioration of its water, physical, and physicochemical properties, and a considerable depletion in soil fertility in Azerbaijan. In the republic, one of the most important tasks of the farming community is to take the necessary measures, tailored to the specific soil and climatic conditions of each farm, primarily focusing on developing the strategies for sustainable restoration of the humus in soils (Madrelemov *et al.,* 1992; Tyulin and Sutyagin, 2016).

The studies took place both in field and laboratory conditions, using samples collected from these soils. The gray soils of the District Sabirabad belonged to the steppe soil types, with the region's subtropical climate characterized by mild winters and dry summers. Experimental soil samples came from the irrigated lands cultivated with the cotton cultivar 'Bayaz Altun.' The physical properties, morphological characteristics, and mineralogical composition of the studied soils underwent thorough investigation. The obtained X-ray images of the soils used the MiniFlex-600 X-ray diffractometer (Rigaku, Inc.). Mineralogical analysis provides valuable insights about the mineral composition found in the soil (Kovda *et al*., 2000; Dronova, 2000).

**Table 1.** Morphological properties of gray-earth soils of the Sabirabad region, Azerbaijan.

| Depth (cm) | Gray soils' distinction has the following morphological features: |
|---|---|
| 0–30 | dark gray, light, loamy, lumpy, roots, rootlets, wet, rapid effervescence, and noticeable transition |
| 30–60 | light gray, dense, single roots, wet, rapid effervescence, rusty spots, and gradual transition |
| 60–90 | light gray, very dense, sparse roots, very wet, rapid effervescence, and gradual transition |
| 90–120 | sulfur, sandy loam, less dense, sparse roots, rootlets, wet, poorly defined structure, rapid effervescence, and gradual transition |

The morphological description of the soils is crucial for understanding their genesis and qualitative characteristics and also essential for developing an effective system of agrotechnical and agro-ameliorative measures (Table 1). By studying the soil samples, macroscopic heterogeneities and variations in pores and soil aggregates were notable (Gorbunov*,* 1978; Boychova *et al.,* 2018). Such types of studies are highly crucial for understanding the physicochemical properties of soils, such as hardness, cohesion, filtration, and other essential characteristics (Gradusov*,* 2005).

The presented mineralogical studies have determined the relative composition and characteristics of sierozem soils, described as follows: at a depth of 0–30 cm, the content of quartz was 24%, feldspar (14%), calcite (12%), and illite (10%). The highest concentration of montmorillonite (17%) was evident at a depth of 30–60 cm, while kaolinite (15%) appeared both at the 0–30 and 30–60 cm depths. It is noteworthy that the feldspar content in the upper horizons ranges from 14% to 15%, while it declines with depth, reaching 12%–13% in the lower soil profile. (Boychova *et al.*, 2018).

The results further revealed the illite content was 10% in the 0–30 and 30–60 cm horizons and decreased slightly with depth, reaching 9% at the greater depth. In all the horizons, mineral montmorillonite content ranges from 17% to 18%, while the content of kaolinite fluctuates between 14% and 15%, on average, across the depth profile. The said distribution of various mineral components likely indicates the detailed soil composition in the studied gray soils. The X-ray analysis results for soil mineral composition at various depths are available in Figures 1 and 2 (Dronova, 2000).

The scrutiny of the chemical elemental composition of the irrigated meadow-gray soils also progressed. With the application of fertilizers and chemicals to the soils, along with irrigation, the content of chemical elements in these soils surfaced, which are particularly noteworthy. The anthropogenic impact is an important criterion for assessing the transformation of the chemical composition, especially in areas with compact soils. Additionally, it is essential to mention that variations in the content of chemical elements reflect alterations in the mineral composition of the meadow-gray soils.

In arable soils, differences occurring in the mineral composition mostly attained influences from using fertilizers and the agrotechnical measures implemented under the conditions of soil compaction. The use of both mineral and organic fertilizers also has a considerable effect on the soil pH. Meadow-gray soils of the Mughan Steppe were alkaline, with pH values ranging from 8.04% to 7.65% (Mustafayev *et al*., 2022).

The chemical composition of soil is a vital factor in soil fertility. Currently, 20 chemical elements are seemingly essential for plant nutrition, including nitrogen, phosphorus, potassium, carbon, sulfur, calcium, magnesium, sodium, iron, oxygen, hydrogen, chlorine, copper, zinc, boron, molybdenum, iodine, manganese, cobalt, and vanadium. Each element performs specific physiological functions involved in the growth and development of crop plants; however, when a deficiency or excess exists of any element, it adversely affects plant growth and development (Ahmadova, 2023).

