# Spatial analysis in decision-making on agriculture activities

*Mamanbek* Reimov[1], *Zokhid* Mamatkulov[1*], *Utkir* Shermanov[2], *Rustam Oymatov*[1], *Akbarjon* Khamraliev[1] and *Bayram* Abdurashitov[1]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, 39 Koriy Niyoziy str., 100000, Tashkent, Uzbekistan
[2]Department of Digital Development under Tashkent City Government, Tashkent, Uzbekistan

**Abstract.** Geoinformation technologies (GIS) play an important role in precision agriculture and the organization of smart agriculture. This can impact deeply the analysis of the state of agricultural lands, mainly irrigated lands, and find a positive solution to the problem based on digital data consisting of different thematic layers. In this research, spatial analysis of agro-ecological conditions was carried out in order to establish effective precision agriculture in the Pakhtazor massive of the Mirzachul district of the Jizzakh region. Representing agro-ecological (soil, climate, groundwater, weather) and social (population, settlements, roads for transport) factors that directly affect the efficient production in agriculture through geospatial analysis and thematic maps were developed. In the process of creating thematic maps and analysing the data, spatial analyses such as IDW, Euclidean distance, and Kernel density were performed using ArcGIS software. As a result of spatial analysis, soil quality was assessed with an average value. Groundwater level and mineralization were in normal condition with 2-2.5 meters and 0-3 gr/l respectively. Infrastructure, irrigation-drainage system, and weather are sufficient to carry out effective agricultural activities, especially crop cultivation.

## 1 Introduction

Today, there is a growing concern for government agencies about the need to provide the food resources needed to support sustainable population growth. It is projected that current crop production should double by 2050 to meet future food needs [1]. For such purposes, GIS can help to predict and plan the amount of arable land needed to provide food to the future population. GIS is a tool that creates visual representations of data and performs spatial analysis to make informed decisions [2]. It is a technology that combines hardware, software, and data. If the data has a geographical component, it can represent almost anything imaginable [3].

More sophisticated spatial analyzes for agriculture can compare variables such as soil type, wind direction, rainfall, slope, aspect, topography, or elevation, which can be used to manage crops, plot suitability, and drainage, as well as flood control, helps prevent the risk of drought and floods [4, 5]. GIS helps the farmer to adapt to these different variables,

*Corresponding author: zohid3095@gmail.com

monitor the health of individual crops, evaluate yields from a particular field, and maximize yields [6]. GIS has become an increasingly valuable resource by helping farmers increase production, reduce costs, and provide effective tools for land resource management [7].
Precision agriculture is very important in making various decisions on crop fields. Precision agriculture gained popularity when it realized that different land plots had different characteristics. Large plots of land usually have spatial variations in soil types, moisture content, nutrient availability, and so on [8]. Therefore, using geographic information system technologies will help farmers use more valuable resources, such as fertilizers, pesticides, and herbicides, and more efficiently use water resources. In this research, the agro-ecological and social conditions of the study area will be analysed based on GIS technologies in order to gain complex data on the study area. Through these results, scientific recommendations will be obtained on the creation of digital agriculture and its use for various agricultural purposes.

## 2 Materials and methods

### 2.1 Study area

In this research, spatial analysis was conducted in order to geospatial analyse agro-ecological and social conditions on effectively organized agriculture in the Pakhtazor massive of the Mirzachul district of Jizzakh region of the Republic of Uzbekistan. Mirzachul district is located at a longitude of $68^0 10'$ and latitude of $40^0 30'$ [9]. It is bordered from the north and northeast by the southern regions of the Republic of Kazakhstan, and from the northwest bordered by a large artificial lake – Aydarkul (Uzbekistan) (Figure 1). The Pakhtazor massive is one of the main agricultural producers in the Jizzakh region, which has good conditions for growing cotton, wheat, melons, fruits, and vegetables due to its favourable latitude, relief, and climate. The average annual temperature is around 14-18 $^0$C and mean precipitation is about 0.6-1 mm [10]. The relief is almost flat. The main income of the population is derived from the production of agricultural products.

