Creation of Hydromodular Zoning Maps of Irrigated Agricultural Lands Based on Geoinformation Technologies

M Khamidov[a], A Inamov[b], U Islamov[c], J.Ishchanov[d] and Z.Mamatkulov[e]
National Research University of the "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers", Kory Niyoziy str., 39, 100000, Tashkent, Uzbekistan
Correspondence: zohid3095@gmail.com

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Abstract: Nowadays, global climate change has a positive effect on the melioration and agro-ecological condition of the irrigated lands of the Republic of Uzbekistan. As a result of the occurrence of secondary salinization in agricultural fields in accordance with the climate and soil conditions of the region, it is observed that there are partially or completely out of use many of irrigated lands lose their function of planting agricultural crops and. One of the main factors behind such negative changes is the lack of digital hydromodular zoning (HMZ) maps, which are used to determine irrigation regimes for agricultural crops. In this research, on the basis of GIS technologies, the irrigated agricultural lands in the regions of the Amudarya river basin are Republic of Karakalpakstan, Khorezm, Bukhara, Navoi, Kashkadarya, and Surkhandarya regions, creating a geodatabase of monitoring wells installed for monitoring the dynamics of groundwater levels and mechanical composition of soils the hydromodular zoning map creation method has been improved. The IDW interpolation algorithm and raster calculator functions of ArcGIS were used in the analysis of the obtained data. As a result, the areas of irrigated land in the regions of the Amudarya river basin were determined overall IX hydromodular zones, and electronic maps were developed by the regions. Based on the study, 7.2 % of the irrigated land in the regions of the Amudarya river basin belongs to I, 9.1 % to II, 6.3 % to III, 13.3 % to IV, 7.2 % to V, 8.3 % to VI, 17.1 % to VII, 16.4 % to VIII and 15.1 % to IX were found.

1 INTRODUCTION

In the world, global climate change is becoming a factor that can have a significant impact on all areas of human activity. It has a negative impact on the environment in many regions of the planet, on the life and health of the population in various sectors of the economy. The impact of climate change on agriculture is particularly high, as agriculture is one of the most weather-dependent sectors of the economy. Climate change will cause 10-15% more water evaporation from water surfaces and 10-20% more water use due to increased plant transpiration and irrigation rates. This leads to an average 18% increase in non-renewable water consumption. Assessment of the possible increase in water consumption in irrigated lands due to changes in climate conditions, hydromodular zoning of irrigated lands in order to ensure efficient use of water resources, and development of scientifically based crop irrigation procedures for each hydromodular region is an urgent problem of today (Khamidov, Inamov, Islomov, Mamatkulov, 2023; Khamidov, Matyakubov, Gadaev, Isabaev, Urazbaev, 2023; Khamidov, Ishchanov, Khamidova, Isabaev, Altmishev, 2023).

The first scientific research works on hydromodular zoning in Central Asia were carried out in 1915 by S.K. Kondrashov, and later, in 1932-1951, by V.M. Legostaev, B.S. Konkov and G.P. It was

[a] https://orcid.org/0000-0002-5513-4933
[b] https://orcid.org/0000-0001-8753-7748
[c] https://orcid.org/0000-0002-5880-4154
[d] https://orcid.org/0000-0001-5595-5603
[e] https://orcid.org/0000-0001-9853-856X

carried out by Geltser, and the mechanical composition of the soil and surface condition of seepage water were taken as the main indicators of hydromodular zoning (Matyakubov, Goziev, Makhmudova, 2021; Matyakubov, Yulchiyev, Kodirov, Axmedjanova, 2021). Today, the implementation of hydromodular zoning of irrigated lands requires the development of high-precision digital hydromodular zoning maps using modern and innovative technologies, in particular, GIS technologies. Application of GIS technologies in the management and use of water resources ensures easy, fast and accurate fulfillment of most of the tasks being implemented (Mamatkulov, Abdivaitov, Hennig, Safarov, 2022; Inamov, Avilova, Norbaeva,...Idirova, Vakhobov, 2021).

2 MATERIALS AND METHODS

2.1 Study area

These scientific studies were conducted in the irrigated agricultural lands of the regions of the Amudarya River basin (Fig.1).

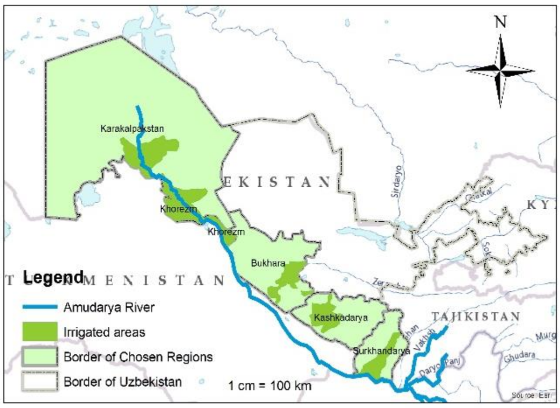

Figure 1: Study area.

