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GIS-BASED ASSESSMENT OF THE AGROCHEMICAL AND MELIORATIVE STATUS OF IRRIGATED SEROZEM-MEADOW SOILS IN MIRZAABAD DISTRICT, SYRDARYA REGION

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ОЦЕНКА АГРОХИМИЧЕСКОГО И МЕЛИОРАТИВНОГО СОСТОЯНИЯ ОРОШАЕМЫХ СЕРО-ЛУГОВЫХ ПОЧВ МИРЗААБАДСКОГО РАЙОНА СЫРДАРЬИНСКОЙ ОБЛАСТИ НА ОСНОВЕ ГИС

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Abstract. This article focuses on the assessment of the agrochemical and ameliorative status of irrigated gray-meadow soils distributed in the G.Yunusov massif of Mirzaabad District, Syrdarya Region, using GIS technologies. The main objective of the study is to determine the spatial distribution of soil properties, assess the condition of existing soil resources from a cartographic perspective, and characterize the main indicators determining soil fertility and ameliorative status across different areas. The study used data on humus content, available phosphorus, exchangeable potassium, soil texture, and the degree of salinity. Using GIS technologies, thematic maps and cartograms were developed to represent the spatial distribution of these soil indicators. The results showed that soil properties within the G.Yunusov massif are not uniformly distributed across the territory. In particular, spatial differences in the degree of salinity and the predominance of moderately saline soils were observed. A separate cartographic analysis of the irrigated lands of the "Mirzaobod

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agro-cluster" farm located within the massif made it possible to assess soil properties at the farm level. The developed cartographic materials are of practical importance for monitoring soil fertility, organizing agrotechnical and ameliorative measures according to the soil characteristics of the territory, and ensuring the efficient use of irrigated land resources.

Аннотация. Рассматривается оценка агрохимического и мелиоративного состояния орошаемых серо-луговых почв, распространённых на массиве имени Г. Юнусова Мирзаабадского района Сырдарьинской области, на основе технологий ГИС. Основной целью исследования является определение пространственного распределения свойств почв, картографическая оценка состояния существующих почвенных ресурсов, а также характеристика основных показателей, определяющих плодородие и мелиоративное состояние почв, в территориальном разрезе. В исследовании использованы данные о содержании гумуса, подвижного фосфора, обменного калия, механическом составе и степени засоления почв. С использованием ГИС-технологий разработаны тематические карты и картограммы, отражающие пространственное распределение указанных показателей. Результаты показали, что свойства почв на массиве имени Г.Юнусова распределены по территории неоднородно. Особенно отмечена пространственная дифференциация степени засоления и преобладание среднезасоленных почв. Отдельный картографический анализ орошаемых земель фермерского хозяйства «Mirzaobod agro-cluster», расположенного в пределах данного массива, позволил оценить почвенные свойства на уровне фермерского хозяйства. Разработанные картографические материалы имеют практическое значение для мониторинга плодородия почв, организации агротехнических и агромелиоративных мероприятий с учётом почвенных особенностей территории, а также эффективного использования орошаемых земельных ресурсов.

Keywords: serozem-meadow soils, GIS, soil map, cartogram, salinity, soil fertility.

Ключевые слова: серо-луговые почвы, ГИС, почвенная карта, картограмма, засоление, плодородие почв.

Soil is one of the main natural resources in agricultural production, and its fertility and ecological-meliorative status are considered important factors determining the productivity of agricultural crops and the sustainable use of land resources. Under irrigated agriculture, long-term and intensive irrigation can cause significant changes in the soil water–salt regime, groundwater conditions, agrochemical properties, and soil fertility. In particular, in arid and semi-arid regions, soil salinity is one of the major problems limiting the effective use of agricultural lands. Long-term monitoring data from irrigated lands in the Syrdarya Region were analyzed to assess the spatial relationship between groundwater level, mineralization, and soil salinity using GIS [1].

A number of studies have been conducted to assess soil salinity in the Syrdarya Region using modern GIS technologies. In particular, Landsat 8 OLI satellite imagery and GIS technologies were used in the Syrdarya Region, and various salinity indices were tested for assessing soil salinity. The SI2, SI3, SI4, NSI, VSSI, and NDSI indices were also used, and remote sensing data were compared with field-based salinity maps, demonstrating the potential of GIS and remote sensing technologies for monitoring saline areas [2].

