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Geographical Information System for Sustainable Management of Water Resources

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***Abstract*—**Fresh water deficit is one of the most important global problems today. In the countries with scarce water resources, they often become a reason of armed conflicts. The peaceful settlement of relations connected with management and water consumption issues within and beyond the frontiers of the country is an important guarantee of the region stability. The said problem is urgent in Georgia as well because of its water objects are located at the borders and the transit run-off that is 12% of the total one. Fresh water resources are the major natural resources of Georgia. Despite of this, water supply of population at its Eastern part is an acute issue. Southeastern part of the country has been selected to carry out the research. This region is notable for deficiency of water resources in the country. The region tends to desertification which aggravates fresh water problem even more and presumably may lead to migration of local population from the area. The purpose of study was creation geographical information system (GIS) of water resources. GIS contains almost all layers of different content (water resources, springs, channels, hydrological stations, population water supply, etc.). The results of work provide an opportunity to identify the resource potential of the mentioned region, control and manage it, carry out monitoring and plan regional economy.

***Keywords*—**GIS, irrigation, water resources.

I. Introduction

WATER is a vital part of our environment, essential for existence of all living species, including human beings. While water is renewable, in case of its improper use, it may become entirely useless. Any earthwork, cutting or planting of forests and windbreak strips can directly change a territory's water-balance and structure.

"Over the past quarter-century, the world has become more drought-prone, and droughts are projected to become more widespread, intense and frequent as a result of climate change. The long-term impacts of prolonged drought on ecosystems are profound, accelerating land degradation and desertification" [1].

The scarcity of available water resources is frequently created artificially by intensive growth of urbanization of population, industry and agriculture without properly taking into account the availability of water resources [2], [3]. Therefore, the system of management of water resources (water resources-water consumption-water supply) must proceed from that position, that deficiency or surplus of water should be evaluated in accordance with the need for it. All this requires the application of corresponding urgent measures for management of water resources. Otherwise, in the near future, under the existing trend of climatic change, serious problems will occur accompanying the intensive migratory processes of the population living in the arid regions.

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II. Study Area and Method

The territory of Georgia comprises 69.7 thousand square kilometers. The population is 4.4 million. Fresh water resources are the major natural resources of Georgia. There are more than 2500 rivers, 800 lakes, 40 water reservoirs, about 700 glaciers, numerous different kinds of springs and swamps (Fig. 1). The volume of all kinds of resources makes 100 km^3. The total run-off of Georgia's rivers composes 65.8 km^3 (24.4 km^3 is the transboundary rivers run-off). The rivers of Georgia belong to the Black and Caspian Sea basins. The river drainage of the Black Sea basin owing to the abundant atmospheric precipitation is much denser than the drainage of the Caspian Sea river basins and they carry much more water than do those of Eastern Georgia [4]. Georgia is rich in available water resources, but due to their non-uniform distribution over the territory, in a number of regions there appears a significant imbalance between the amount and use of water resources. The largest water consuming region of the country is Eastern Georgia, where water supply for population and the territory is four times less than in Western.

The purpose of study was creation GIS of water resources which will be used as a basis for sustainable management of water resources.

Kakheti Region has been selected to carry out the research. Kakheti occupies the leading place by agriculture in Georgia (viticulture, grain growing, livestock farming, etc.). The major part of the population (> 80%) is engaged in agricultural activities, and it is a typical agricultural region. The region's natural conditions enable the need for artificial irrigation on its largest part. The region tends to desertification which aggravate fresh water problem even more and presumably may lead to migration of local population from the area [5], [6].

According to the forecast, at the end of 21st century in the southern part of Kakheti it is expected decrease of hydrothermal coefficient from 1.1 to 0.7, which will shift the region's climate from subtropics into very dry category. The influence will be spread along the entire territory of Kakheti [7]. In case the global warming is developed intensively, the elevation shifting of natural climate zones is possible, as well as an increase of irrigation water consumption, respectively.

In connection with the intensive growth of water consumption and different values of river runoff in addition to quantity, the question of classification of water resources according to the rate of sustainability, regulation and quality, has been ripen. On that basis and from the management point of view water resources of Kakheti region are the important and interesting to proceed to the controlled use of water and to estimate water deficit or excess according to its requirements.

At the first stage of the project implementation, a survey was conducted in villages in order to reveal the population attitude to the water consumption related issues. Within the study, 20 people were interviewed from each village.

