Determination of irrigation regimes based on geospatial technologies in water scarcity areas

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Abstract. In the case of increasing water scarcity, determining the water demand of irrigated land is an important process. The water demand for irrigated lands and crops in the Republic of Uzbekistan is realized through nine hydromodular zones, which were developed regarding Bespolov's methodology in the 1980s. However, in order to determine the water regime in each crop field, it is necessary to create electronic hydromodular zoning maps based on GIS technologies. This study uses GIS technology to create electronic hydromodular zoning maps of the irrigated fields in the Bukhara region of Uzbekistan while considering the mechanical properties of the soils and groundwater levels. Soil mechanical composition of the agricultural land's geodatabase was created and mapped with three categories of soils: light, medium and heavy. Annually obtained data from observation wells was analysed to determine the distribution of groundwater level by Inverse Distance Weighting (IDW) interpolation method referenced detected coordinate values. The raster calculator function of ArcGIS is used to identify the distribution of hydro module zones by definite criteria of soil and groundwater level. As a result, hydromodular zoning maps of irrigated agricultural lands of the Bukhara region were created for the first time in electronic form.

1 Introduction

Irrigation norms, irrigation schemes and irrigation periods for each crop type are determined according to hydromodular zones [1-4]. The soil-ameliorative area, or hydromodular zoning (HMZ), is defined by the proximity of soil thickness, mechanical composition, the aeration zone, water-physical properties, groundwater levels, order, norms, and hydromodular ordinate of irrigation of agricultural crops generally [5-10]. Determining hydromodular zoning (HMZ) of irrigated lands in the Republic of Uzbekistan was developed in 1982 [11-13] and To calculate crop water use and water usage plans, this outdated and imprecise information is still employed. HMZ was classified into nine important zones, accounting for climate, soil mechanical structure, and groundwater depth [14-16].

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However, during the last two decades, using water resources in the republic has changed radically. The demand on the irrigation and collector-drainage networks has significantly grown as a result of the continued usage of the cotton-winter wheat rotation system. In this case, the groundwater level was shifted and affected the process of soil formation in the regions, and an increase in hydromorphic soils is observed in the irrigated areas [14, 15].

In order to address the distribution of irrigated lands via electronic hydromodular zones map, research was conducted in this study with the goal of changing the hydromodular zoning of irrigated lands that was designed in the 1980s. In light of the country's developing water deficit, scientific research using contemporary technology like GIS presents prospects for the effective use of water resources. [15- 18].

2 Materials and methods

2.1 Study area

This study was carried out on irrigated land in the Bukhara region. Bukhara region is located in the southern part of the Republic of Uzbekistan, the following characteristics best describe its climate: temperature total of 4150–4250 from April 1–October 1; vegetation period of 235–245 days; average annual air temperature of 14.5–20.5; The average air temperature in July ranges from 30.3 to 33.4. Strong evaporation occurs in the area, reaching 1750–2050 mm annually. This demonstrates that the air temperature is high enough outside of the vegetative season [18].

The region is actively involved in agricultural production growing mainly cotton, wheat, corn, poly and vegetables on irrigated lands. It has 273.7 thousand hectares of irrigated land, 14.2 thousand hectares of wasteland and 2764.6 thousand hectares of desert pastures (Figure 1).