According to statistics, the irrigated arable land areas in the regions of the Amudarya River basin have been decreasing over the years. The main reason for this is the aggravation of climate change, the allocation of land for state and public needs, and the establishment of new orchards (intensive) and vineyards based on government decisions and programs (Khamidov, Inamov, Islamov, Mamatkulov, Inamov, 2023; Reimov, Mamatkulov, Shermanov, Oymatov, Khamraliev, Abdurashitov, 2023; Khamraliev, Mamatkulov, Musaev, Saipova, Oymatov, Mirjalolov, 2023; Oymatov, Mamatkulov, Maksudov, Bakhriyev, Aminova, Menlimuratova, Esirgapov, 2023).

As of January 1, 2022, the total irrigated land in the regions of the Amudarya River basin is 2025.7 thousand hectares, including 1571.9 thousand hectares of agricultural arable land. These indicators are distributed in the study areas (provinces) as shown in Table 1.

Table 1. Irrigated areas in the Amudarya River basin of the Republic of Uzbekistan (in thousand ha).

№	Regions	Total irrigated area	Total irrigated arable land
1	Karakalpakstan Republic	517.1	418.9
2	Bukhara	276.3	200.1
3	Kashkadarya	513.4	417.3
4	Navoi	126.8	91.9
5	Surkhandaya	324,9	238.4
6	Khorazem	267.2	205.3
	Total	**2025.7**	**1571.9**

2.2 Materials and Methods

The purpose of the research is to use them effectively in the conditions of increasing shortage of water resources, to draw up water use plans, to set allocated water limits and to create hydromodular zoning of irrigated lands, which is the basis for obtaining a high yield from crops, and to create electronic maps of hydromodular zoning in districts. To achieve this goal, the following tasks were performed: development of a digital map depicting the distribution of types of soils with 3 types of mechanical composition (light, medium and heavy sand) by territory; creating an electronic map of the location of seepage waters based on attributive data representing the level of seepage waters in the section of observation wells; creation of hydromodular zoning electronic maps of irrigated lands in the district section.

Today, the irrigated lands of the Republic of Uzbekistan are mainly divided into 9 hydromodular zones: I, II, III, IV, V, VI, VII, VIII and IX according to the thickness of the soil, mechanical composition, location and ground water level in the aeration layer by Professor N.F. Bespalov’s developed method. (Table 3) (Khamidov, Inamov, Islomov, Mamatkulov, 2023; Khamidov, Matyakubov, Gadaev, Isabaev, Urazbaev, 2022).

Table 1: Classification of Hydromodular Zones.

Hydromodular zone number	Soil condition	Groundwater level, m
Automorphic soils		
I	Low-layer sand and thick-layer sand, located on sand-gravel,	> 3.0
II	Medium-layered sand and thick sand and light sand on top of sand-gravel	> 3.0
III	Thick medium and heavy sand and muddy	> 3.0
Semi-automorphic soils		
IV	Sand, medium and low thickness layered sand and clay,	2.0 – 3.0
V	Light and medium sand, single-layer heavy sand, lightening down,	2.0 – 3.0
VI	Heavy sandy, muddy, layered with the same layer and different mechanical composition, layered,	2.0 – 3.0
Hydromorphic soils		

In the course of the research, electronic digital maps of soils according to their mechanical composition were created using the ArcGIS program, and geovisualization of indicators related to the level of flood waters was carried out on the basis of a field layer. In the geovisualization of water level indicators, it is required to determine the coordinate values of observation wells using a GNSS satellite wave receiver.

HI-Target i70 GNSS satellite wave receiver of the I and II frequency was used to determine and digitize the coordinates values of observation wells the level of ground waters. In order to increase the accuracy of the results, the obtained coordinate values were connected to differential satellite geodetic networks. Today, there are a total of 50 differential satellite geodetic networks in the Republic of Uzbekistan, which provide information for equalization of all geodetic field research (Nilipovskiy, Inamov, 2020; Inamov, Sattorov, Dadabayev, Narziyev, 2022).

A geodatabase and thematic layers of existing irrigated agricultural lands in the regions of the Amudarya River basin were created. Initially, during these steps, high spatial resolution satellite images downloaded from the SAS Planet program were added to the ArcMap application of the ArcGIS program. The downloaded satellite image was linked to regional coordinates after the geospatial linking process. The geographic coordinate system was used for linking to regional coordinates (Fig. 2) (Khamidov, Inamov, Islomov, Mamatkulov, 2023; Wojtaszek, Ronczyk, Mamatkulov, Reimov, 2021; Oymatov, Mamatkulov, Reimov, Makhsudov, Jaksibaev, 2021; Inamov, Ibragimov, Mukhamedayubova, 2022).