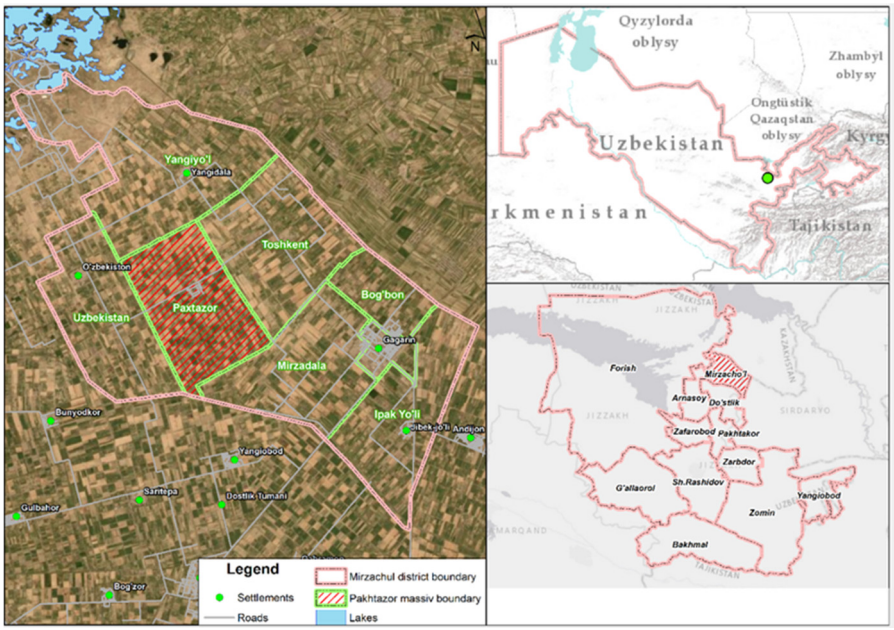


**Fig. 1.** Study area.

## 2.2 Research methodology

A total of 14 types of data on soil, irrigation, groundwater, climate, roads, and population were collected for geospatial analysis to assess the agroecological and social condition of agriculture in the Pakhtazor massive. Since the data were made using materials from various organizations and research institutes, their full description is shown in Table 1.

**Table 1.** List of collected data and their transformation.

| № | Agro-ecologic conditions | Source | Results |
|---|---|---|---|
| 1. | Soil salinity | Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan | GIS Map |
| 2. | Humus level in soil | Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan | GIS Map |
| 3. | Active potassium in soil | Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan | GIS Map |
| 4. | Active phosphorus in soil | Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan | GIS Map |
| 5. | Soil bonitation | Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan | GIS Map |
| 6. | The mechanical structure of soil | Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan | GIS Map |
| 7. | Groundwater level | Ministry of Water Resources, Uzbekistan | GIS Map |
| 8. | Groundwater mineralization | Ministry of Water Resources, Uzbekistan | GIS Map |

| | | | |
|---|---|---|---|
| 9. | Irrigation system network | Ministry of Water Resources, Uzbekistan | GIS Map |
| 10. | Drainage system network | Ministry of Water Resources, Uzbekistan | GIS Map |
| 11. | Annual temperature | UZHYDROMET, Uzbekistan | Diagram |
| 12. | Annual precipitation | UZHYDROMET, Uzbekistan | Diagram |
| **№** | **Social criteria:** | **Source** | **Results** |
| 13. | Distance allocation from agricultural lands | Cadaster agency, Uzbekistan | GIS Map |
| 14. | Road system network | Cadaster agency, Uzbekistan | GIS Map |

***Soil.***

Soil is the main factor of production in agriculture. Studying soil conditions and the practical application of agro-technical, agro-and hydro-ameliorative measures that meet the requirements of the biological characteristics of the crops is very important [11]. Most technical crops require highly productive soils. Loamy and silt and soils with high calcium carbonate are best for crop cultivation. In addition, fertile soil with high water retention capacity is ideal for all types of crops. Highly saline and drought soils are extremely not suitable for crop development [12]. The IDW algorithm of the ArcGIS program was used in the spatial analysis of the condition of the soils in the area of the Pakhtazor massive.

***Groundwater condition.***

The critical level and mineralization of groundwater are very vital agroecological parameters for crop development and other agricultural activities [13]. Roots of crops go down deeper through the soil during the development period. Most crops have no tolerance to the high groundwater table and its mineralization [14]. When the groundwater level is close to the land surface, the oxygen transport regime changes and the root system of crops damage worse. A high level of mineralization (salinity) of groundwater has a negative effect on soil conditions and the development of crops. Usually, it leads to highly saline soil and poor yield of the crop [15]. The IDW interpolation algorithm of the ArcGIS program was used for spatial analysis and mapping of groundwater status in irrigated lands in the Pakhtazor massive.