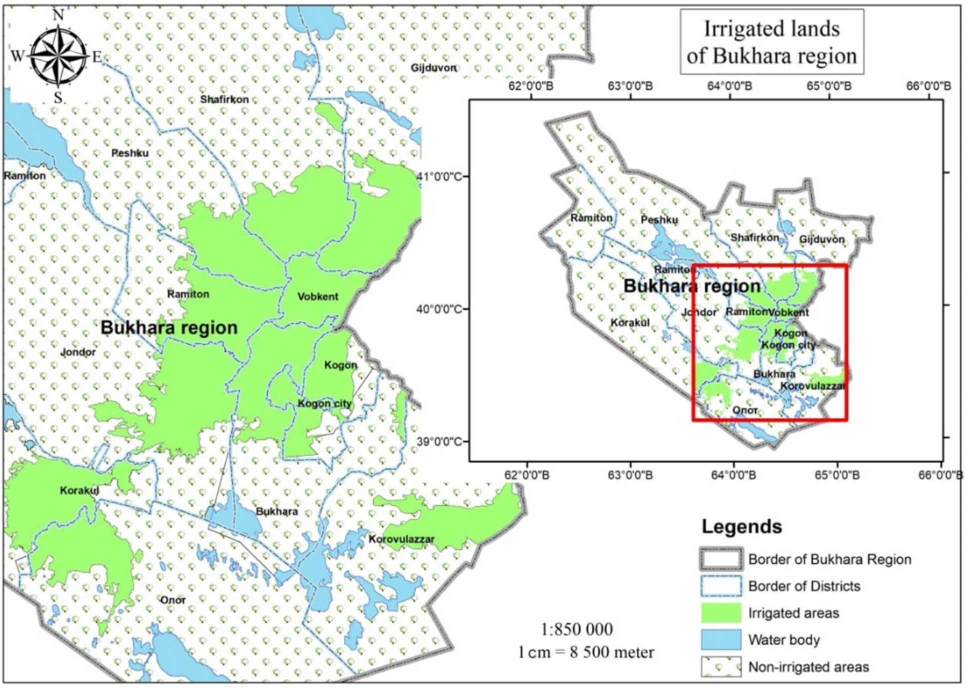

Fig. 1. Study area.

2.2 Research methodology

According to Bespalov's [1] technique, the soil-forming is divided into 9 hydromodular zones in the irrigated area based on the lithological composition of the rock and its relationship to the level of groundwater. A description of each zone is provided in Table 1 [6, 7].

Table 1. Classification of Hydromodular Zones.

Hydromodular zone number	**Soil condition**	**Groundwater level, m**
Automorphic soils		
I	Sand-gravel surfaces with low-layer and thick-layer sand	> 3.0
II	Sand-gravel over a medium-layering of thick and light sand	> 3.0
III	Muddy and medium-heavy, thick sand	> 3.0
Semi-automorphic soils		
IV	Sand, clay, and layers of differing thicknesses of sand	2.0 – 3.0
V	Sand that is light and medium in weight, heavy in one layer, and lightening	2.0 – 3.0
VI	Layers of heavy sand, mud, and varied mechanical compositions with the same layer between them	2.0 – 3.0
Hydromorphic soils		
VII	Low to medium thickness layers consisting of sandy and loamy sand and clay	1. 0 – 2. 0
VIII	strong sand that loosens up, single-layer sand, and light to medium sand	1. 0 – 2. 0
I X	the same layer of heavy sand and clay with a distinct mechanical composition	1. 0 – 2. 0

Areas with deep groundwater levels have good flow and are not involved in the process of soil formation. Areas with groundwater that is closer to the surface have good flow from the outside but are difficult to drain; these areas are involved in the process of soil formation. Areas with shallow groundwater levels that fluctuate based on the local environment have difficult flow and draining from the outside [1, 19, 20].

Currently, there are no digital maps for determining the irrigation regime on the basis of hydromodular zoning maps in Uzbekistan [3]. Within the framework of this research, using modern GIS technologies electronic hydromodular zoning map of the Bukhara region was developed.

Based on information from local reclamation expeditions, the groundwater level in the aeration layer of irrigated farms in the Bukhara region was examined [14, 15]. In this instance, the map of the administrative-territorial unit's boundaries (scale 1: 50000) in the area's districts and the expedition's included observation wells were used. The exact geographic location of all observation wells was determined by the GNSS receiver and entered into the database of ArcGIS software in vector form in order to visualize the distribution of observation wells (Figure 2).

