Gypsum content and gypsum morphotypes in irrigated soils of the Zhezkazgan Botanical Garden (Semideserts of Kazakhstan Republik)

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Abstract

The aim of the research was to identify possible changes in the quantity and nature of gypsum morphotypes as a result of 80 years of irrigation in the Zhezkazgan Botanical Garden. Zhezkazgan is located in the semi-desert zone of Central Kazakhstan. The soils of the Zhezkazgan Botanical Garden belong to Gypsysols. For all soils in the key area, the presence of a gypsum horizon in the profile at a depth of 45 to 80 cm with a content of 30-65% is characteristic, which aligns well with literary data (Soils..., 1960). In Russian literature, the deep occurrence of a gypsum horizon is often considered a characteristic feature of grey-brown desert soils (Soils..., 1960; Gerasimova et al., 1992).

The simultaneous presence of carbonates and gypsum in the soil profile, with crystal sizes not discernible by the human eye (less than 0.25 mm), complicates field diagnostics. In literature, a $BaCl_2$ solution is used to refine field diagnostics of gypsum. There are numerous laboratory methods for

determining gypsum, broadly classified into three major groups: chemical, thermal (based on gypsum losing crystallization water), and conductometric methods - which are useful for determining actively water-soluble gypsum, as well as an indirect method based on sulfate ions in aqueous extract. We decided to refine field diagnostics by combining X-ray fluorescence analysis (XRF) with a portable Olympus Delta analyzer and measuring the conductivity of a 1:5 extract (Alvarez et al., 2022). The authors (Alvarez et al., 2022) believe that pure gypsum in a 1:5 aqueous extract may contribute to conductivity values not exceeding 2.2 mS/cm. Determining gypsum based on sulfur content seems to be a promising XRF method (Weindorf et al., 2009). Sulfur - a component of gypsum (chemical formula $CaSO_4*2H_2O$) - was determined using portable XRF. Therefore, conductivity values above 2.2 mS/cm would indicate the presence of easily soluble salts (particularly sodium sulfates) in the profile, necessitating corrections for their content. If the conductivity value does not exceed 2.2 mS/cm and sulfur is present according to XRF results, gypsum content can be recalculated using the formula:

$$x(CaSO_4*2H_2O, \%)=(S(\%)*Mr(CaSO_4*2H_2O))/Ar(S),$$

where M is the molar mass of gypsum and Ar is the atomic mass of sulfur.

To verify the obtained soil compounds containing gypsum that is difficult to identify, they were examined under a binocular microscope and an electron microscope. Gypsum in soil exhibits various morphotypes detailed by the authors' team (Alvarez et al., 2022). Some of these formations are characteristic only of original rock materials, while others are specific to secondary, soil-related formations. In a significant portion of gypsum-containing samples, gypsum appeared as lenticular crystals with a wide range of crystal sizes ranging from 10 μm to several centimeters. Microcrystalline gypsum (known as "gazha") with crystal sizes less than 10 μm is identified by its yellowish colours under a binocular microscope.

Irrigation in the key area is carried out by furrow irrigation and hose watering with good quality water having SAR=3.5 and slightly above 1 g/L mineralization of calcium-sodium chloride-sulfate composition. Kurlow's formula for water is provided below.

$$M\ 1{,}16\ \frac{Na\ 42\ Ca\ 42\ Mg\ 15}{SO_4\ 53\ Cl\ 46};$$

The results obtained by us fit within the range of annual variations in mineralization and composition of water obtained by other researchers. The source of irrigation is the waters of the Kara-Kengir River below the Kengir reservoir and the industrial zone of the city of Zhezkazgan. Long-term monitoring of the Kara-Kengir River shows variability in total mineralization ranging from 200-300 mg/L during the flood period to 2-3 g/L during the autumn-winter thaw. The composition of water varies from hydrocarbonate-calcium to chloride-sulfate-calcium and even chloride-sulfate-calcium-sodium.

During irrigation, gypsum can recrystallize and undergo gradual decomposition along cleavage planes (Poch et al., 2018), exhibiting a specific texture resembling a "fractured battlement" under an electron microscope. However, we observed the "fractured battlement" texture in a localized area of soil sample that has never been irrigated, possibly preserved from earlier times.

Regarding the quantity of gypsum, it was estimated that irrigation with Kara-Kengir waters on this site over 80 years could accumulate no more than 10% gypsum. The remaining variability is associated with the heterogeneity of gypsum-bearing parent rocks. We used the Radioactive Fluorescence Analysis (RFA) method to determine the gypsum content. The gypsum content was determined based on sulfur content with control of electrical conductivity and calcium activity. The main assumption is that sulfur is present in the soil in

the form of sulfates. As shown in Figure 1, the correlation between sulfur content and electrical conductivity is not very reliable, as it is complicated by the presence of easily soluble salts and incomplete dissolution of gypsum.