***Irrigation/drainage network***

Almost, all crop types perform best in effortless watering lands with reasonable drainage systems. Water supply on time provides a high amount of harvest [16]. Drainage networks help to supply favorable nutrients, moisture, heat, and balanced groundwater and air regimes for crop roots. As cotton and vegetables are very susceptible to waterlogged conditions, areas with poor drainage should be prevented [17]. In this research, the Kernel density algorithm was used to visualize and map in order to analyze the distribution of the irrigation/drainage network.

***Climate***

Geographically, Uzbekistan is located in a hot area. It helps to cultivate hot lover crops such as cotton and fruits [18]. The mean (optimal) temperature for growing and developing for main crops is 20-35$^0$C during the vegetation period. When the temperature drops to 17$^0$C, the development of summer crops slows down. Precipitation also plays a vital role in certain development of agricultural crops [19]. Winter wheat and some vegetables require the necessary amount of precipitation during late autumn, winter, and early spring [20].

***Population***

Human labor is very high in the care of the main types of agricultural crops grown in Uzbekistan. People who are able to work in the fields are used to taking care of the crop in case of cultivating and gathering harvest [21]. In areas where unemployment is high, planting labor-intensive crops will reduce unemployment and create better living conditions for certain populations [22]. However, most part of agricultural areas is far away from residential areas and it can be difficult commuting for local people [23]. This kind of inland plot is recommended for planting crops that require less manpower. Concerning determining far irrigated land plots from residential areas spatial analysis was carried out by the Euclidean distance algorithm.

***Roads (infrastructure)***

Accelerated development of agriculture, effective agro-technical measures in the fields, as well as the implementation of such processes as planting and harvesting, are required [24]. One of the main factors is to create conditions for easy access of vehicles to each field and easy access of people to the fields. In order to determine the distribution of roads in areas spatial analysis was carried out by the Euclidean distance algorithm.

## 3 Results and discussion

By spatial analysis of soil condition, maps of soil condition soil bonitation Figure 2a, active potassium in the soil Figure 2b, humus level in soil Figure 2c, active phosphorus in the soil Figure 2d, soil salinity Figure 3a, and mechanical structure of soil Figure 3b are developed.


**Fig. 2.** Visualization of agroecological conditions (a - soil bonitation, b - active potassium in the soil, c- humus level in soil, d - active phosphorus in the soil).

The groundwater condition was analyzed based on the annual data which were obtained from observation wells in irrigated areas of Pakhtazor massive and groundwater mineralization Figure 3c and ground water level Figure 3d.