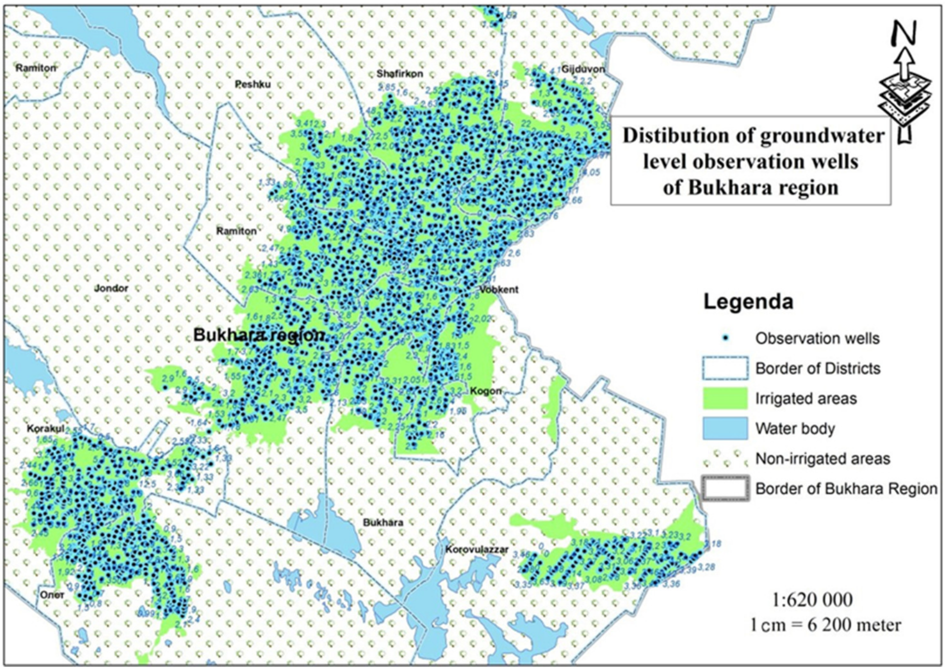

Fig. 2. Distribution of observation wells in irrigated lands of the Bukhara region

Based on the annual average groundwater level data from observation wells gathered by the reclamation expedition was analysed by the IDW interpolation algorithm of ArcGIS software. As a result, the distribution of groundwater level through the irrigated area was geovisualized (Figure 3).

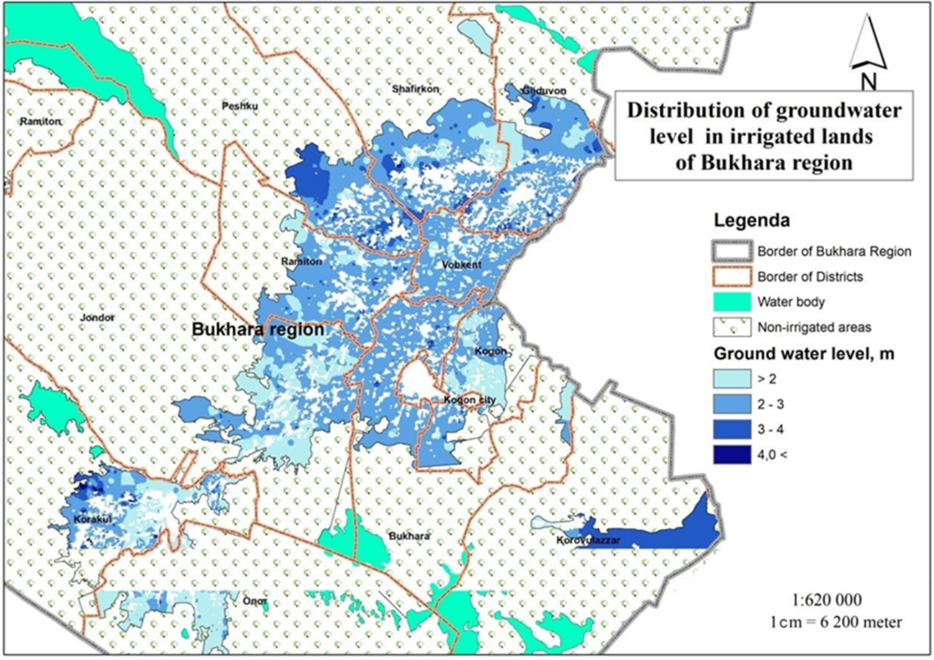

Fig. 3. Groundwater level distribution in irrigated lands of Bukhara region

Soil mechanical composition of the agricultural land's geodatabase was created and mapped with three categories of soils: light, medium and heavy (Figure 4). In this study, it is necessary to rasterize the mechanical composition of soils with a vector appearance in order to conduct a critical analysis of the theme layers. This was accomplished by utilizing the command to convert (export) vector layers with a field view to a raster format unit in the ArcToolbox panel.

