Impact of Climate Change on Water Resource Management. Case study on Kura basin

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Abstract- The effects of climate change on freshwater systems and their management occurs mainly due to the observed and projected increase in temperature, increase in precipitation, rise in sea level and precipitation variability. By this, climate warming accelerates the global water cycle on the planet, making arid regions even drier and leading to flooding in the wet ones. According to the findings of scientists, made on the basis of 13 years satellite observations, the warming of the Earth's climate leads to increased evaporation of water from the surface of the oceans, which causes more rainfall than before, that riverbeds return to the ocean. The volume of water circulating in this cycle, increasing annually by 1.5%. For the period from 1994 to 2006, the volume of fresh water annually entering the oceans has increased by 18%. Since more than a sixth of the world's population lives in river basins supplied by meltwater of glaciers and snow, those people will affect the reduction of the water volume stored in glaciers and snow cover, raising the ratio of volume of winter to annual flows, and possibly a reduction in minimum flows. Sea level rise will expand the area of salinization of groundwater and estuaries that will reduce water availability for people and ecosystems in coastal areas. The increased intensity and variability of precipitation, according to forecasts, will increase the risk of flooding and drought in many areas. Up to 20% of the world population lives in river basins that are to 2080 years is likely to face increased flooding risks in the course of global warming. Thus, increasing of water temperature, precipitation increase and the increase of periods of minimum runoff is likely to exacerbate many forms of water pollution that will have consequences for ecosystems, human health, reliability of water supply and operating costs for these systems.

Index Terms- Water resource management, environmental management, climate change, water security

I. Introduction

Achieving and maintaining water security amid climate change is a direct challenge to adaptation. Water security requires the implementation of technical and institutional innovations and can contribute to the emergence of opportunities for improving the supply of services and to initiate new economic activities.

Achieving water security itself is a fundamental development issue. In addition to the natural variability of weather, which affects the water cycle, there are many competing requirements are essentially fixed volumes of this resource. These include increasing water demand because of growing consumption by the industry, raising living standards and changes in human nutrition and in the production structure (for example, the expansion of biofuel production).

In many countries, pollution in the discharges of municipal and industrial wastewater also reduces the volume of usable water. Along with climate change, this increases the complexity of the problems faced by water managers and their organizations, as they are struggling to meet the new requirements. Therefore, the problem lies not only in achieving water security in the face of climate change and the rise of all the other pressures on water resources, but also in its preservation.

The most important problems are the forecast changes of water resources and hydrological characteristics of rivers, lakes and reservoirs. This forecast is the most difficult, because you need to take into account many influencing factors and mechanisms of positive and negative feedback. Thus, the increase in precipitation is usually the growth of the flow. But in some regions due to evaporative losses, even a significant increase in precipitation will not lead to an increase in flow.

Achieving and maintaining water security in a broader sense, defined as the use of the productive potential of water and limiting its destructive potential, are the essence of adaptation strategies and action plans. For countries which do not ensure water security, climate change will have more serious consequences. For those who have provided water security, may be difficult to keep it. All will probably need to allocate more resources to water management.

Thus, water is the primary medium through which climate change affects humans, ecosystems and the economy. Therefore, water management should be focused on adaptation to climate change.

In recent years the Earth's climate varies considerably: some countries suffer from the extreme heat, while others suffer from too harsh and snowy winters, unusual for the area they live. Environmentalists are pointing at global climate change, including an increase in average annual temperature, causing melting glaciers, and rising of Global sea level. In addition to warming, there is also an imbalance of all the natural systems, which leads to changes in rainfall, anomalies in temperature and increase of extreme events frequency, such as hurricanes, floods and droughts. Simply put, it is the result of the acceleration of the global water cycle in nature. To track this trend, scientists were allowed a long-term space satellite monitoring of the water level in the seas, rainfall and evaporation. In other words, it is the result of the acceleration of the global water cycle in nature.

According to the scientists, for the first ten months of year 2015, the average temperature of the planet was 1.02 °C higher than that recorded in the nineteenth century (when it started the observation of changes in global temperature). The threshold of one degree has been exceeded for the first time in modern history. Scientists agree that human activity, such as burning oil, gas and coal, leads to greenhouse effect which is causing a rise in average temperature. Experts note that between 2000 and 2010 it was observed the largest increase in greenhouse gas emissions over the past 30 years. According to the world meteorological organization, in 2014, their concentration in the atmosphere reached a record high level.

