Application of geographic information system technologies in soil fertility modeling

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Abstract: *The article deals with problems of development of soil fertility models on the example of irrigated serozem-meadow and meadowsoils of Syrdarya region. In particular, the main blocks of soil fertility models are described: agroecology, soil mechanical content, a block of agrophysical properties, a block of agrochemical properties, a block of salinization of soils and a block of agglomelioration. The possibility of using modern geoinformation technologies in the field of soil fertility models development has been studied.*

Key Words: *Soil fertility model, geoinformation systems, spatial data, digital maps, agroecology, soil mechanical composition, agrophysics, agrochemical properties, type and degree of soil salinization.*

1. INTRODUCTION:

Land resources represent the basis of integrity and the basis of development of any state. In Uzbekistan, full and comprehensive knowledge of land resources has always been recognized as important. The lack of modern information support deprives the bodies of state and municipal management of the ability to form a real, objectively and regionally differentiated tactics and strategy for the development of economically viable, socially acceptable and ecologically permissible use of the country's soil resources adequate to modern economic tasks. These requirements are among the main criteria for sustainable development of agriculture, which are adopted by the main for the country in the foreseeable future in the 21st century.

Thus, the course of development of soil science predetermines the need to develop new approaches to the analysis of soil resources in Uzbekistan. One of the promising approaches is the introduction of geoinformation technologies for the inventory of soil and resource data, their storage and scientific and applied analysis, which predetermines the relevance of the research topic. At the same time, the rapid introduction of geoinformation technologies into scientific research in recent decades has created a basis for the development of new methods of inventory, modeling of soil and resource information, as well as its subsequent applied analysis.

For development of agricultural production in the Syrdaryo region main objective is determine the appropriate fertile soils for cultivating the main agricultural crops in Uzbekistan and yields of the crops in different individual soils. For successful solution of the task, soil surveys of the Syrdaryo region are of great importance in order to clarify the areas of soil for agricultural crops, the development of a set of measures to improve soil fertility. All this is to some extent determined by the development of GIS models of soil fertility. This field of research has a very great theoretical and practical significance.

By geoinformation modeling is meant a method based on the construction and use of models of spatial objects, their interrelationships and the dynamics of processes using GIS. This method belongs to the group of methods of information modeling and is based on the theory of information systems.

In geoinformation modeling, the most important concepts are the data model and the analysis algorithm. A data model is a set of principles for organizing data; a mathematical construction for the representation of geographic objects or fields, and under the data analysis algorithm a logically conditioned sequence of program actions in order to obtain a definite result. The data model itself determines the methods of analysis.

2. MATERIALS AND METHODS:

Syrdarya region of the Republic of Uzbekistan is located at 39°30 and 41°20 north (longtitude) and 66°30' east (latitude). This region is bordered with the Republic of Kazakstan in the North, in the East with Tashkent region, in the South and South-East with the Republic of Tadjikistan, in the West with Samarkand region and in the North-East with Navoiy regions. Its highest mountains are the Turkistan and Nurota; rivers: Syrdarya, Sangzor, Zominsuv. The lowest point is the lake Tuzkhona – absolute height is 230 m above the sea level, the highest point is Mount Bozorhon in the Turkistan mountain chain with 3401 m height.

In common, the climate of the Mirzachul steppe is continental and subtropical. The average annual weather temperature of the region is among +12.9 and + 14.90 C. Relative air humidity is not high, June-August are the driest season of a year, and yearly average air humidity is about 31-48%. Increase of weather temperature in the summer causes more evaporation, and the amount of evaporation is rather more than the yearly average amount of atmospheric precipitation. This condition of nature causes to soil salinity and increase water demand of plants.

The object of the study was the irrigated serozem-meadow and meadow soils common in the Syrdaryo region. The research were carried out on field and laboratory conditions, physical and chemical analyzes were carried out on the basis of generally accepted methodological instructions in soil science [1, 2, 3, 4].

