One of the main advantages of the method is the possibility of forecasting discharge in rivers located at high elevation basins (between 2,4-3,7 km in this study), where obtaining information on snow accumulation or precipitation in winter period is problematic without using satellite data.

Water related organizations, energy companies or state emergency organizations can benefit by using such methodology which enables to identify whether the season will water scarce or water excess year and take measures according to that.

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ПРИМЕНЕНИЕ ГИС В ПРОЦЕССЕ АНАЛИЗА ИСПОЛЬЗОВАНИЯ ВОДНЫХ РЕСУРСОВ В СТРАНАХ ЦЕНТРАЛЬНОЙ АЗИИ НА СОВРЕМЕННОМ ЭТАПЕ (НА ПРИМЕРЕ АРАЛЬСКОГО МОРЯ И РЕКИ НАРЫН)

APPLICATION OF GIS IN THE PROCCES OF ANALYZE OF WATER RESOURCES IN CENTRAL ASIAN COUNTRIES AT THE PRESENT STAGE (ON THE EXAMPLE OF THE ARAL SEA AND THE NARYN RIVER)

Геоинформациялык системалар (ГИС) Борбор Азия регионундагы суу проблемаларын комплекстүү изилдөөгө ыңгайлуу мүмкүнчүлүктөрдү түзөт. Конфликт кырдаалды алдын алууда жана коопсуздукту изилдөөдө ГИСти колдонуу өтө маанилүү. Калктын өсүшү, дарыя агымын сарамжалсыз пайдалануу, суу-энергетикалык комплексти башкаруудагы маселелер суу ресурстарын башкарууну интеграциялоого алып келет. Аталган маселени

чечүүдө ГИС негизги каражат катары колдонулат. ГИСти колдонууну жакшыртуу менен региондогу сарамжалсыз пайдаланып жаткан суу ресурстарына интеграциялык башкаруунун оптималдаштырылган механизимин ишке киргизүүгө болот. Макалада авторлор тарабынан ГИСти колдонуу менен Арал денизин изилдөө жана түрдүү жылдардагы Нарын дарыясынын суу агымынын көлөмүнө баа берүү маселеси каралды. ГИСти колдонуу менен суу ресурстарын башкарууну интеграциялоо маселесин чечүүгө аракет жасалды.

Ачкыч сөздөр: *Борбордук Азия, суу ресурстары, ГИС, Арал денизи, Нарын дарыясы.*

Геоинформационные системы (ГИС) позволяют более удобное и комплексное исследование водных проблем в Центрально-Азиастком регионе. Для изучения безопасности и предотвреашении конфликтных ситуации очень актуально примение ГИС. Рост населения, нерациональное использование стока рек, неспособность упраления водно-энергетическим комплексом вызывает вопрос интегрированного управление водными ресурсами. Применение ГИС является одним из важных инструментов в решении данного вопроса. Нерациональное изпользование водных ресурсов в регионе представляет внедрения оптимизированного механизма интегрированного управления, совершенствования применения ГИС в этой области. В статье авторами рассматриваются вопросы применения ГИС для изучения Аральского моря и оценки объема притока воды на реке Нарын в разные годы. Делается попытка решения вопроса в рамках примения ГИС в интегрированном управлении водными ресурсами.

Ключевые слова: *Центральная Азия, водные ресурсы, ГИС, Аральское море, река Нарын.*

Geographic Information Systems (GIS) allow a more convenient and comprehensive study of water issues in Central Asian region. To study a security and prevention of conflict situations, the using of GIS is topical. Population growth, irrational use of river flow, inability of water and energy complex management causes the issue of integrated water resources management. The use of GIS is an important tool in resolving this issue. Irrational use of water resources in the region requires introduction of optimized mechanism of integrated management and improvement of the application of GIS in this field. The author considers the questions of using of GIS to study the Aral Sea and the assessment of water inflows on the Naryn River in different years. An attempt is made to resolve the issue within the framework of GIS using in integrated water resources management.