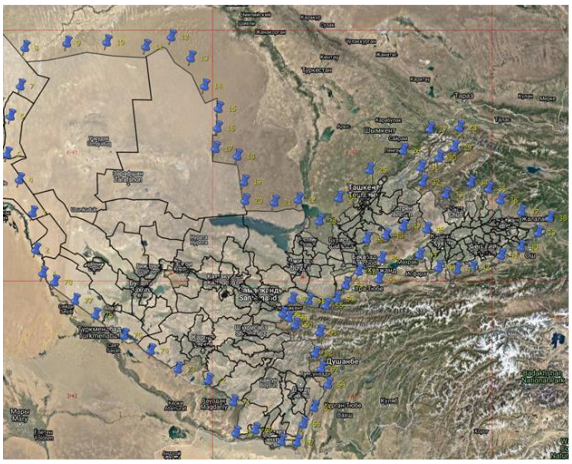

Figure 2: Georeferancing to regional coordition system.

When creating hydromodular zoning maps of irrigated agricultural land areas, ground water level data is considered one of the main data. Nowadays, the collection of ground water level data is carried out every 10 days by observation wells installed in the irrigated areas by the district departments of the Reclamation Expedition under the Irrigation System Basin Administration in the provinces of the Republic of Uzbekistan.

Monitoring wells are installed in the upper, middle and lower parts of the irrigated land, and their number is determined based on the land area and reclamation conditions of the district. All wells were marked on the district territory and their serial number was indicated.

A geodatabase of all districts was created in the section of regions in the Amudarya River basin, and vector layers were formed by land types. At the same time, geographical location of observation wells, seepage water level and other attributive data were collected in the section of land types, and 23,646 observation wells were entered into a geodatabase based on the digitization method (Table 3).

Table 3: Monitoring wells located in the irrigated areas of the in the Amudarya River basin of the Republic of Uzbekistan (by regions).

№	**Regions**	**Observati on wells**	**Attached fields to wells, ha**
1	Karakalpakstan Republic	3659	499725
2	Bukhara	2590	381281.66
3	Kashkadarya	1293	159605.56
4	Navoi	5718	692326.49
5	Surkhandaya	1320	389394.90
6	Khorazem	2012	262338
Total		**16592**	**2384672**

The total number of wells monitoring the level of ground water in the regions of the Amdurayo basin was calculated, and maps were analyzed that visualized the geographic location of wells monitoring the level of ground water in a schematic view. At the same time, the data on wells monitoring the level of seepage water in the Republic of Karakalpakstan, Bukhara, Navoi, Kashkadarya, Surkhandarya and Khorezm regions have been collected, and the water levels obtained in the months of March, April, May, June, July and August 2022 by decades have been collected and the average levels was determined. The sequence number (ID-number) of monitoring wells, service area, depth of wells and fixed point values of the well were formed in the section of arrays (associations of water consumers).

3 RESULTS AND DISCUSSION

As a result, a geodatabase of all regions in the Amudarya River basin, and vector layers were formed by land and soil types. At the same time, geographical location of monitoring wells, ground water level and other attributive data were compiled in the section of land types (Fig. 3).

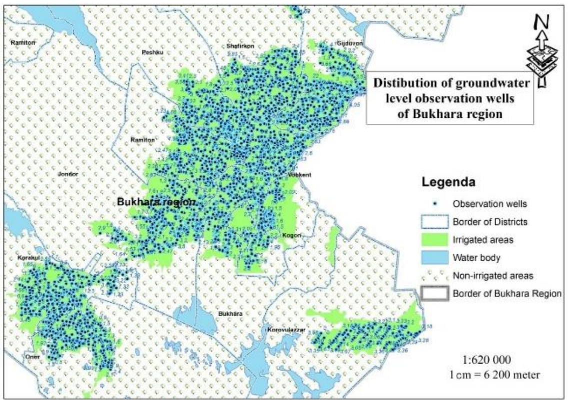

Figure 3: Distribution of observation wells in irrigated lands.

Based on the IDW algorithm of the ArcGIS program, the geographical distribution of the ground water level map was formed according to the data obtained from the observation wells (Fig.4).