The research on the creation of a fertility model of irrigated serozem-meadow soils are based on the methodological recommendations of L.L. Shishov [5]; L.L. Shishov, I.I. Karmanov, D.N. Durmanov [6]; D.N.Durmanov, D.S. Bulgakova, A.S. Frid [7]; G.Sh. Mamedov [8].

All operations for creating a digital map, correcting it, making approximations and interpolations of data, and their geo-information analysis, were carried out in the environment of the computer system ArcGIS Desktop version 10.3, developed by ESRI (USA) - Environmental Systems Research Institute. For this purpose Geostatistical Analyst, 3D Analyst, Surface Analyst, and Model Builder modules and add-ons of this software were used.

3. RESULTS:

In the object of the study, environmental conditions, physical, chemical properties, soil productivity were comprehensively analyzed. Here, based on the results of the study, a conceptual model of fertility for irrigated serozem-meadow and meadow soils of the Syrdarya region was created. (Fig 1.).

According to our developments in the Syrdarya region, the conceptual model of soil fertility consists of six blocks, which differ in their significance in the management of soil fertility. The conceptual models of soil fertility have of a number of blocks: agroecology, mechanical content, agrophysics, agrochemistry, soil salinity, agromelioration.

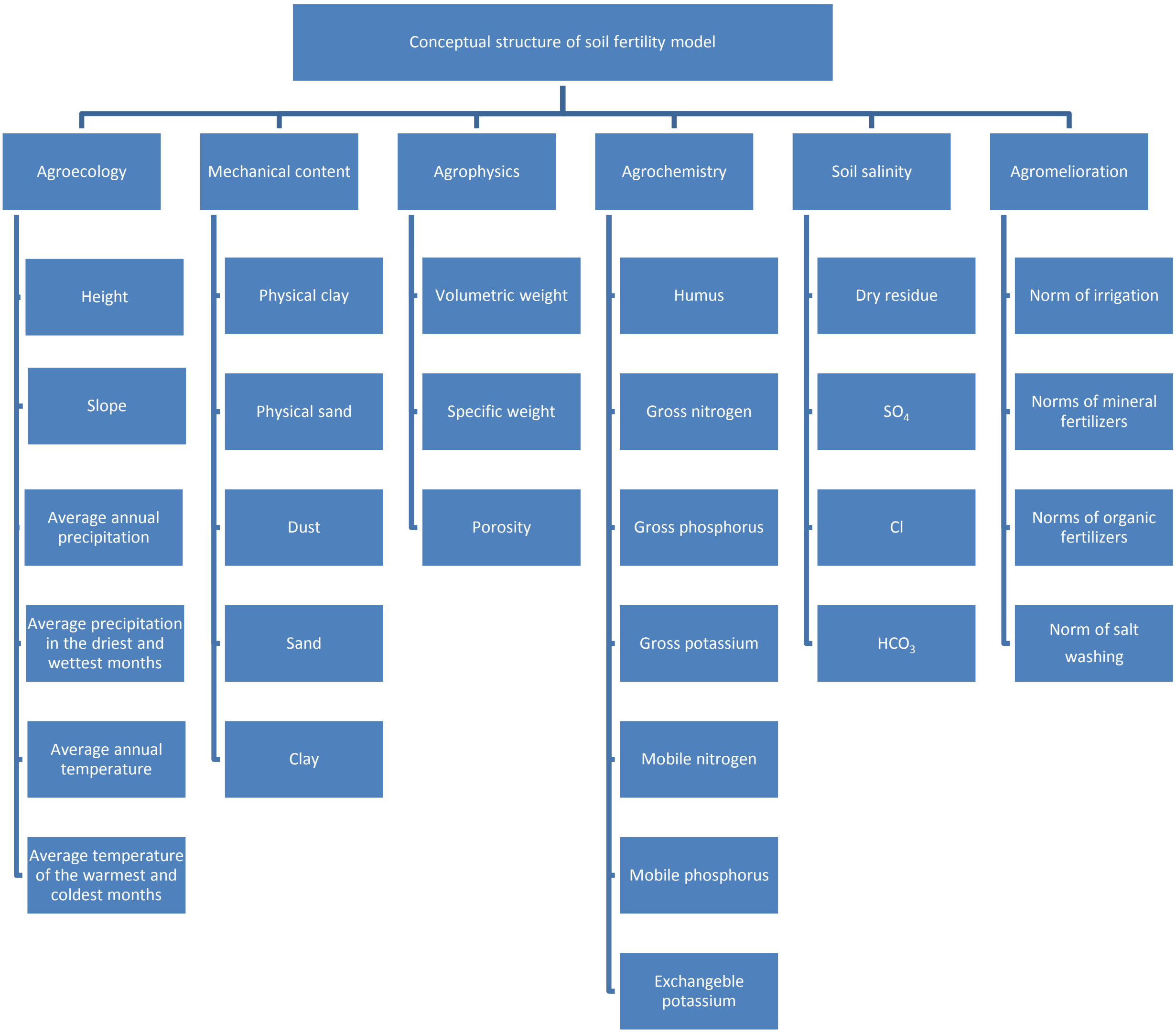

Fig 1. Conceptual soil fertility model of irrigated serozem-meadow and meadow soils of Syrdarya region.

Below are the numerical values of the individual parameters and components that we developed separately for blocks for fertility models.

1) *Agroecology block:*

Height above sea level-180-280 m; Slope - 0-10°: Average annual precipitation - 260-400 mm; Average precipitation in the driest month - 1-3 mm; The average precipitation in the wettest month - 45-70 mm; Average annual temperature - 15-16.5°C; Average temperature of the warmest month - 32.3-36.7°C; Average temperature of the coldest month -3.4-5.0 ° C.

2) *Block of soil mechanical content:*

Physical clay - 16-51%; Physical sand - 50-85%; Dust - 47-98%; Sand - 4-43%; Clay - 3-17%.

3) *Agrophysics block:*

Volumetric weight - 1.30-1.60 g/cm^3; Specific weight - 2,46-2,72 g/cm^3; Porosity - 40-50%.

4) *Agrochemistry block:*