Studies on long-term remote sensing-based monitoring of saline lands in the Syrdarya Region assessed the spatial changes in soil salinity during 2000–2011 using Landsat imagery and field data.

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Soil salinity was classified into “non-saline,” “slightly saline,” “moderately saline,” and “highly saline” groups, and an increase in the proportion of moderately saline soils was reported [3].

GIS-based maps were developed for irrigated lands in the Khovos District of the Syrdarya Region, and slightly saline soils were found to predominate across most of the territory. In addition, slightly saline areas accounted for 73.1%, while moderately saline areas accounted for 26.75% of the irrigated lands in Khovos District. This study demonstrates the spatial differentiation of salinity in the irrigated lands of the Syrdarya Region and supports the need for detailed studies at the level of individual farms and agricultural massifs [4].

The spatial and temporal dynamics of soil salinity in the irrigated lands of the Syrdarya Region were assessed using monitoring data for 2004–2024 by integrating GIS, remote sensing, and field measurements. In the study, spatial maps of groundwater depth, groundwater mineralization, and soil salinity were developed in the ArcGIS environment using IDW interpolation [5].

The need for a detailed study of the agrochemical status and the ameliorative and ecological conditions, as well as the water and water–salt regimes, of the irrigated gray-meadow soils of Mirzaabad District has been noted. Particular attention was also paid to assessing the agrochemical status of the soils in this area [6].

Data on the agrochemical status of newly developed irrigated gray-meadow soils in the Mirzaabad District of the Syrdarya Region have also been reported. It was determined that the contents of humus, total nitrogen, total phosphorus, and total potassium in the plough layer ranged from 1.088–1.214%, 0.079–0.089%, 0.109–0.124%, and 1.15–1.24%, respectively. The findings provide an important scientific basis for assessing the nutrient status of irrigated soils in the Mirzaabad area [8].

The agrochemical properties of irrigated gray-meadow soils distributed within the G. Yunusov massif of Mirzaabad District were studied, particularly the contents of humus, available phosphorus, and potassium; their low and medium levels of nutrient supply across the territory were reported [9].

Materials and Methods

The study object consisted of irrigated gray-meadow soils distributed within the G. Yunusov massif of Mirzaabad District, Syrdarya Region. Within the study area, an irrigated land area of 186.84 ha belonging to “Mirzaobod agro-cluster” LLC was additionally selected for assessment at the individual farm level.

Geographic Information System (GIS) technologies were applied as a tool for determining the spatial distribution of soil properties, integrating available field and laboratory data spatially, and developing thematic cartographic materials. Initially, available soil maps, soil contours, and data on agrochemical and ameliorative indicators of the study area were systematized. In studies on GIS-based mapping of soil salinity in Mirzaabad District, approaches involving the development of salinity maps using various cartographic methods have been applied [9].

An analysis of humus content, soil texture, and fertility status in irrigated meadow soils of Sardoba District, Syrdarya Region, is important for assessing humus content in soils and determining its relationship with soil fertility. This approach can be used as a comparative scientific basis for assessing the spatial distribution of humus within the G. Yunusov massif [10].

Results and Discussion

Particular attention was paid to determining the spatial distribution and variability of the main properties of irrigated gray-meadow soils in assessing their agrochemical and ameliorative status within the study area. The results showed that the agrochemical and ameliorative status of irrigated gray-meadow soils distributed within the G. Yunusov massif was not uniform across the territory.

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Using GIS technologies, thematic maps and cartograms were developed for humus, available phosphorus, exchangeable potassium, soil texture, and salinity degree. This cartographic approach made it possible to identify spatial differences in soil properties and to comparatively assess them at both the massif level and the level of an individual farm area.