- **The research objectives were:** The study of the forms of rural water supply; The study of the satisfaction of the population with the agricultural water quantity and quality; Identification of the water supply related problems.
- **The target group was:** The rural population (one representative from each of the selected households)
- **Selection method was** random selection,
- **Research tool -** semi structural questionnaire and
- **Research method -** face to face interview.

Kakheti region is marked by a deficiency of water resources and, often, the present resources are used inappropriately and irrationally. One of the objectives of the project is to assess the water deficiency or its excess in order to take on the managed water consumption with respect to its demand. The implementation of this task within the study was mainly based on the analysis of the secondary data, i.e. the analysis of databases (water resources; water consumption; hydrometeorological, demographic and other data). However, to describe the water consumption related real picture, it became necessary to study the attitude of the population to the water consumption related issues.

Per one member from each of the selected households was interviewed, as the issue to be studied is equally problematic for all members of the household. The research was mainly focused on interviewing of the people involved in the agriculture, because one of the objectives of the research was to highlight the existing problems in the irrigation water consumption. However, those persons, who consume only the municipal and drinking water, participated in the research.

Employment form is similar for all the interviewed respondents: The population is mainly engaged in agriculture, rarely – in cattle breeding or in both.

Population attitude towards the water supply-related issues turned out to be similar. The respondents note that in the village of Giorgitsminda, the water supply facility is the spring from which the water supply system is done. The water is supplied to the houses of population. That is the main source of drinking water for them. The population almost does not use alternative means, such as, for example, the wells. Also, there are the water taps for common use in the streets. However, population in some districts did not have access to spring water due to the water supply system there and they have to carry the water by cars to those districts. The situation is similar in the Udabno village. The population of the village of Udabno is supplied through two water supply systems. From the Ujarma village, a new water line was constructed, but the part of the village is supplied for few days a month. Discussions with the population revealed that the water pipes are damaged; water is wasted and lost.

The villages of Giorgitsminda and Udabno do not have the irrigation water supply system; therefore, the population has no access to irrigation water. At the same time, the agriculture is the main activity of the population. The interviewed respondents mainly cultivate the vineyard in the farm lands, which require irrigation 3 or 4 times a year on average. Population depend entirely on natural water resources and, at the same time, constantly suffer from a lack of natural resources, which often leads to the spoiling the crop yield.

As for the drinking water, its supply in the village of Giorgitsminda is limited through a schedule. The water is supplied in the morning or in the evening for 1-2 hours. The overwhelming majority of the interviewed respondents keep the water in stock during the day. Water limit is also a significant problem; after it is expired, the water supply is cut for several days, until the reservoir is filled up with the spring water. The overwhelming majority of the respondents believe that the drinking water is thoroughly insufficient. Thus, there is no irrigation water in the village of Giorgitsminda and there is a lack of the drinking water as well. The situation is similar in the village of Udabno. Drinking water schedule is established there. But the drinking water provided by schedule is limited and population uses it until its stock is exhausted. The overwhelming majority of the interviewed respondents in the village of Udabno are dissatisfied with the amount of drinking water.

One of the objectives of the study was also the drinking water quality assessment. The respondents' attitude to this issue is mainly similar: The respondents note that they are more dissatisfied than satisfied with the quality of drinking water. The main reason for dissatisfaction is a problem of clean water, as the population is supplied with the dreggy water. Thus, the following facts were revealed as a result of the study: In the Kakheit region, in the villages of Giorgitsminda and Udabno the population is provided with the drinking water only through the water supply system, where the water is dreggy in many cases. The drinking water is provided to them by schedule and the drinking water limit is imposed too: as soon as the stock is exhausted, the water is cut for a certain period, until the stock is filled up. Also, the population is not provided with the irrigation water, due to which they use only the natural water resources in agriculture, which is almost never enough for the crops such as, for example, vine. Thus, the survey results confirm that there is a drinking water shortage and the irrigation water acute shortage in the mentioned villages of the Sagarejo municipality. A similar situation is in the other municipalities of the region as well.

The project carried out with the known GIS software ArcGIS. The database of GIS contains the whole data information about water and water demand, which were

existed in various departments and published in the literary sources (monograph, article, atlases, statistical handbooks and other); all of the above mentioned materials are freely available [8]-[10].

Basis of hydrological GIS is the digital version of three-dimensional topographic map of Kakheti region (1:200 000). In the implementation the project were used the following layers of the above-mentioned map: river, lake, reservoir, springs, channels, the populated areas, roads, hydrological stations, etc.