Keywords: *Central Asia, water resources, GIS, Aral Sea, Naryn River.*

One of the sub-regions of Asia-Pacific region is the Central Asia, in which socio-economic and environmental problems are exacerbated. Meanwhile, the region has sufficient natural resources and human potential for development.

The region has significant reserves of oil and gas, coal, iron and copper ores, phosphate, uranium, nonferrous metals and construction materials. So, Kazakhstan, Turkmenistan and Uzbekistan have significant reserves of strategically important energy resources: oil and natural gas. Turkmenistan ranks third among the world's largest gas suppliers, and Uzbekistan - eighth in the world in gold production. Stocks of the fresh water are concentrated in glaciers in mountain ecosystems of Kyrgyzstan and Tajikistan, which occupies a leading position in the world in hydropower recourses, potential of the latter is used by only 10% of the total/1/.

At the beginning of this century, water resources in Central Asia experienced the powerful anthropogenic press, i.e. direct and indirect impacts of mankind’s economic activities on water resources. All this is reflected not only on the quality of surface waters, but also on their inventories, leading to the depletion of water resources and significant degradation of water bodies.

At the present stage of development of security in the region priority threats are folding of water scarcity mode, population growth in the region, the irrational use of river flows, lack of understanding of foreign states in the regulation of the problems of water and energy scarcity (see.

Figure 1). Fears of states in this regard cause set of expectations of a worse position than it actually is.

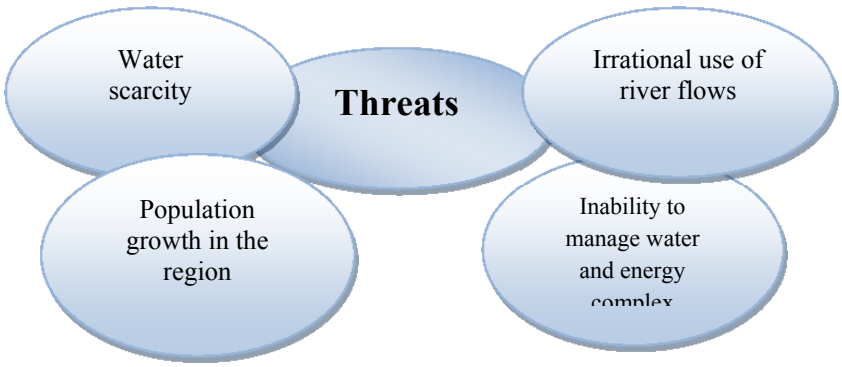

Figure 1. Priority threats of water shortage in Central

In order to attempt to solve the above threats in this article could be given some examples of GIS use in the integrated management of Central Asian countries' water and energy resources, which plays an important role for people who make these decisions, in this case, the use of GIS technique for better reflecting of the water and energy situation in Central Asia on a regional map.

As we know, World Resources Institute in ArcGIS field developed a very useful and interesting cartographic material containing information on water issues around the world in the visual form.

From this point of view, this GIS project comprises a lot of layers (availability and seasonal variability of the amount of water resources, the risk of occurrence of floods and recurrence of droughts, the availability of water resources underground, extent of contamination of surface water, etc.) and sequentially turning on and off one of them it could be found a situation that is emerging in different parts of the world. You can display the resulting map, which takes into account all of the water problems (see. Figure 2) /2/.