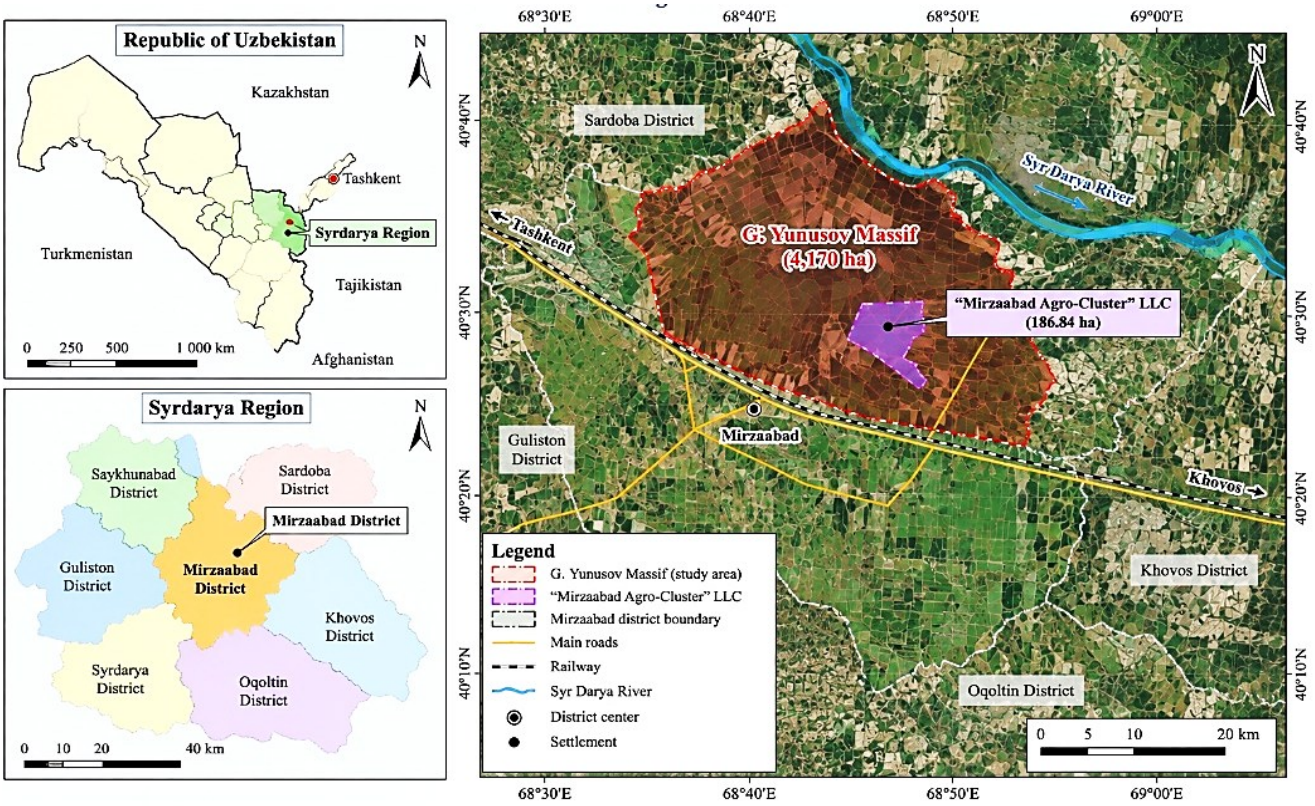


Figure 1. Location of the G.Yunusov massif in Mirzaabad District, Syrdarya Region, and the territory of "Mirzaobod agro-cluster" LLC

The spatial distribution of humus content in the irrigated gray-meadow soils of the G. Yunusov massif was analyzed using GIS technologies to assess the fertility status of the study area. Within the massif's 4,169.8 ha of irrigated land, the humus supply level was classified into very low, low, medium, high, and very high groups. According to the cartogram data, areas with a very low humus supply accounted for 77.5 ha (1.9%), low-supply areas for 705.8 ha (16.9%), medium-supply areas for 2,509.6 ha (60.2%), high-supply areas for 803.0 ha (19.3%), and very high-supply areas for 74.1 ha (1.8%) (Figure 2).

A separate cartogram prepared for the 186.8 ha of irrigated land belonging to the "Mirzaobod agro-cluster" LLC, located within the massif, enabled a more detailed assessment of the humus supply status at the farm level. Within this area, low humus-supply soils occupied 4.2 ha (2.2%), while medium-supply soils covered 182.7 ha (97.8%). No separate areas belonging to the very low, high, or very high humus-supply groups were recorded in the cartogram data. Thus, medium-supply soils clearly predominated within the territory of the "Mirzaobod agro-cluster" LLC, occupying 182.7 ha or 97.8% of the area. This value is considerably higher than the 60.2% share of medium humus-supply soils recorded for the massif as a whole (Figure 2).