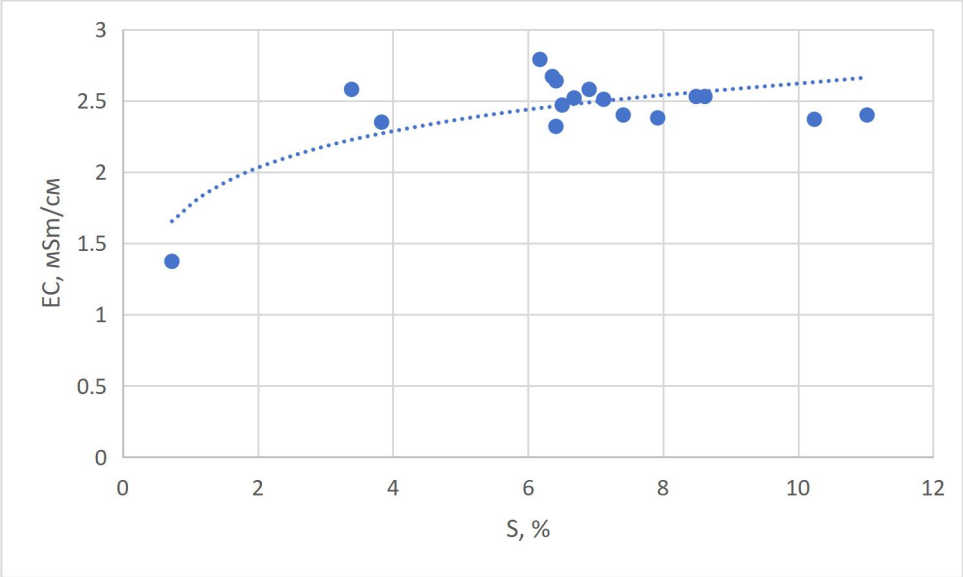

Figure 1. The relationship between XRF sulfur content and electrical conductivity (water extract 1:5) in soils with morphological gypsum formations.

However, sulfur content can be used to assess the profile distribution of gypsum content in the soil (example - Figure 2, well Zh27-2). The conversion of sulfur S (%) into gypsum was performed using the formula: gypsum (%) = (S (%) * 172)/32.

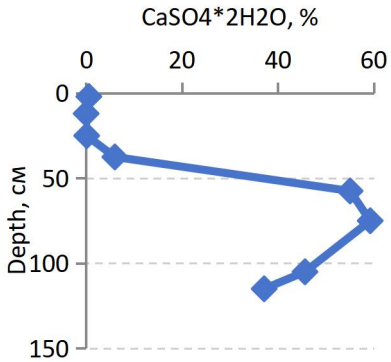

Figure 2. Profile distribution of gypsum content in irrigated soil.

Presumably, as a result of the interaction of irrigation water with the

underlying gypsum containing rock during furrow irrigation, dissolution of gypsum occurred, transitioning it into a microcrystalline form. The coarse crystalline form was preserved at a depth of 90 (see Figure 3) and deeper. Overall, gypsum in the botanical garden is noted at a depth of 40-90 cm predominantly in a coarse crystalline form.

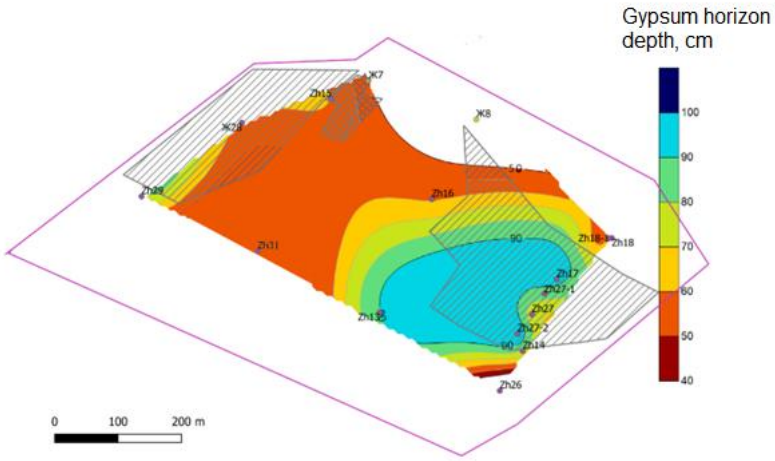

Figure 3. Map of the depth of occurrence of coarse crystalline gypsum (with crystal sizes larger than 0.25 mm). Hatching indicates irrigated areas.

A more detailed study of gypsum forms in irrigated soil under an electron microscope will be performed later; for now, we present the profile appearance of irrigated soil under a binocular microscope (magnification 10X and 20X).

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Profile

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