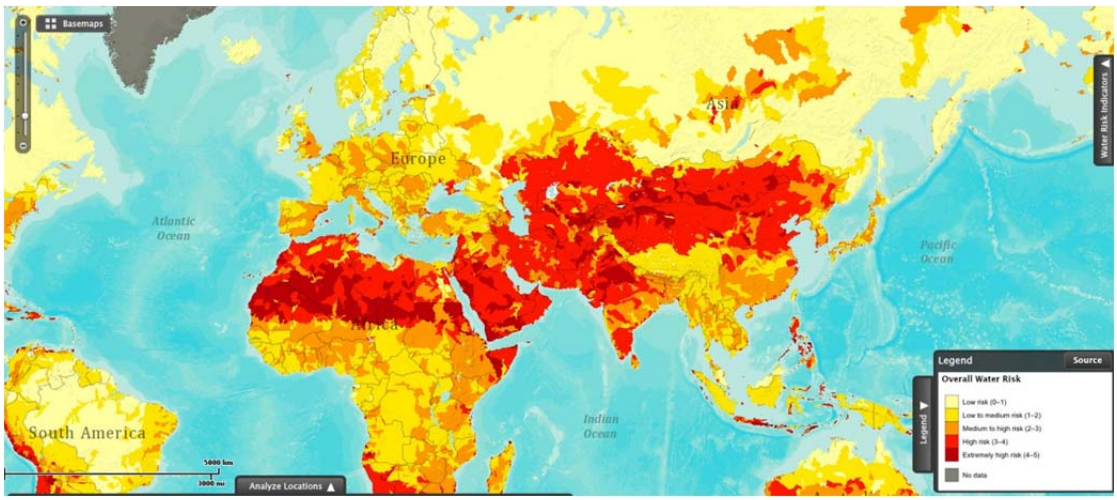

Figure 2. Map of global water problems

As we see the Central Asian region is more prone for high risk of water shortages (red color indicates regions where a lack of water is detected).

In his article«Curb vast water use in central Asia» the author Olli Varis writes that today country of the region are water users with the highest rate in the world per capita – on average, each Turkmen consumes 4 times more water than a US citizen, and 13 times more than a Chinese one[4] (see 'Top 20 consumers'). More than 90% of the region's water use is irrigating thirsty crops including cotton and wheat /3-27/.

Decade of overly vigorous activity led to the draining of the rivers Amu Darya and Syr Darya flowing into the Aral Sea. Local farms which are engaged in the cultivation of livestock, hunting and fishing are disappeared; brackish water ecosystem of the Aral Sea, the delta of rivers, river banks, steppes and the fertile valleys of the rivers have collapsed. With the disappearance of water borders, the local climate has changed dramatically with extreme heat and harsh solar sandstorms in the summer; severe frosts in winter.

On research indicators of D.A. Sorokin, Sh.Sh. Zaitov scientists of the Regional Scientific-Information Center ICWC of Tashkent (Uzbekistan) in assessing the dynamics of the Aral Sea based on remote sensing data, involving methods of processing, modeling, analysis and mapping (Figure 3) shows the reduction of water in the Aral Sea basin.

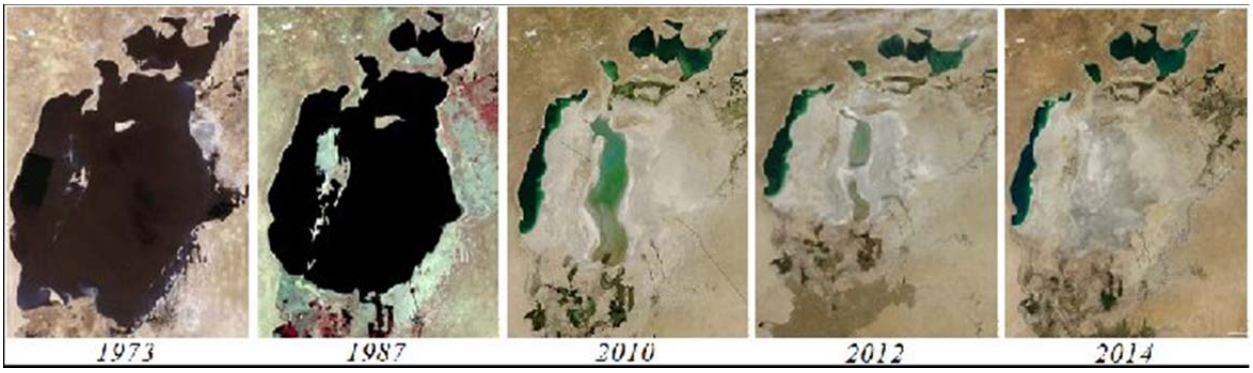

Figure 3. Space images of Aral Sea water area

For the monitoring of the water surface and coastal waters of the Aral Sea a group of GIS professionals of the SIC ICWC were used images of spectroradiometer MODIS (Moderate Resolution Imaging Spectroradiometer - one of the key instruments on board of the US satellites) TERRA «13A1 NDVI» and Landsat TM (satellite on obtaining satellite images of the Earth planet) for 1973, 1987, 2010, 2012 and 2014 years.