The soil elemental composition analysis provides critical information about the soil-chemical, geochemical, and ecological parameters. The soil chemical elements affect

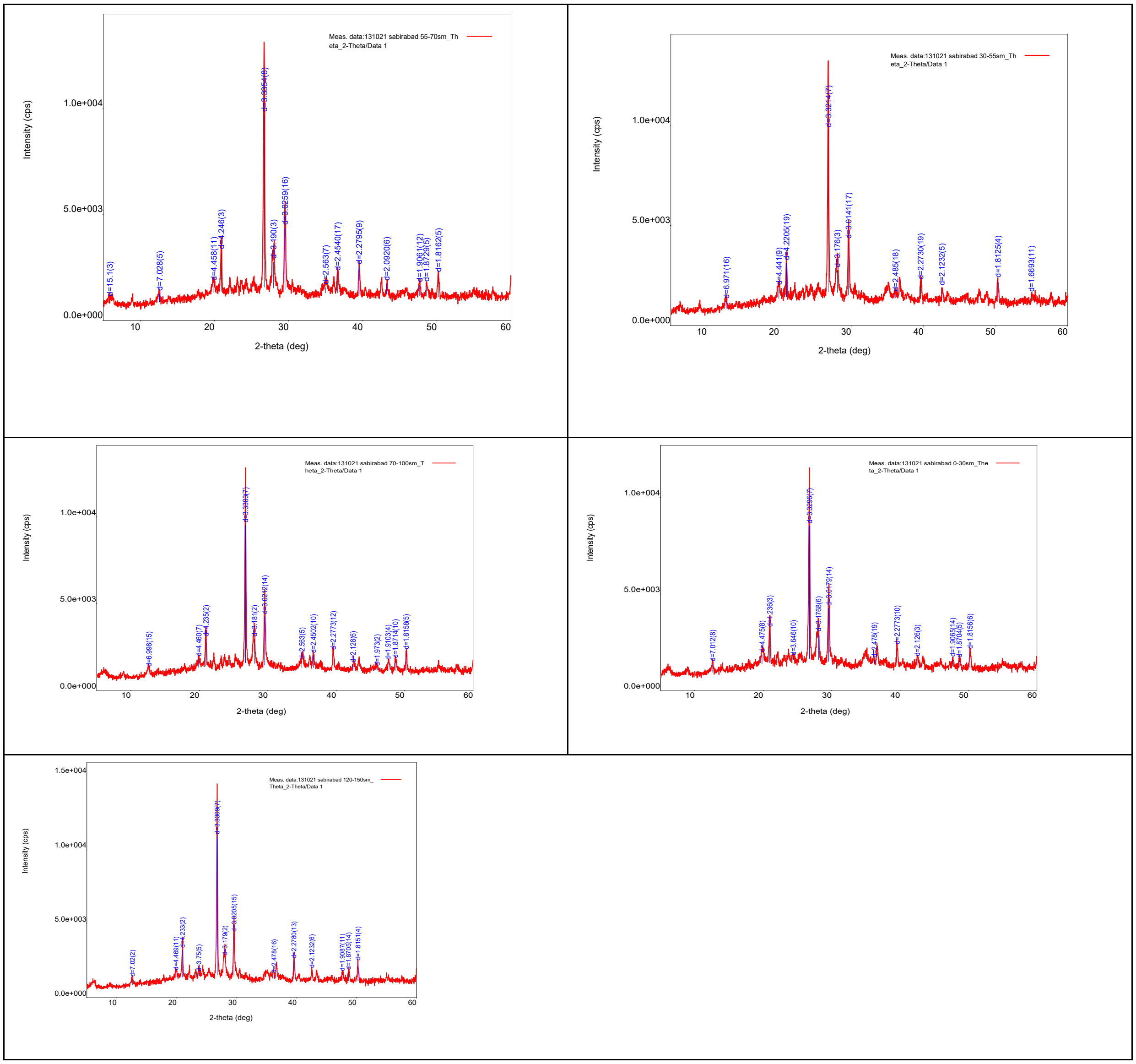


**Figure 1.** Roentgenograms of gray soils of the Sabirabad District.

the plant nutrition and the progression of soil formation processes. Moreover, the analysis of toxic elements is crucial for studying the sources of chemicals involved in soil contamination. The studied meadow-chernozem soils, analyzed by horizons and metal content, showed various differences. These metals (Ca, Fe, Zn, Pb, and Cu) were likely the components of mineral compounds that make up the soil-absorbing complex. Therefore, it is imperative to note the activity of different processes and the role of these metals in the organic-mineral complex (Garske *et al*., 2020).

Noting the accumulation of chemical elements in the genetic horizons of meadow-chernozem irrigated soils, as well as the effects of fertilizers and chemicals applied to the soil is essential. The chemical element analysis showed significant variations in values of chemicals found in the soil across different depths. For instance, calcium (Ca) ranges from 41.200 to 47.300, iron (Fe) from 29.300 to 30.200, and potassium (K) from 11.800 to