During the field works collected demographic data (population, its density, urban and rural population, etc.), inventoried water objects: rivers, mudflow rivers (Fig. 2), irrigation channels (Fig. 4), springs, lakes, reservoirs, collected of data on water use and requirements (hydropower, irrigation, public utilities, industry, etc.) and digitalized. Created of the data base spatial structure and transformed of GIS base for the project tasks requirements.

After modification of the GIS basis and establishment of database structure, the above mentioned information was downloaded in the system. Thus, hydrological information system of Georgia consists of the following layers: rivers, lakes, reservoirs, underground water, irrigation systems, hydrological stations, river basins, settlements, roads, etc.

At current stage of project implementation was calculated and mapped water supply of the population by municipalities (Fig. 3); water supply of the territory by municipalities (Fig. 5); the maximum possible number of population (per capita) for different water use standards; calculating of water resources and water use ratio, etc.

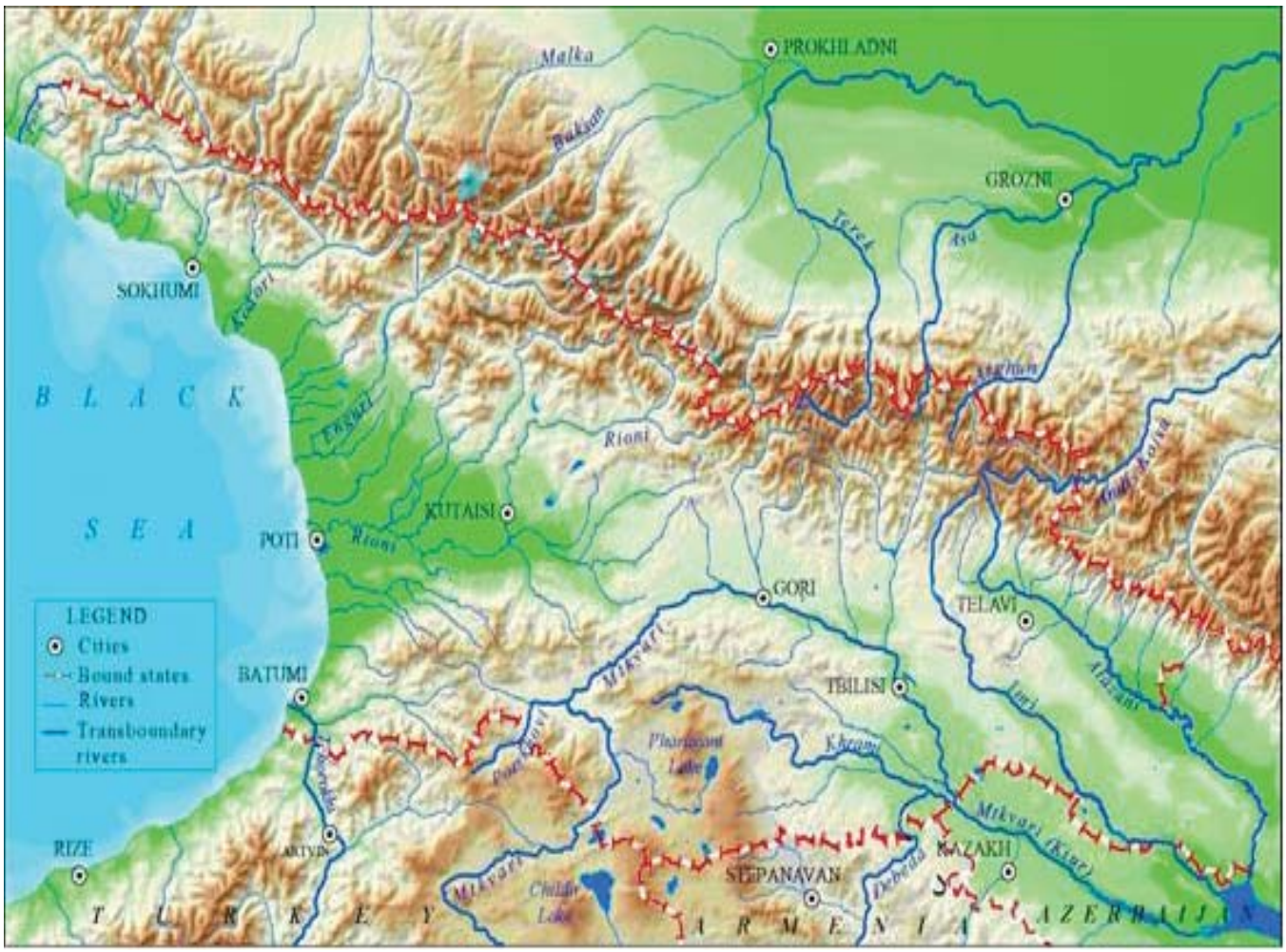

Fig. 1 Physical map of Georgia

Fig. 2 Inventory of mudflow river Duruji

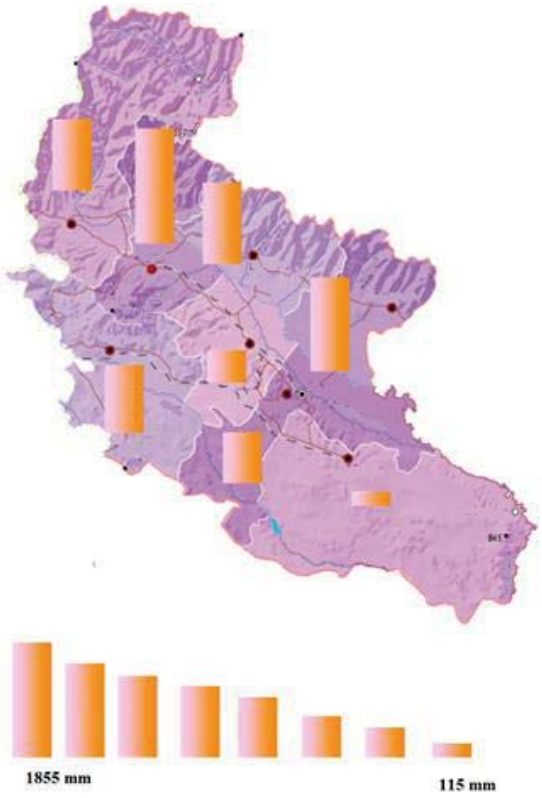

Fig. 3 Water supply of the population by municipalities

Together with water resources, GIS created the multimedia software package with flexible searching engine and a photo gallery. Using of which will give the possibility for customers easily find information relevant to their needs. It will be available to publish a part of the multimedia in Internet, as well as to install it on the user's computer. So, user could work with the lack of connection to the Internet, too.