MODIS consists of two scanning spectrometers, one of which (MODIS-N) shoots to the nadir and the other shooting axis (MODIS-T) may be rejected. 36 MODIS spectral bands covers the range of wavelengths from 0.4 to 14.4 microns. Shooting in two zones (620-670 and 841-876 nm) is carried out with a resolution of 250 m, in the five areas of visible and near infrared range with a resolution of 500 m, and the rest (0.4 to 14.4 micron range) - 1000 m /4/.

The obtained data on water and land resources in the Aral Sea basin was meant, first and foremost, to support decision making in the water sector of Central Asia. The main objective of the information system is the creation of a single instrument of the accounting of land and water resources of the Aral Sea basin, with the possibility to assess various aspects of the effectiveness of their use and the forecast. It promotes the sustainable management and control of water resources.

Evaluation of the mirror area of the water surface of the Aral Sea with the help of GIS technologies and a comparison with the results of the simulation show that the intensity reduction in Western part of the Aral Sea is less than the East. Calculations and analysis of remote sensing data have confirmed the hypothesis of the existence of an underground inflow from the Eastern part of the Big Aral Sea to the Western part. This allowed adjusting the method of calculating the water balance of the Big Aral.

For example, the calculation of the water balance for August 2014 of the western part of the Big Aral Sea shows that water evaporation losses are about 0.74 cubic km, while the amount of the volume loss (with changing space from 3.39 to 3.38 sq.km) estimated only 0.14 cubic km; the difference is the filtration rate of 0.6 cubic km per month (at that time there was no surface inflow into the Western Sea). While a decrease of water surface of the Eastern part in the period from

September to December the filtration consumption drops sharply to 0.10 - 0.15 cubic km per month /4/.

The largest transboundary watercourses of the Central Asian Region (CAR) originate from the Tien Shan Mountains: Amu Darya, Syr Darya, Chu, Talas, Karkyra, Tarim, which provide water not only Kyrgyzstan, but also neighboring Kazakhstan, China, Tajikistan, Turkmenistan, Uzbekistan.

In the present conditions and in the long term, the deficit of water resources in Central Asia is regarded as one of the major limiting factors in the development of the region's countries. The expected increase in water consumption leads to competition for water at the regional and local levels between irrigation and energy, and other sectors of the economy /5-440/.

With the collapse of the Soviet Union the main watercourses in the region: the Amu Darya and Syr Darya - in fact acquired the status of "international rivers", and in this new conditions, Kyrgyzstan is taking steps to change relations in the use of resources of the Toktogul water reservoir. It takes into account the needs of lower countries for 11 billion m^3 of irrigation water, damaging the hydropower interests of the Kyrgyz Republic, when Toktogul HES could not work in the power mode in autumn and winter. The average annual electricity generation at Toktogul HES equals to 4 billion kWh and 1.1 billion kWh accounts for the winter period. According to calculations, a decrease of released summer water volume to 2.9 billion m^3 will allow to work out on this HES additional 2.1 billion kWh of electricity in winter, which is equivalent to saving 650 thousand tons of liquid fuel products. Taking into account that a reduction in the volume of water in the reservoir is reduced and the generation of electricity, the actions of the parties when the facts took place similar to 2014, when the reservoir remained 9.995 billion m^3 of water due to excessive summer water releases for irrigation, which was less for 2.046 billion m^3 compared to 2012-2013, for 9.047 billion m^3 to 2010, should be regulated by international agreements. It should be noted that when the volume of water for 13 billion m^3 Toktogul HES generates 4780000000000 kWh of electricity, for a volume of 10 billion m^3 its value is reduced to 3.44 trillion kWh. In winter 2014, Kyrgyzstan due to the power shortage of electricity imported electricity from Kazakhstan.