The spatial distribution of available phosphorus was analyzed using GIS technologies to assess the nutrient supply status of the irrigated gray-meadow soils of the G. Yunusov massif. Within the massif's total 4,169.8 ha of irrigated land, the content of available phosphorus ranged from 6.5 to 32.4 mg/kg. Areas with very low phosphorus supply accounted for 132.8 ha (3.2%), low-supply areas

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for 86.1 ha (2.1%), medium-supply areas for 3,244.8 ha (77.8%), and high-supply areas for 705.1 ha (16.9%). The corresponding mean phosphorus contents in these groups were 6.5, 12.5, 20.1, and 32.4 mg/kg, respectively. The results indicate that the majority of the irrigated lands in the massif, namely 77.8%, had a medium level of available phosphorus supply (Figure 3).

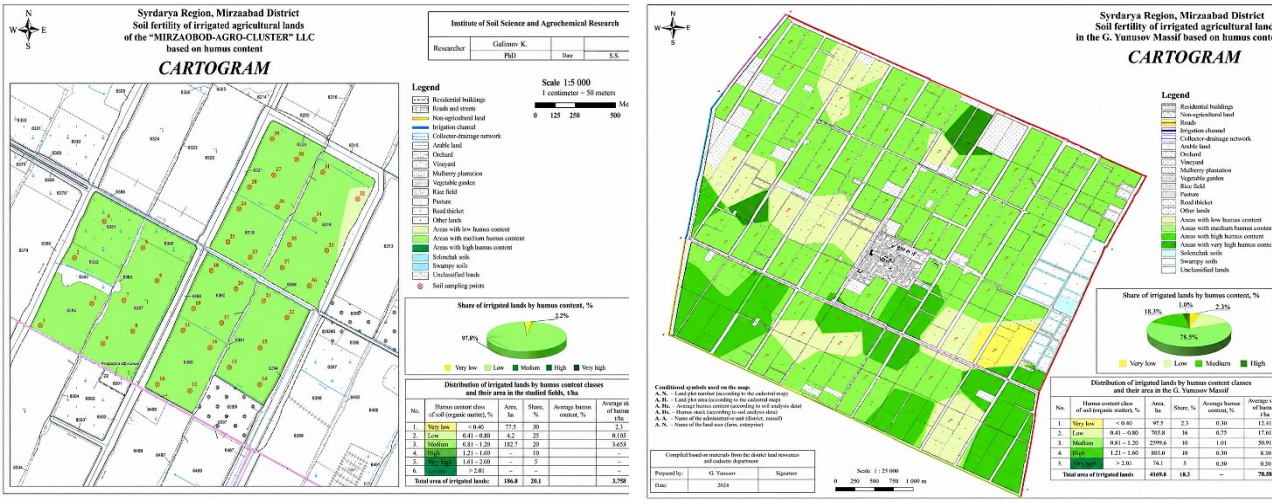


Figure 2. Cartogram of the spatial distribution of humus content in the irrigated lands of the G.Yunusov massif and "Mirzaobod agro-cluster" LLC, Mirzaabad District

A separate cartogram prepared for the 186.8 ha of irrigated land belonging to "Mirzaobod agro-cluster" LLC, located within the massif, enabled a more detailed assessment of the phosphorus supply status at the farm level. Within this area, very low phosphorus-supply soils occupied 0.5 ha (0.3%), low-supply soils 3.6 ha (1.9%), medium-supply soils 182.4 ha (97.8%), and high-supply soils 0.3 ha. Thus, medium phosphorus-supply soils clearly predominated within the territory of "Mirzaobod agro-cluster" LLC, covering 182.4 ha or 97.8% of the area. This proportion is higher than the 77.8% recorded for medium phosphorus-supply soils across the massif as a whole (Figure 3).