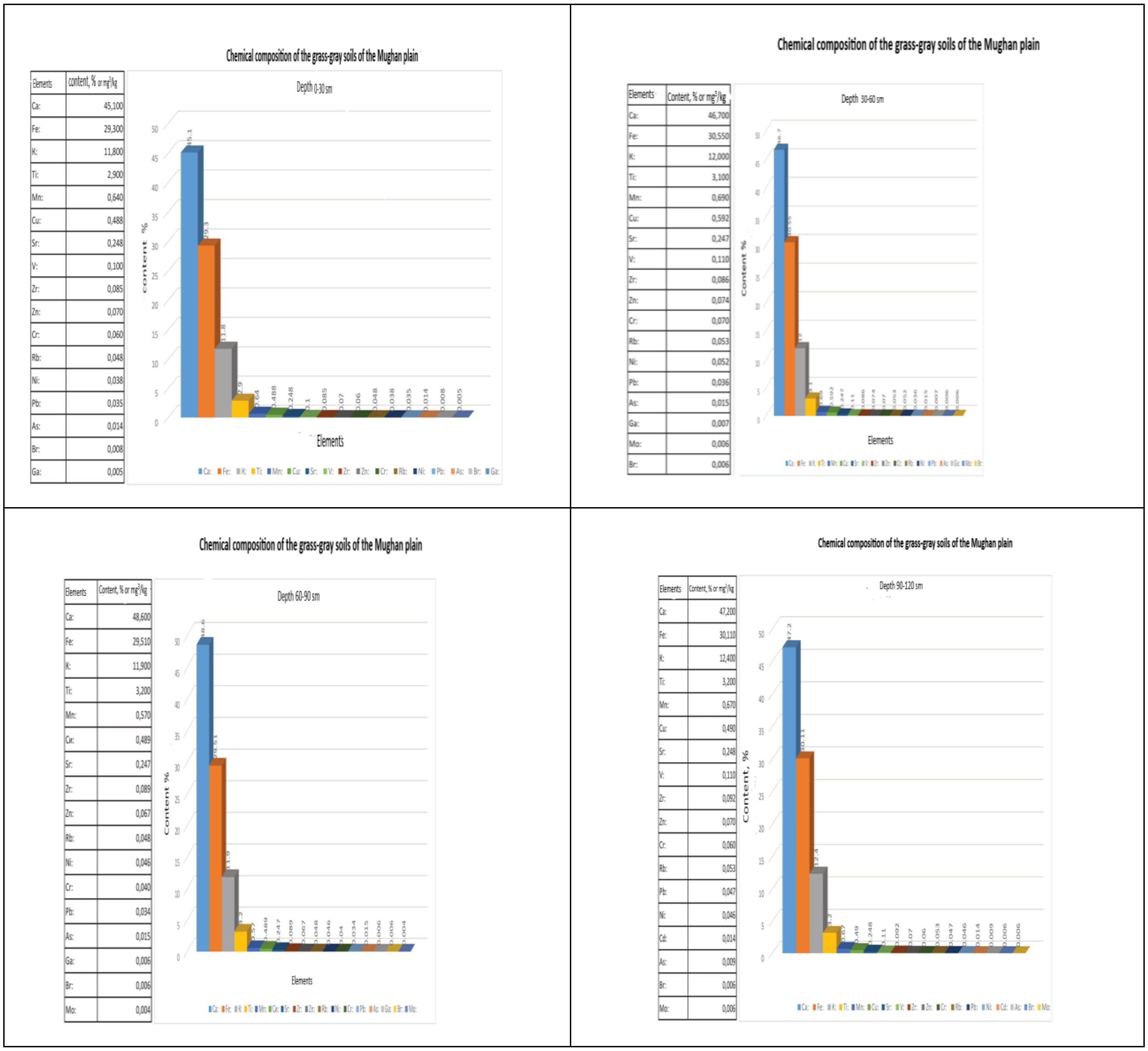


**Figure 2.** Chemical composition of the grass-gray soils of the Mughan plain.

12.900. The microelements indicators emerged in relatively smaller quantities. Notably, the deficiency or excess in these microelements can have a detrimental effect on the growth and productivity of the cultivated crops (Musacchio *et al.,* 2020).

Calcium is part of the exchangeable cations accumulated in the soil in the form of carbonate and sulfate salts. It stabilizes the soil solution's pH, binds humus substances, and participates in soil structure formation, as it is an effective coagulant for soil colloids. Iron and aluminum are components of primary and secondary minerals, amassed in the form of hydroxides and oxides. These metals also determine the pH of the soil solution and participate in the process of structural formation (Merzlaya *et al.*, 2022).

Potassium is also an indispensable element for plant nutrition, found in the composition of primary and secondary minerals. Plants can relatively easily extract this element from biotite and muscovite (Zhapayev *et al.,* 2023). Microelements indicators are mostly evident in smaller quantities. One should note that a shortage or excess of any microelements negatively affects the growth and development of crops. The presented research further showed the elemental composition of meadow-chernozem soils does not exceed the permissible standards and concentrations of chemical substances in the soil.

## CONCLUSIONS

The mineral composition of irrigated meadow-gray soils provides a basis to understand how irrigation and agrotechnical methods influence the balance between primary and secondary mineral rocks, particularly clay minerals. Mineralogical studies revealed variations in the mineralogical composition of the gray soils in the District of Sabirabad, Azerbaijan. Morphological and mineralogical analyses indicated an accumulation of clay minerals at intermediate depths, which results in compaction of these soils. The elemental composition of the studied soils showed characteristics of varying chemical elements, with seeming influences from both the soil-forming parent materials and the application of fertilizers and chemicals to the soil.

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