At the final stage, a web-site will be created, which will have text and graphic, as well as geographic information update facilities. Web-site will allow all interested customers to get the project results, except the information, which belongs to the category of limited access according to the Georgian legislation.

Fig. 4 Inventory of irrigation channel

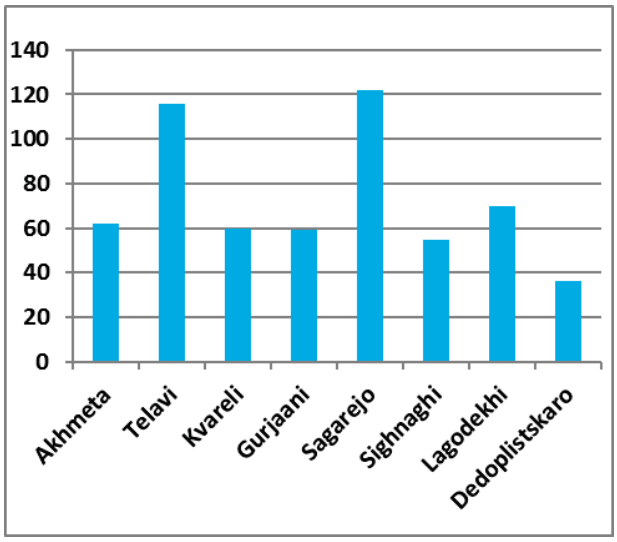

Fig. 5 Water supply of the territory by municipalities

III. Conclusions

The project will make possible to receive the real picture of quantitative characteristics of water resources available in Kakheti; to create GIS databases and thematic maps of water resources that will make it possible to control and plan regional economy by the governmental bodies.

The project results will help to establish and develop tight bonds between different water users; will improve transparency of water resources management, more rational use of water resources and measures against water losses that will have positive results for the economy and social environment of the country.

The innovation of study consists of creation of water resources management base by means of GIS.

The ratio between water resources and water use per regions will be determined for the first time for different standards of water use and respective maps will be prepared.

The vulnerable territories will be specified according to the water resources.

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