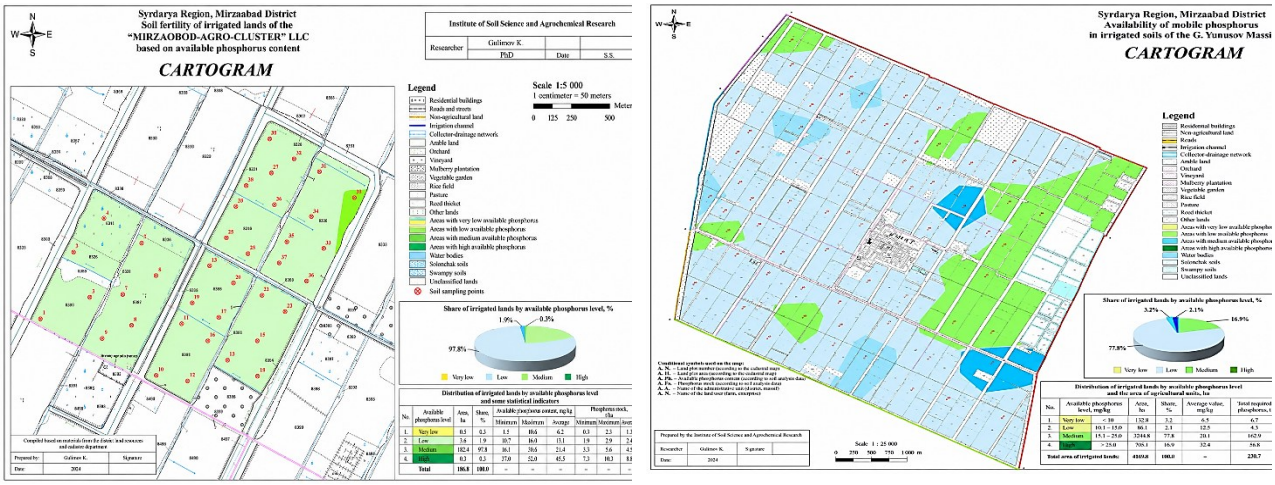


Figure 3. Cartogram of the spatial distribution of available phosphorus content in the irrigated lands of the G.Yunusov massif and "Mirzaobod agro-cluster" LLC, Mirzaabad District

The spatial distribution of exchangeable potassium content was analyzed using GIS technologies to assess the nutrient supply status of the irrigated gray-meadow soils of the G. Yunusov massif in Mirzaabad District. Within the massif's 4,169.8 ha of irrigated land, the soils were classified

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into very low, low, medium, high, and very high potassium-supply groups. The following ranges were used: very low (<100 mg/kg), low (101-200 mg/kg), medium (201-300 mg/kg), high (301-400 mg/kg), and very high (>401 mg/kg). Spatial differentiation among these groups was observed. The largest proportion was represented by soils with a medium level of potassium supply, covering 2,200.7 ha (52.8%). Low-supply soils occupied 288.9 ha (6.9%), high-supply soils 704.8 ha (16.9%), and very high-supply soils 975.3 ha (23.4%) (Figure 4).

A separate cartogram prepared for the 186.8 ha of irrigated land belonging to “Mirzaobod agro-cluster” LLC, located within the G. Yunusov massif, enabled a more detailed assessment of potassium supply at the farm level. According to the cartogram data, the majority of the farm’s territory consisted of soils with a medium level of potassium supply. This group covered 179.8 ha, accounting for 96.3% of the farm’s irrigated land (Figure 4).