Humus - 0,50-1,30%; Gross nitrogen - 0.02-0.11%; Gross phosphorus - 0.04-0.50%, Gross potassium is 0.91-1.74%; Mobile nitrogen - 8.3-81.6 mg/kg; Mobile phosphorus - 3,5-20,0 mg/ g; Exchangeble potassium - 100-280 mg/kg.

5) Block soil salinity:

Dry residue - 0.11-1.86%; Salts of SO_4 - 0,08-1,10%; Salts of Cl - 0.01-0.11%; Salts of HCO_3 - 0.014-0.028%.

6) Agro-melioration block:

Norm of irrigation - 5000 m^3/ha; Norm of salt washing - 3000-6500 m^3/ha;
Norms of mineral fertilizers: nitrogen - 150-250 kg/ha, phosphorus - 145 kg/ha, potash - 80-120 kg/ha; Norms of organic fertilizers are 25-35 t ha.

Following the development of soil fertility models, digital maps using geo-information technology technologies have been developed. The spatial analysis based on the relevant soil parameters using Geostatistical Analyst module of the ArcGIS software has carried out. As a result, digtal maps of each parameter of the model have been created and to model soil fertility using GIS, Model Builder of ArcGIS applied.

Today, geoinformation modeling (GIS-modeling) is increasingly used to solve these problems, which is an effective tool for data collection, systematization and analysis, reflecting both past and present situation in the region used in forecasting and planning for rational nature management.

Most of the possibilities of cartographic modeling come from the flexibility of the functions of spatial analysis. Spatial functions and operations are a set of tools that can be mixed and matched in cartographic models. Overlay, proximity, reclassification and most other tools of spatial analysis are quite common. These tools can be combined in an amazingly large number of ways, by selecting different tools and by changing their sequence of applications. For example, differences in distance tables, thresholds, and reclassifications may be indicated. These changes will lead to different levels of output, even if the same levels of input data are used. With a small set of tools and layers of data, we can create a huge number of cartographic models. Designing the best cartographic model to solve the problem - choosing the appropriate spatial tools and specifying their sequence - is perhaps the most important and often the most complex process in cartographic modeling.