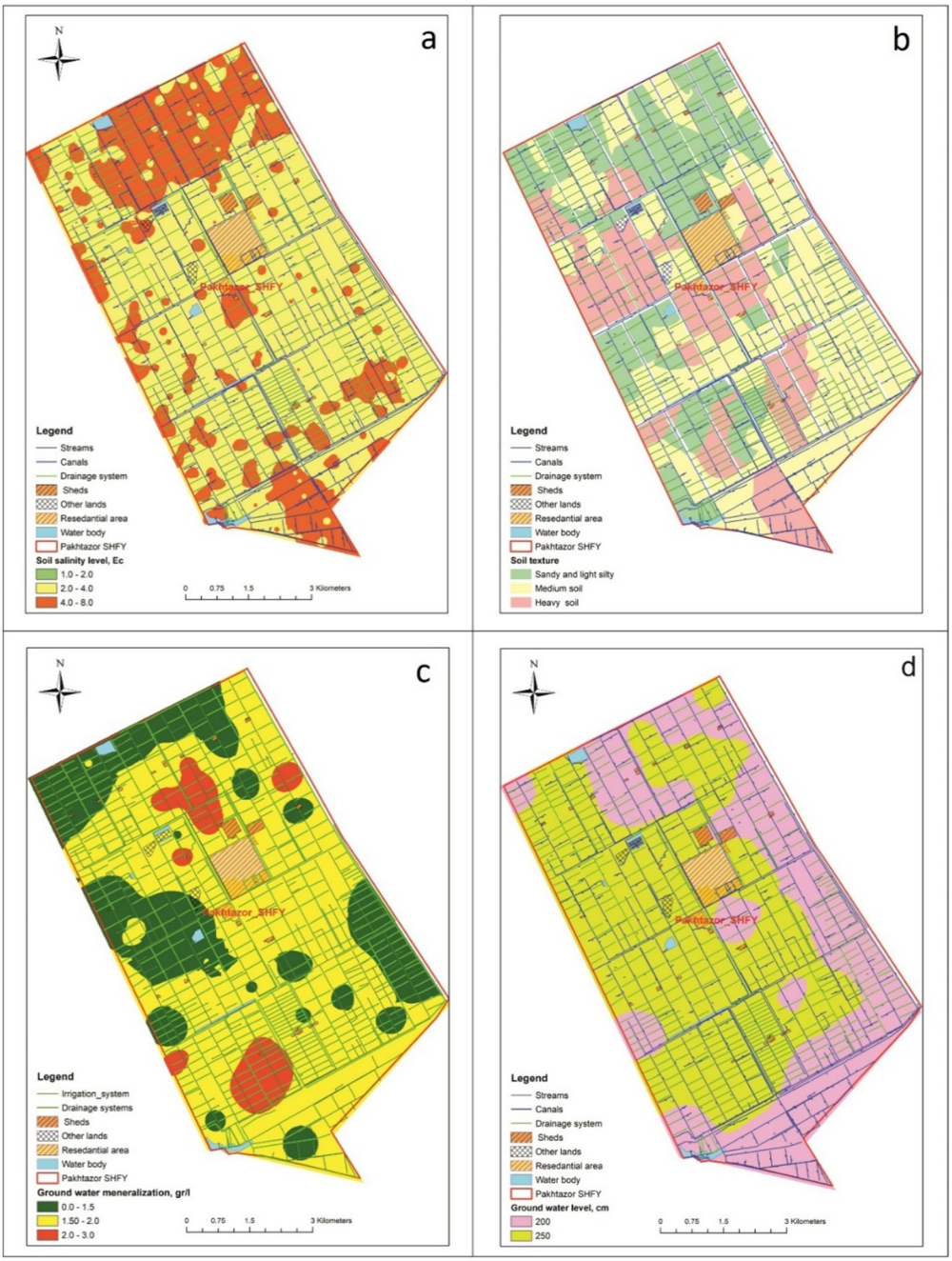


**Fig. 3.** Visualization of agro-ecological conditions (a - soil salinity, b - mechanical structure of soil, c- groundwater mineralization, d – ground water level).

The condition of irrigation (Figure 4a), drainage (Figure 4b), and road (Figure 4c) systems were analyzed through spatial analysis, and maps of their distribution in the

massive were created. Spatial analysis of the distance of settlements from agricultural lands was carried out and a thematic map in Figure 4d of the massive was developed.