At present time, Kyrgyzstan, using from the lower Naryn only 2% of water supplies of reservoir for hydroelectric irrigation purposes, must put the interests of the hydropower industry in water management strategies at the forefront. Therefore, from our point of view, there is a need to develop inter-state documents that meet equally the interests of all countries in the region for hydropower and irrigation water management. To do this, they must develop a scheme of the agreement on the distribution of water in the Syr Darya basin, based on the realities of present time /6-9/.

At present time in the Syr Darya basin formed a very tense situation with the use of water resources which is already in the early 70-ies water consumption volume exceeded the stock low-water years. Irrigation water deficiency leads to inconsistencies in its use, causing deviations from the regime rules of the reservoirs use. Violations of the previously agreed project rule is most clearly seen in relation to the Toktogul reservoir, - object, which has a special role in the basin on providing guaranteed water loss, predetermined both its geographical position in the Naryn-Syrdarya cascade (command over three quarters of irrigated arrays of the basin) and useful capacity of the reservoir (14.0 km^3, i.e. more than half of the usable capacity of the system reservoirs) that holds 1.23 annual rate of flow at the site of hydroelectric (11.5 km^3 / year, or 1/3 of the Syr Darya norm - 34.5 km^3 / year, given to the alignment Chardara) /7/.

Designed previously "irrigation" exploitation regulations and reservoirs built on them was not satisfied Kyrgyzstan and Tajikistan in the territory of which there are basic formation of water resources and irrigation requirements can resourced lateral inflow without flow regulation. In recent years, the "upper" states more and more began to use "their" reservoir mainly in the "energy" mode

(with high winter water loss), which leads to infringement of interests of "lower" states: Uzbekistan, Kazakhstan and Turkmenistan. The water from the Syr Darya flows into Kazakhstan by polluted and unusable form through Tajikistan and Uzbekistan. Now recorded a high concentration of toxic substances in the river, its water "should not be used for agricultural purposes as well as for fishery management" ... According to the Kazakhtan researcher W. Besterkov, the most toxic substances recorded in the waters of the Syr Darya, bordering Uzbekistan. He noted that it will be extremely difficult to clean water, for a start you need to find out what the company which country pollutes it. Scientists estimate that the water may be suitable after at least ten years after treatment /8/. Thus, each state where the Syrdarya flows relentlessly pollutes river flow. In such a situation, the interests of Uzbekistan, where formed less than 10%, and is consumed (and mainly for irrigation) up to 60% of water resources of the region - are affected to the greatest extent. Moreover, the basic regulatory capacity of reservoirs located outside its borders (85% of the Amu Darya, the Syr Darya basin - 75%), which greatly limits the possibility of the state to impact directly on the management of water distribution in the case of inter-state conflicts (which, unfortunately, have already taken place in the past and are not excluded in the future).

The HES has a great importance not only for Kyrgyzstan, but for the energy systems of Central Asian countries and Southern Kazakhstan. Water flows on the objects located on the territory of these countries from the Toktogul reservoir for many years of the HES cascade on Naryn river, located on the territory of Kyrgyzstan.

In recent years, in connection with the transition to energy modes of the HES cascade observed significant fluctuations in water flow in the cross-sections of these facilities and difficulties in water resources management.

The intensive economic use of the Syr Darya river and other water bodies by Central Asian states, increasing pollution and depletion of its water resources urgently require the development and composing of rational use and protection schemes of water resources at the regional level, the creation of a permanent water accounting and disbursement systems (water cadaster) with the purpose of the operational water management. In this respect, the use of modern development of storage and processing of hydrological information technologies are a very important issue. These circumstances make optimization of water resources and monitoring actual.

To research this question we received pictures from Landsat - the longest of the project to obtain satellite images of the Earth planet. The first satellite in the program was launched in 1972, the latest Landsat 8 on February 11, 2013. Equipment installed on the Landsat satellites has made billions of images that are a unique resource for many scientific researches in the field of agriculture, cartography, geology, forestry, education, water management and national security /4/.