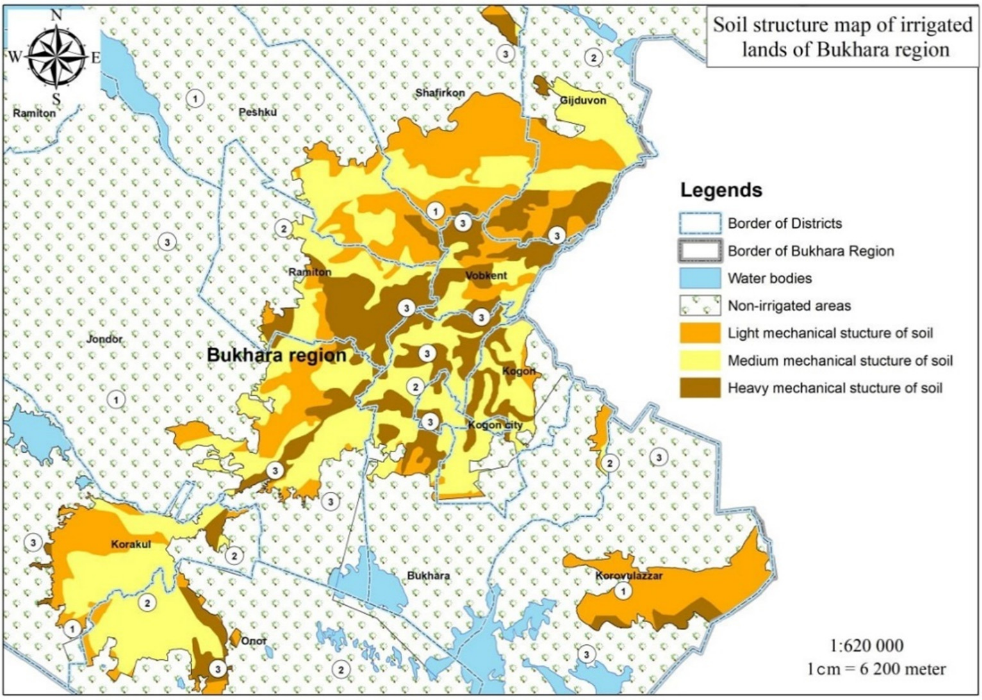

Fig. 4. Soil mechanical structure distribution in irrigated lands of Bukhara region

3 Results and discussion

After the aforementioned procedures are finished, a hydromodular -zoning map can be made. In this instance, the distribution of hydromodul zones was determined by specific parameters for soil and groundwater levels using ArcGIS's raster calculator function. HMZ standards were created using the "If condition" process. A new themed raster-shaped layer is created as a result of the raster computation. Hydromodular zones are used to visualize the raster layer that is created on demand according to the conditions.

The Arc Toolbox panel is used to vectorise the raster-shaped layers on the hydromodular zoning. Thematic layers are conditionally marked and cleared in accordance with state standards and are rendered in vector form (Figure 5).

As a result of this study, statistical report of irrigated lands of Bukhara region about 9 hydromodular zones: I, II, III, IV, V, VI, VII, VIII and IX by districts. (Table 2).

It can be seen from Table 2 that the distribution of hydromodular zones across districts of the Bukhara region is different, and the largest areas are belonging to 4 (23.96%), 5 (16.68%) and 6 (14.62%) contrariwise, the least amount is 3 (1.52%), 8 (7.9) and 9 (4.35%) hydromodular zones.