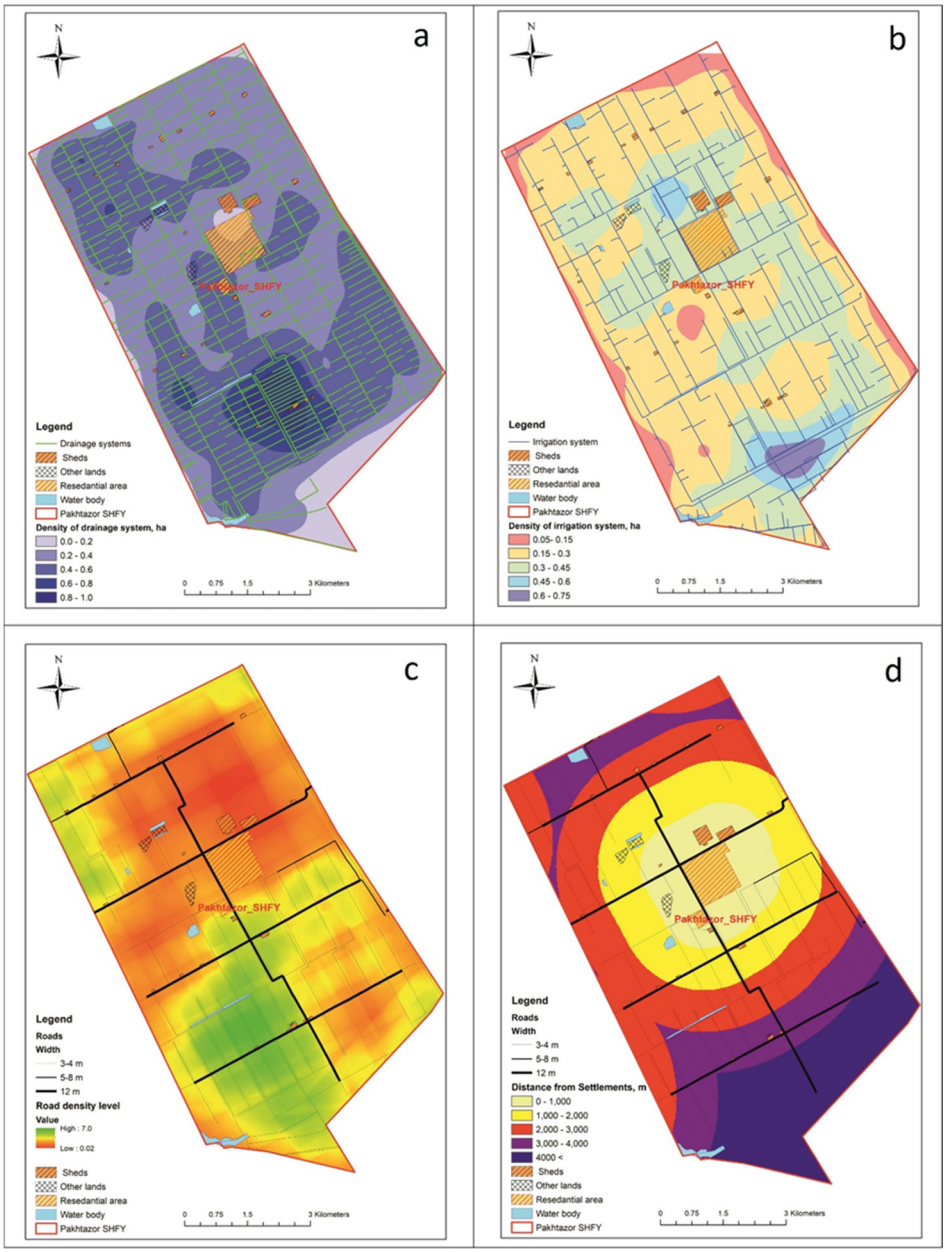


**Fig. 4.** Visualization of agro-ecological and social conditions (a – density of drainage system, d – density of irrigation system, c- road density, d – a distance of agricultural lands to settlements).

Analyzing long term (1990-2020) climate condition of the Mirzachul district showed that, the mean annual precipitation in Figure 5 is between 0.6 – 1 mm/day. The mean annual temperature in Figure 6 is about 14-16$^0$C.