For example, Landsat 7 delivers images in 8 spectral bands with a spatial resolution from 15 to 60 meters per point; frequency of data collection for the entire planet was originally 16-18 days.

In order to receive satellite images from one inflow point of Naryn river flowing to the Toktogul reservoir, at the same time from one point with a periodicity of 2000 (Landsat 7), 2008 (Landsat 5), 2008 (Landsat 5), 2015 (Landsat 8) and covered the July period because the water content of the Naryn river is in flood mode.

For research of a water body (inflow of the Naryn river), water resource and the various stages monitoring in the water resources integrated management we used the geoinformational software ArcGIS. ArcGIS is a software product for visualization and processing of Earth remote sensing (ERS) data, which includes a set of tools for data processing of the complete cycle from orthorectification and spatial referencing images to obtain the necessary information and its integration with GIS data.

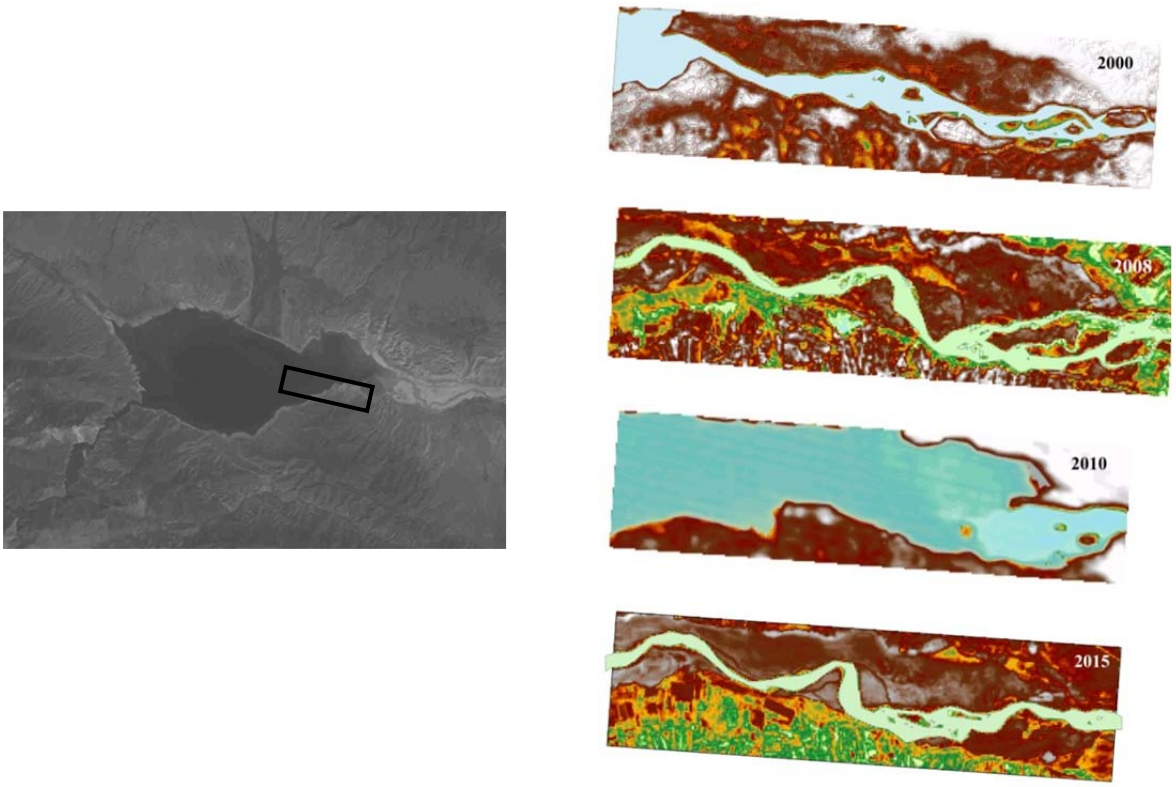

Figure 4. Receiving a picture of the study area from Landsat

According to the ArcGIS program calculate the change of water surface in the Toktogul catchment of the inflow of the Naryn river.