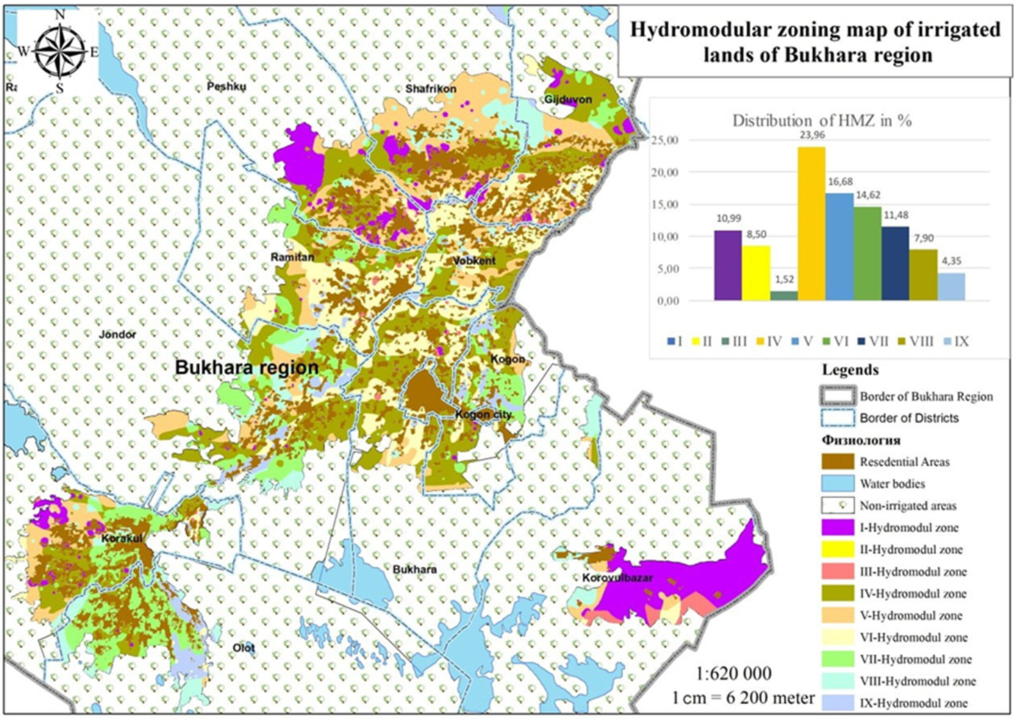

Fig. 5. Hydromodul zones map of irrigated lands of Bukhara region

Table 2. Distribution of hydromodul zones of irrigated lands of Bukhara region by districts, %

№	Districts	I	II	III	IV	V	VI	VII	VIII	IX
1	Bukhara	0.56	0.00	1.11	43.67	5.89	40.03	1.36	5.64	1.74
2	Vopkent	0.56	0.53	0.76	29.62	16.76	43.68	1.92	1.89	4.28
3	Gizjduvan	6.87	2.21	2.42	33.26	21.63	17.05	6.10	9.41	1.05
4	Jondor	0.44	0.13	0.00	31.90	14.35	7.34	23.00	15.04	7.79
5	Kogon	0.63	0.00	0.10	42.22	8.80	13.95	21.59	0.70	12.01
6	Korakul	9.34	7.60	0.46	24.82	23.85	4.23	21.58	7.37	0.74
7	Karoulbazar	42.10	42.10	6.51	0.00	4.33	1.71	0.00	3.25	0.00
8	Olot	0.24	0.00	0.00	10.06	0.83	1.68	45.87	22.68	18.65
9	Peshku	29.41	11.68	0.59	26.77	24.26	3.75	2.00	1.43	0.10
10	Romiton	0.48	0.12	1.38	24.44	13.63	41.22	13.83	1.61	3.29
11	Shofirkon	8.69	5.79	0.02	12.56	48.68	1.63	1.89	15.73	5.00
	Total	**10.99**	**8.50**	**1.52**	**23.96**	**16.68**	**14.62**	**11.48**	**7.90**	**4.35**

In addition, it is clearly seen from Figure 5 and Table 2, except for Karoulbazar and Olot districts, there are 9 hydromodular zones in all districts of the region. The VII, VIII and IX hydromodular regions mainly corresponded to the share Jondor, Korakul, Kogon and Alot districts.

In general, the increase in the area occupied by the VIIth, VIIIth and IXth hydromodular zones has a high impact on the change in the irrigation norm of agricultural crops. At the same time, these indicators also describe the deterioration of the reclamation condition of agricultural lands.

4 Conclusions

Hydromodular zones I, II and III, belonging to the automorphic soils of the Bukhara region, where the groundwater level is deeper than 3.0 meters, cover 80,447.47 thousand hectares or 21% of the total irrigated area. Semi-automorphic soils, ie IV, V and VI hydromodular areas with a groundwater level of 2.0-3.0 meters, cover 211709.28 thousand hectares or 55.26% of the total irrigated area. The remaining 90947.8 thousand hectares or 23.74% of irrigated lands belong to hydromodular regions VII, VIII and IX with a groundwater level of 1.0-2.0 meters (hydromorphic soils). This means, the creation of electronic hydromodular zoning maps of irrigated lands, allows to make quick decisions on the efficient use of water resources and their rational management. The use of geoinformation systems technology (GIS) in agriculture and water management allows for solving many problems quickly.

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