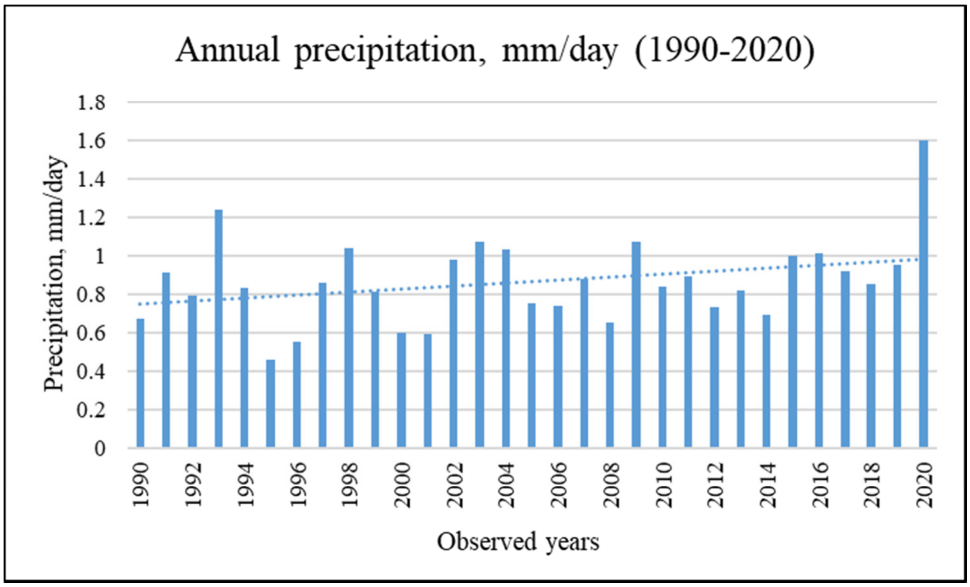


**Fig. 5.** Annual precipitation, mm/day (1990-2020).

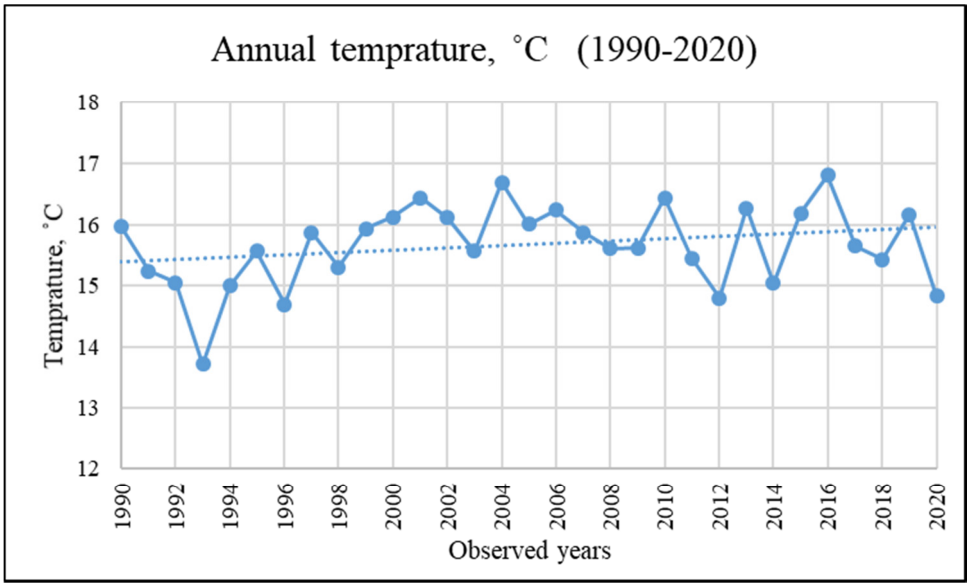


**Fig. 6.** Annual temperature, ˚C (1990-2020).

According to the results of all spatial analyses of the Pakhtazor massive, the following conclusions were drawn:

- most of the factors determining soil quality in the massive are moderate to average with 50-60 points of soil bonitation (Figure 2a);

- groundwater levels and mineralization are normal in most parts of the massive with 2-2.5 meters and 0-3 gr/l respectively (Figures 3c and 3d);
- irrigation and drainage networks are adequately provided mostly in the southern part of the massive (Figures 4i and 4j);
- there is a well-established network of transport and public roads to the fields (Figure 4c);
- 30-35% of the irrigated agricultural land in the massive is located 3 km or more from settlements (Figure 4d);
- the massive has enough temperature and rainfall needed to grow main crop types.

To date, many scientists [25-29] have carried out research on the determination of agricultural land productivity and land suitability assessment for crop types and decision-making through geospatial analysis of the agroecological condition of agricultural land, and excellent results have been achieved. This scientific study was carried out through GIS spatial analysis methods and statistical analysis without denying the scientific results of other scientists. Because, in this research, data regarding groundwater and soil are variable, and these data change during the seasons and years. However, the conditions of infrastructure and collector-drainage networks can maintain their stable state for many years. Considering the above, the information obtained as a result of the conducted research was relative.

## 4 Conclusions

It should be noted that GIS plays an important role in the decision-making process in agriculture. GIS is one of the important tools of information technology that is very suitable for agriculture. This technology integrates with spatial databases and socio-economic variables such as soil, hydrology, weather, etc., allowing for a wider range of verification and processing. Simultaneous examination of these variables leads to a better understanding of the various processes associated with agriculture and their interactions in space and time. This leads to an accurate description of resources and, from time to time, the identification of relevant domains focused on new technologies. Spatial analysis of agroecological and social conditions through GIS databases is currently one of the areas of active research on agriculture.

## Acknowledgement

Acknowledgement to United Nations Food and Agriculture Organization of the United Nations, as these results of the scientific article are results of the FAO-financed project "GIS tools and spatial data for more productive and SMART farming". Acknowledgement to Mr. Sherzod Umarov, Assistant Food and Agriculture Organization of the United Nations (FAO) Representative in Uzbekistan.