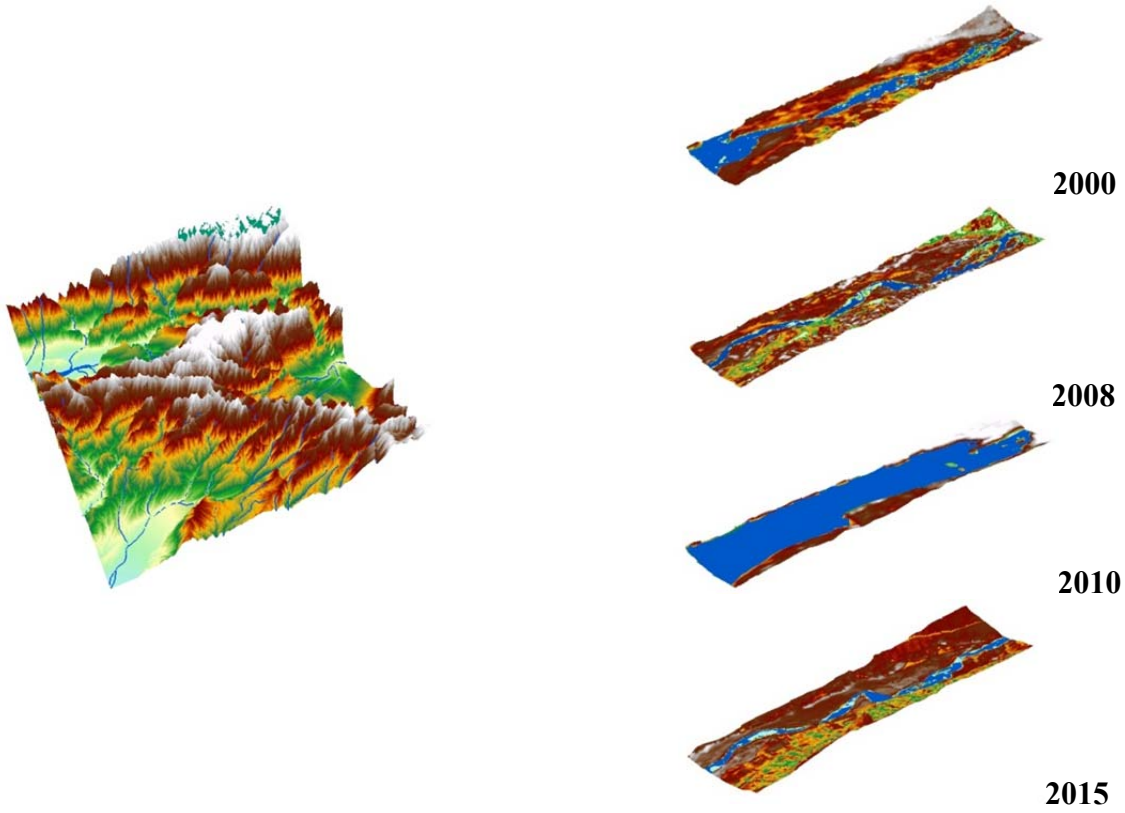

Figure 5. Digital map of the study area

The following table shows some basic data for the compilation of comparative forecast for four years of the Naryn river inflow. Using the classification of water cover of a certain area of the river we derived following results and their comparative analysis:

Year	The amount of water (m2) Resulting in the processing and classification of Landsat images	The amount of water (mln. m^3) Monthly average calculation	The amount of water (m^3/s) Monthly average calculation
2000	4402251,889	1859	694
2008	2564792,435	1307	488
2010	16185232,38	3067	1145
2015	2763140	2756	1029

Comparative data shows the same results for the balance of water in the Toktogul reservoir alignment. The water can remain in the river in a large amount but show less value for the selected area.