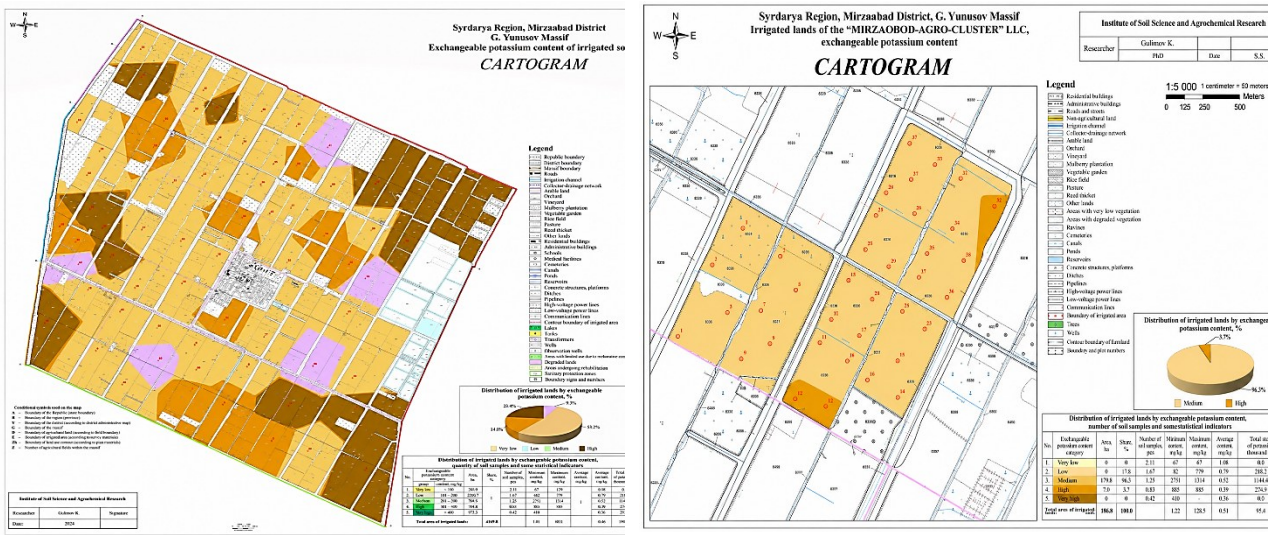


Figure 4. Cartogram of the spatial distribution of exchangeable potassium content in the irrigated lands of the G.Yunusov massif and “Mirzaobod agro-cluster” LLC, Mirzaabad District

To assess the physical properties of the irrigated lands of the G. Yunusov massif in Mirzaabad District, the soil texture was analyzed cartographically using GIS technologies. The results showed spatial differentiation of soil texture across the massif, represented by sandy, sandy-loam, light loam, medium loam, and heavy loam soil types. These groups are presented in different colors on the cartogram, clearly illustrating the spatial distribution of soil contours according to their texture. The soil texture map showed that medium-loam and light-loam soils predominate across most of the territory. Heavy-loam and sandy-loam soils were also found in some areas. Such spatial differentiation of soil texture is an important factor affecting soil water permeability, moisture-retention capacity, aeration, and water movement during irrigation. Therefore, the soil texture map is important not only for characterizing the physical properties of irrigated soils but also for the spatial differentiation of irrigation and ameliorative measures (Figure 5).

A separate soil texture map prepared for the 186.84 ha of irrigated land belonging to “Mirzaobod agro-cluster” LLC, located within the massif, enabled a more detailed assessment of soil texture at the farm level. According to the cartographic data, light-loam, medium-loam, and heavy-loam soils are distributed within the farm territory. Among these, medium-loam soils occupy the largest area, covering 165.09 ha (88%). Light-loam soils cover 18.9 ha (10%), while heavy-loam soils occupy 2.85 ha (2%). Thus, medium-loam soils clearly predominate within the irrigated lands of “Mirzaobod agro-cluster” LLC, accounting for 165.09 ha or 88% of the total area. Light-loam and

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heavy-loam soils account for 10% and 2%, respectively. These results indicate that the soil texture of the farm territory is relatively uniform, with the majority of the area consisting of medium-loam soils. Such a distribution of soil texture is important for the infiltration and movement of irrigation water, moisture retention, and regulation of the soil water-air regime. From this perspective, the predominance of medium-loam soils should be considered one of the main soil properties when planning irrigation and agrotechnical measures within the farm territory (Figure 5).