## References

1 M. Khamidov and B. Matyakubov *Cotton Irrigation Regime and Water Saver Technologies* Tashkent (2019)

2 M. Khamidov, A. Inamov, U. Islomov, Z. Mamatkulov. *E3S Web of Conferences*, **365**, 01008. (2023)

3 B.S. Matyakubov, Z.J. Mamatkulov, R.K. Oymatov, U.N. Komilov, G.E. Eshchanova. *Materials of International Conference "InterCArto, InterGIS"* **26 (3)** (2020)

4 B. Saipova, Z. Mamatkulov, A. Altiev, M. Rajapbaev, K. Bekzod. *AIP Conference Proceedings*, 2432(1), 040038 (2022)

5 K. Khasanov, A. Ahmedov. *E3S Web of Conferences*. **264** 03058 (2021)

6 A. Teshome, A. Halefom. *Model Earth Syst Environ*. (2020)

7 Z. Mamatkulov, E. Safarov, R. Oymatov, I. Abdurahmanov, M. Rajapbaev. *E3S Web Conf.* **227** (2021)

8 M.K. Khamidov, D. Balla, A.M. Hamidov, U.A. Juraev. *IOP Conference Series: Earth and Environmental Science*, **422 (1)**, 012121 (2020)

9 R.K. Oymatov, Z.J. Mamatkulov, M. P Reimov, R. I. Makhsudov, R.N. Jaksibaev *IOP Conf. Ser.: Earth Environ.* Sci. **868,** 012074 (2021)

10 M.V. Wojtaszek, L. Ronczyk, Z. Mamatkulov, M. Reimov. *E3S Web of Conferences*, **227**, 01001 (2021)

11 H. Akıncı, A.Y. Özalp, B. Turgut. Comp Electro Agric 97 (2013)

12 S.A. Azimboyev. *Farming, Soil and Agro-Chemical Science*. Tashkent (2006)

13 R.Q. Kuziev, G.Yu. Yuldashev, I.A. Akramov. *Soil bonitation*. Tashkent (2003)

14 F.A. Baraev, S.A. Kasimbetova, N.M. Karimova, G. Axmedjanova, A.B. Mamasoliev, N.O. Shaymanov Forecasting crop yields during land reclamation. Tashkent (2010)

15 S. Bandyopadhyay, R.K. Jaiswal, V.S. Hegde, V.Jayaraman. Inter. Jour. of Remote Sens. 30(4) (2009)

16 T. Sh. Beisenboyev, N.F. Bespalov. *Salinization Dynamics of Irrigated Soils and Cotton Productivity*.Tashkent (1993)

17 Kh. M. Makhsudov, L. A. Gafurova. Erosion studies Tashkent (2012)

18 L.E. Clark, T.R. Moore, J.L. Barnett. Journal of Production Agriculture **9(1)** (2013)

19 *Livestock in Uzbekistan: current state, problems and development prospects*. UNDP Publishing (2009)

20 *Agricultural policy in wheat production and diversification of crop production in Uzbekistan.* Country report on AGRIWANET project (2016)

21 *Farm Restructuring in Uzbekistan: How Did It Go and What is Next?* ASA Support to Agricultural Modernization in Uzbekistan (2019)

22 Detailed Sector Assessment: Agriculture, Natural Resources, and Rural Development.

23 D. Rosa, R. Sobral. *Soil quality and methods for its assessment* Land Use Soil Res. (2008)

24 *The data collection survey on agriculture sector in Republic of Uzbekistan.* Japan International Cooperation Agency (JICA) (2017)

25 M. Moshia, M. Mashatola, P. Shaker, P. Fouché, M. Boshomane. Journal of Agriculture and Social Research (2009)

26 A. Ramlan, S. Baja, S. Arif, R. Neswati. *IOP Conference Series: Earth and Environmental Science* **157(1)** (2018)

27 M.K. Boitt, C.N. Mundia and P.K. Pellikka Journal of Agricultural Informatics **6(2)** (2015)

28 Z. Mamatkulov, K. Abdivaitov, S. Hennig, E. Safarov Inter. Jour.of Geoinformatics. **18(1).** 2022

29 A. Babajanov, R. Abdiramanov, I. Abdurahmanov, U. Islomov. *E3S Web Conf.* **227** (2021)