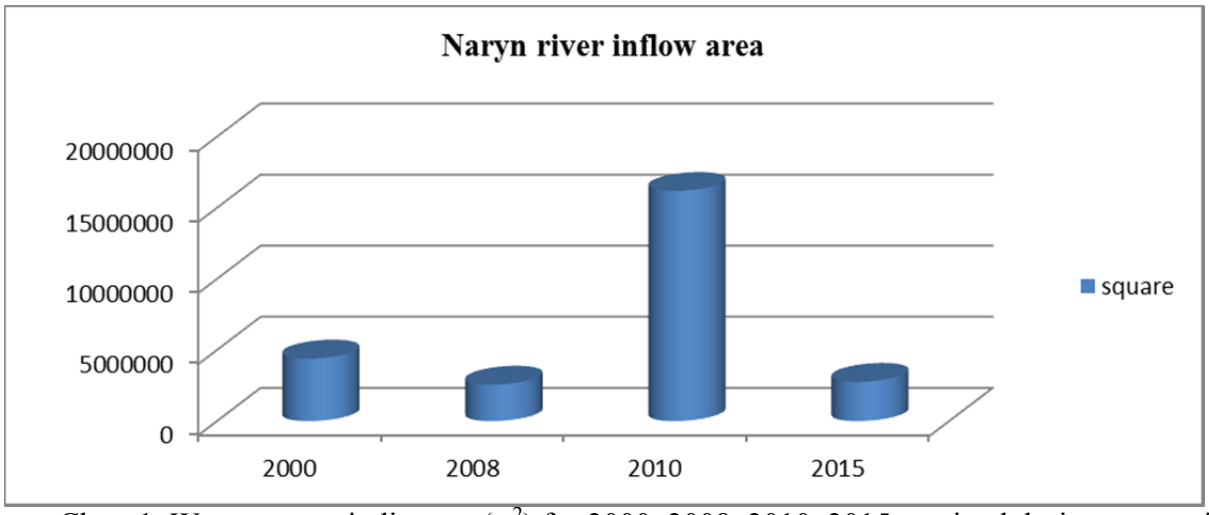

Chart 1. Water square indicators (м^2) for 2000, 2008, 2010, 2015 received during processing and classification of Landsat images

In this case, it is necessary to take urgent measures and provide preparation of the sustainable development strategy of the region, without which there can appear a conflict mod, and the mutual distrust between the states of Central Asia.

The main problem in relations between countries is an unbalanced system of water resource management in the hydropower mode, in which the winter floods are replaced by water shortages during the growing season of major agricultural crops. Solving problems in the management and joint use of water and energy resources of transboundary rivers for irrigation purposes for downstream countries - Kazakhstan, Turkmenistan and Uzbekistan, and hydropower for countries zone of runoff formation - Kyrgyzstan and Tajikistan, it is possible today only through constant dialogue /9-26/.

Exploitation of water resources by countries located down and upstream of transboundary rivers in Central Asia - a problem that took a protracted nature, and the parties cannot agree on the regulation of the growth of water consumption, water supply and water management, water purification and others.

It is possible to adjust the Naryn-Syrdarya cascade in such a way as to meet the needs of hydropower, food and ecosystems. The rules and regulations have been developed, but have not yet been applied in practice. This will happen only if there is political will and commitment to international law /10-54/.

In conclusion we can say that water resources are one of the main natural resources of Central Asia and factors of the socio-economic and secure development. While researching Aral Sea and certain point of Naryn river inflow and taking into account the classification of the water cover by ArcGIS program can draw the following conclusions:

- It is possible to estimate the volume of water inflow into the reservoir of Naryn river and on its basis to predict its content by GIS;
- GIS makes it possible to assess various aspects of the use and forecast effectiveness, which contributes to the sustainable integrated management and control of water resources use in Central Asian region;
- Allows doing the analysis and monitoring of violations of the water balance in the region.

It could be said that with the application of GIS technology can be solved following objectives of an integrated water resources management:

- Water allocation between water using parts at all hierarchical levels from the irrigation system to water use planning area;
- Drawing up plans for the development prospects of water bodies and land exploration;
- Assessment of the status and prospects for the use of water resources in various sectors of the economy;
- Identify the causes of water shortages, pollution and the development of a long-term plan for a more efficient method to use the available water resources.

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