GIS models are often summarized in block diagrams. A block diagram is a graphical representation of spatial data, operations, and their sequence of use in a map model. It is necessary to identify suitable sites that are near roads, near lakes and are not wetlands. The data layers are represented by rectangles, operations with ellipses and the sequence of operations with arrows. Operations are indicated inside each ellipse. The agency or organization often requires a flowchart to document the completed spatial analysis. Because a consecutive set of symbols helps in the effective communication of the cartographic model, a standard character set and flowchart methods can help in understanding the data and operations used in the analysis.

The first of all using block diagrams binary gis models of each block of soil fertility model is devloped. So independent sub models of agroeceolgy, mechanical content, agrophysics, agrochemistry, soil salinity, agromelioraation blocks are created (Fig. 2). For example, for agroecology block relief, rainfall and temperature parameters of the model conditional raster algebra functions of the ArcGIS software used. The parameter values are given to the function condtion as limits.

After developing all sub models, overall final model for the fertility of soils are created. The relevant block diagram for the overall model has been developed. (Fig. 3).

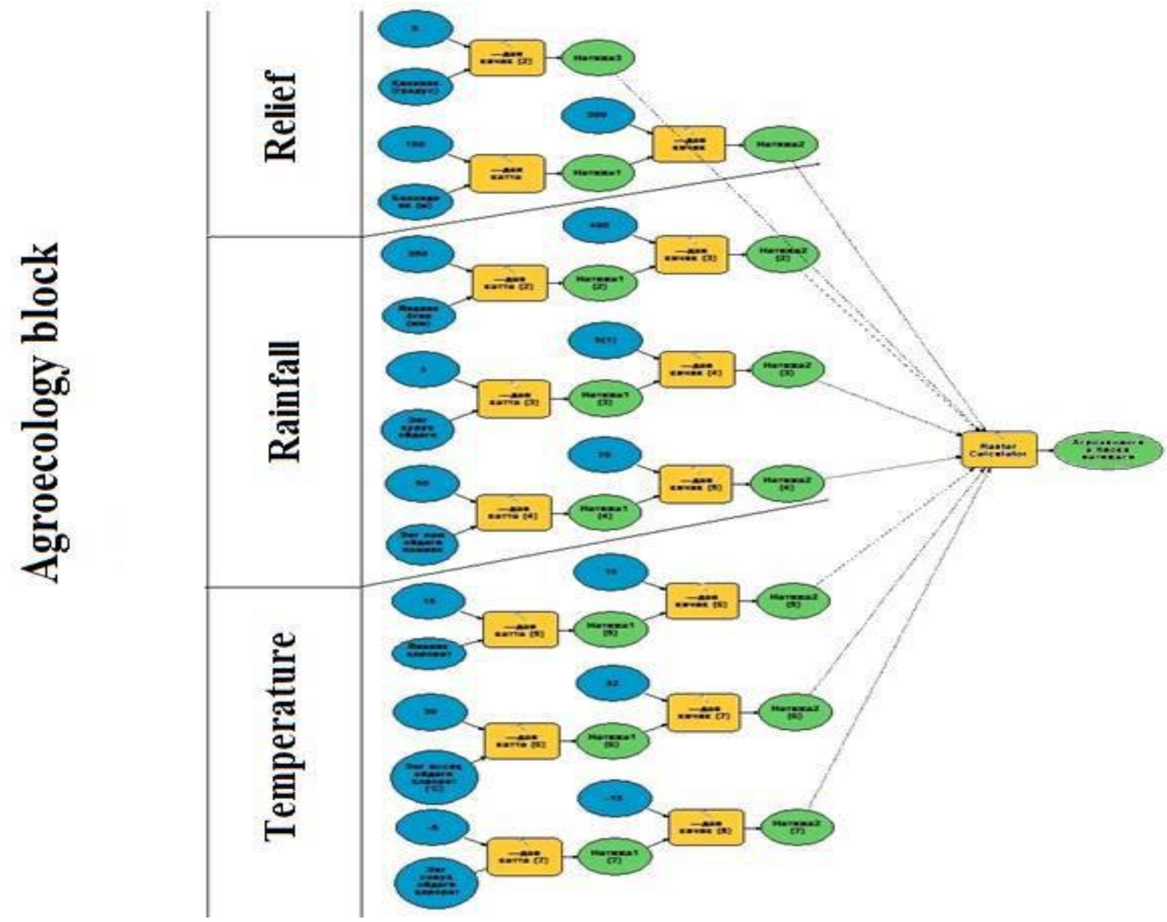

Fig. 2. A block-diagram for calculating gis model of the agroecology block of the model.

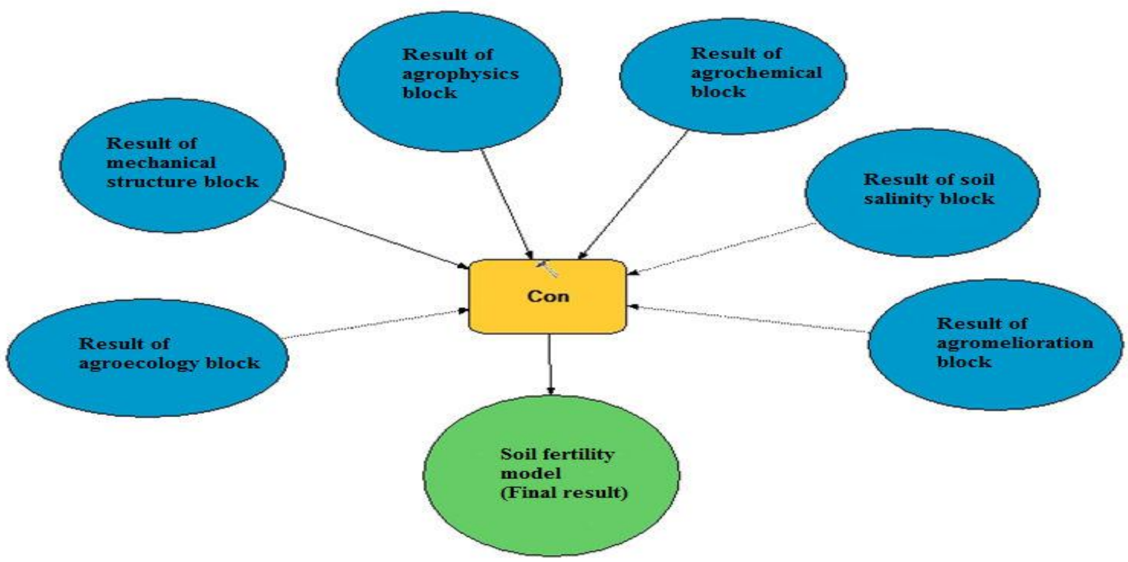

Fig. 2. A block-diagram for calculating overall gis model of the soil fertility.

4. CONCLUSION:

Based on the results of the research, the structure of the soil fertility model for irrigated soils of the Syrdarya region has been developed, consisting of the conceptual structure of interconnected blocks and parameters. The use of modern geographic information systems based on this fertility model provides the ability to store, select and systematize data collected by the region's soils, including their fertility status. This, in turn, plays an important role in the implementation of key tasks such as rational use of land resources, conservation and enhancement of soil fertility.

Main conclusions and recommendations based on the results of the research can be used in the development of targeted government programs aimed at evaluating soil fertility, drawing up maps of crops and improving reclamation of irrigated lands. Also theoretical and practical proposals and scientifically-based recommendations based on modeling can be introduced into practice in many other regions of the country.

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