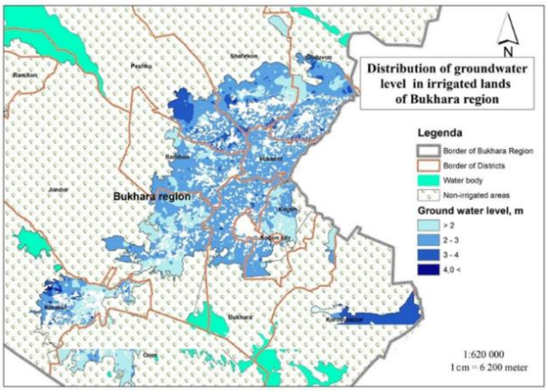

Figure 4: Groundwater level distribution in irrigated lands.

The digital map of soil mechanical composition in raster form was vectorized based on thematic layers, and the corresponding soil classifications are entered into attributive tables. The mechanical composition of soils according to the irrigated land areas of the regions was categorized based on the classes of light, medium and heavy mechanical composition. As a result, a map with the mechanical composition of the soil in electronic digital form was created (Fig.5)

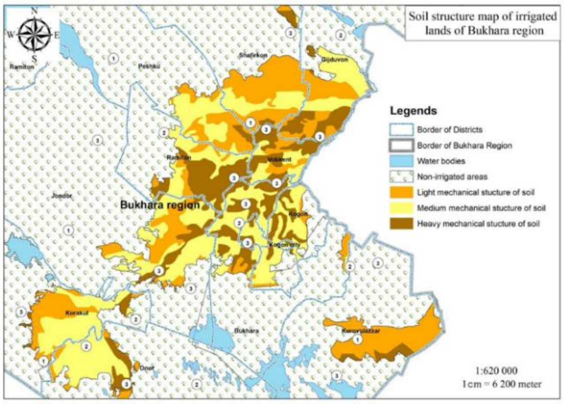

Figure 5. Soil mechanical structure distribution in irrigated lands.

Based on the Bespalov's hydromodular zoning table, an algorithm was developed by using of raster calculator of ArcGIS. The algorithm was developed based on "If condition" methodology (Con ((("interpolation" >= 200) & ("interpolation" <= 300) & ("Soils" == 1)),1,0)) that divided irrigated lands to nine hydromodular zones.

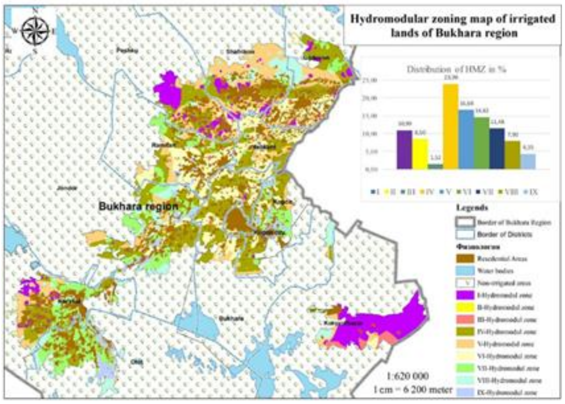

Figure 6: Hydromodul zones map of irrigated lands.

As a result, the areas of irrigated land in the regions of the Amudarya river basin were determined overall IX hydromodular zones, and electronic maps were developed by the regions. Based on the study, 7.2 % of the irrigated land in the regions of the Amudarya river basin belongs to I, 9.1 % to II, 6.3 % to III, 13.3 % to IV, 7.2 % to V, 8.3 % to VI, 17.1 % to VII, 16.4 % to VIII and 15.1 % to IX were found. (Fig. 6).

4 CONCLUSIONS

The purpose of hydromodular zoning of irrigated lands is to divide the territory into taxonomic units, to use land and water resources efficiently, to use scientifically based irrigation regimes, and to obtain high yields from crops. Hydromodular zoning is a part of the soil-melioration zone, soil thickness, mechanical composition, location in the aeration zone, water-physical properties and the location of the groundwater level, irrigation regime, standards and hydromodular ordinate. As a result of this study, a mechanism for dividing the water demand of irrigated agricultural arable land into regions based on the mechanical composition of the soil and the depth of the seepage water level was developed. Hydromodular zoning irrigation channel calculations and water use planning and management system have been improved. All irrigation and watering norms, the period between waterings, that is, hydromodular laws, were set for irrigation with sawing. As a result of research, it was systematized that if the mechanical structure of the soil is light and the groundwater is deep, the irrigation rate should be set higher, and the watering rate should be small, but more numerous (watering period is extended).

GIS technologies can provide an opportunity to create large-scale electronic digital irrigation maps of all regions of our republic, to enter the results of periodic field research into this digital map, and to create a hydromodular zoning map of the region based on valid data. In the regions of the Amudarya River basin of the Republic of Uzbekistan, hydromodular zoning maps for the coverage of districts were created in full digital form.

5 FUNDING

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