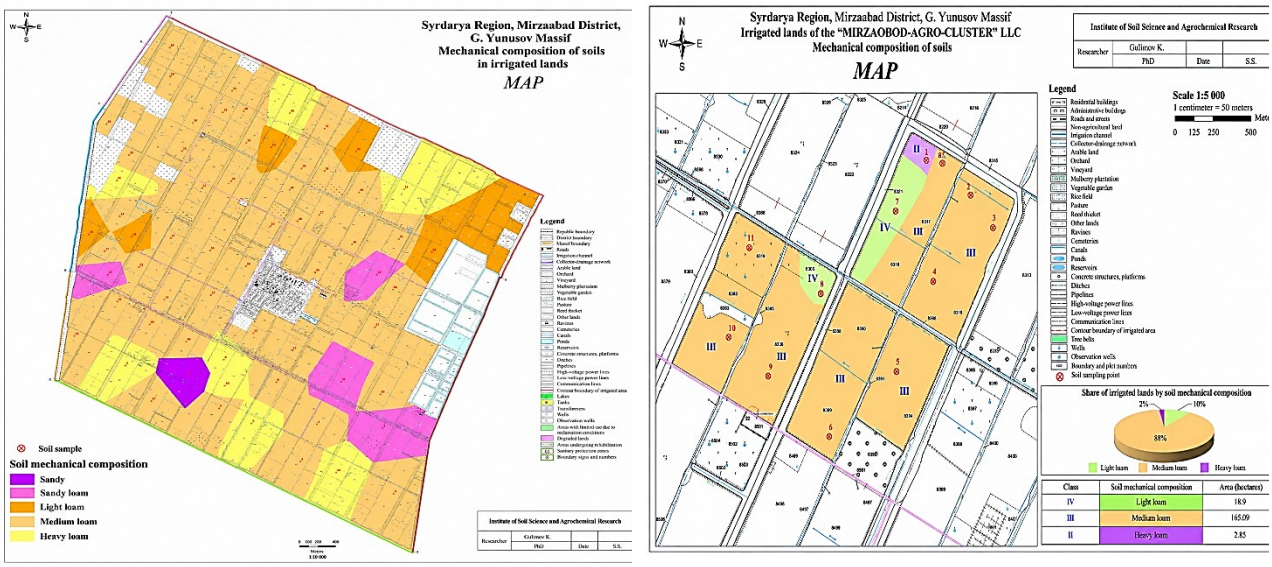


Figure 5. Soil texture map of the irrigated lands of the G.Yunusov massif and "Mirzaobod agro-cluster" LLC, Mirzaabad District

To assess the ameliorative status of the irrigated lands of the G.Yunusov massif in Mirzaabad District, the spatial distribution of soil salinity was analyzed using GIS technologies. The spatial differentiation of salinity levels across individual soil contours was represented using different colors. The results showed that the degree of salinity was not uniformly distributed throughout the massif, with some areas exhibiting relatively higher levels of salinity, while other areas had lower levels. The total area of irrigated land within the G. Yunusov massif is 4,169.8 ha. The cartogram distinguishes areas according to different degrees of salinity, with moderately saline soils accounting for the largest proportion. Slightly and highly saline areas were also identified in certain parts of the territory. The absence of very highly saline soils is one of the important findings for assessing the overall ameliorative status of the massif. A separate cartogram prepared for the 186.8 ha of irrigated land belonging to "Mirzaobod agro-cluster" LLC, located within the massif, enabled a more detailed assessment of the ameliorative status of the farm territory. According to the cartographic data, slightly, moderately, and highly saline soils were distributed across the farm area. Their spatial distribution is represented by different colors on the cartogram. Moderately saline soils predominated, occupying 164.45 ha (88%). Slightly saline soils covered 33.60 ha (9%), while highly saline soils occupied 5.83 ha (3%). Very highly saline soils were not recorded within the farm territory (Figure 6). The fact that 88% of the irrigated lands of "Mirzaobod agro-cluster" LLC are characterized by moderate salinity is a key indicator in assessing the ameliorative status of the territory. These results indicate the need for differentiated monitoring and agromeliorative measures according to the degree of salinity to improve the ameliorative condition of irrigated lands. In particular, the large proportion of moderately saline areas requires regular monitoring of the effectiveness of irrigation and collector-drainage systems (Figure 6).

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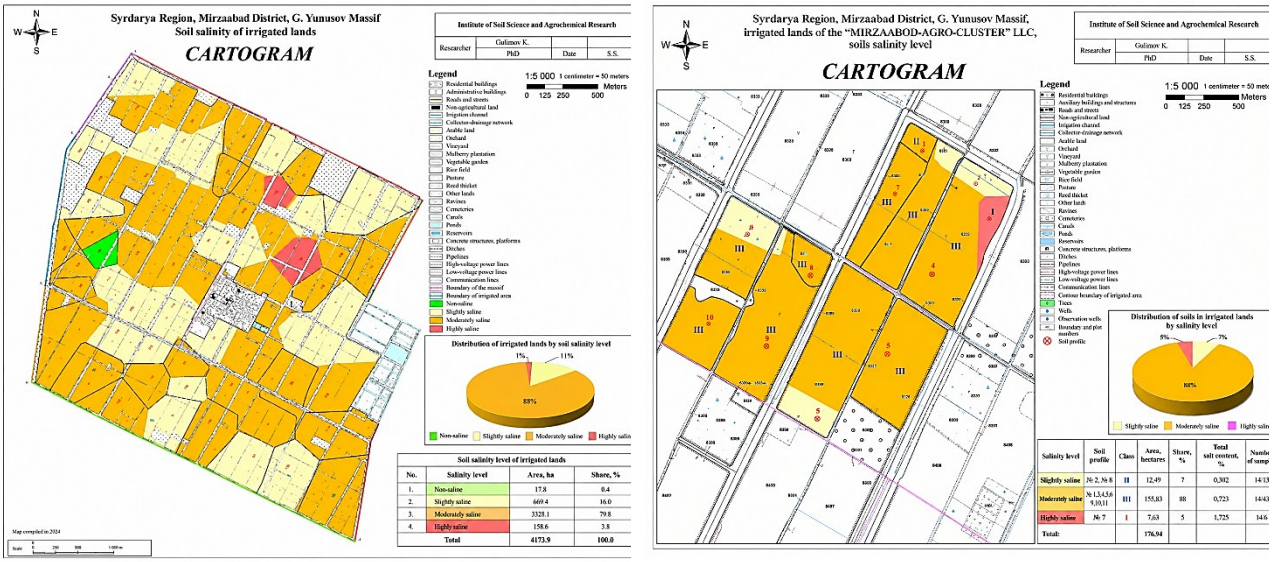


Figure 6. Cartogram of the salinity degree of the irrigated lands of the G.Yunusov massif and "Mirzaobod agro-cluster" LLC, Mirzaabad District

Conclusion

The assessment of the agrochemical and ameliorative status of irrigated gray-meadow soils distributed within the G. Yunusov massif of Mirzaabad District, Syrdarya Region, using GIS technologies demonstrated that soil properties are spatially heterogeneous. The thematic maps and cartograms developed in the study made it possible to characterize soil fertility and ameliorative conditions in greater detail across different parts of the study area. The results showed that medium humus-supply soils predominated within the massif, covering 2,509.6 ha (60.2%). Medium available-phosphorus supply was also dominant, accounting for 3,244.8 ha (77.8%). Regarding exchangeable potassium, soils with a medium supply occupied 2,200.7 ha (52.8%), while areas with high and very high potassium supply together accounted for 1,680.1 ha. These findings indicate spatial differences in the nutrient-supply status of the soils depending on soil properties and local environmental conditions. The separate cartographic assessment of the irrigated lands of "Mirzaobod agro-cluster" LLC, covering 186.8 ha, showed that medium levels of humus and available phosphorus predominated. In particular, medium humus-supply soils occupied 182.7 ha (97.8%), while medium available-phosphorus soils covered 182.4 ha (97.8%). Regarding exchangeable potassium, 179.8 ha (96.3%) of the area had a medium supply level, while 7.0 ha (3.7%) had a high supply level. The spatial assessment of soil texture showed that medium-loam soils predominated within the lands of "Mirzaobod agro-cluster" LLC, occupying 165.09 ha (88%). Light-loam soils covered 18.9 ha (10%), while heavy-loam soils accounted for 2.85 ha (2%). These results indicate the importance of considering the physical properties of soils when planning irrigation and agrotechnical measures. The spatial distribution of salinity, which is an important indicator of ameliorative status, showed that 164.45 ha (88%) of the irrigated lands of "Mirzaobod agro-cluster" LLC were moderately saline, 33.60 ha (9%) were slightly saline, and 5.83 ha (3%) were highly saline. The absence of very highly saline areas represents an important characteristic in assessing the ameliorative status of the territory. Overall, the use of GIS technologies made it possible to identify the spatial variability of soil properties within the G. Yunusov massif, cartographically assess its agrochemical and ameliorative status, and spatially identify areas requiring particular attention. The obtained results can provide a scientific and practical basis for monitoring the fertility of irrigated lands, applying mineral fertilizers in a differentiated manner, planning agromeliorative measures in saline areas, and promoting the efficient use of land resources.

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