Global climate change in recent decades has occupied a firm place among the major environmental problems facing the world community. From how the modern world will cope with climate change, will be directly affected prospects for further development of mankind.

II. TECHNICAL PROBLEMS OF WATER RESOURCE MANAGEMENT

Many of the expected impacts of climate change will manifest themselves through changes in the status of water resources. There is general agreement about the fact that climate change will have a significant negative impact on the global cycle of fresh water. This section discusses some of the key technical problems:

A. Changes in precipitation

It is projected that the increased intensity and variability of precipitation will increase the risks of floods and droughts in many regions of the world.

While the quantity and timing of precipitation is particularly important to some water users, especially farmers, the majority of water users take water from surface water sources such as rivers and lakes, or from underground sources. They are fed by the rainfall, but the relationship between the magnitude of precipitation and amount of water in rivers, lakes or aquifers is rather complex.

B. Surface runoff and water flow in rivers

The reduction in surface runoff may become the most serious effects of global warming on the aquatic environment. The runoff increases when rainfall drips through the earth's surface or seep into the aquifers, then to turn into springs. Ceteris paribus, if a drier surface of the earth and increased evaporation in a hot climate, less water flows into rivers or seeps into deeper aquifers. That's why climate change is manifested in enhanced water cycle.

Other things such as vegetation type and the time of deposition and intensity of rainfall, are also unlikely to remain constant. The intensity and time of rainfall will change as a consequence of changing surface circulation regime, typical for general atmospheric warming. In some of the most arid regions of the world, particularly in Africa, on the border with the Sahara to the Mediterranean region and southern Asia and Australia, spending cuts of the rivers more than 50% predicted with sufficient degree of certainty that will lead to seasonal or permanent drainage of many streams. This change could have a devastating impact on the economic activities of people and cause irreversible changes in ecosystems, including extinction of many species.

C. Temperature, evaporation and aridity

As it was previously mentioned, the effect of increasing temperature should lead to an increase in the rate of evaporation. As the ratio of the values of evaporation and precipitation determines whether a climate is moist or arid, aridity will increase where the increase in temperature does not correspond to the increase in precipitation. The aridity will have a significant impact on surface runoff and replenishment of groundwater. In arid climates, the amount of potential evaporation exceeds precipitation, and actual evaporation depends on the amount of water available for evaporation. Only in periods when there is sufficient rainfall to flood the evaporation, there is a flow going on or infiltration into groundwater.

D. Changes in the replenishment and groundwater

One of the most difficult problems of water resources management is the monitoring and management of groundwater, from these it depends on the water supply of many communities. Since they are “invisible”, their irrational use is often recognized only when the pumps cease to pump water. When runoff, generated by precipitation and reach rivers and other watercourses, is affected by changes in temperature and patterns of land use, they equally affect the infiltration of water into aquifers.

E. Water quality

The ability of surface water to take, to dilute and to restore the quality of wastewater depends on the volume of runoff. Any reduction in the flow of rivers will reduce their ability to dilute wastewater; and additional investments will be required to provide the same standards of protection of the environment or wastewater treatment for reuse. The change in the flow regime and temperatures can lead to negative impacts on water quality making the water unfit for use.

F. Floods, droughts and more intense and frequent storms

One of the direct and obvious impacts of a changing precipitation regime will change the nature of floods and droughts. Increased air temperatures will cause more evaporation from the surface of the ocean and other water surfaces, which in turn will create the potential for loss more frequent and intense precipitation.

G. Melting and reduction of inventories of glaciers and snow cover

The shrinking of area of glaciers and reduction in the volume of water “stored” on the snowy plains is one of the first impacts on water resources is expected as a result of climate change. The loss of glaciers is particularly important in the Andes region of South America and the Himalayan region in South Asia. In the Andes the water supply usually depends on the melting of glaciers and snow. The Ecuadorian capital, Quito, for instance, receives 50% of water for its water supply due to melting glaciers Antisana and Cotopaxi. In a rich agricultural basin of the Indus River, where around 180 million people, 50% of river runoff is formed due to melting glaciers. The attendant risk is the uncertainty about possible floods in the breakout of lakes created by glaciers. As glaciers melt, they often form lakes, the water level of which is propped up by bog sediment dams formed by boulders and soil, otragenie moving glacier. During the retreat of glaciers, these lakes increase, and their naturally formed dams is increasing the pressure by raising the water level. The result of the breakthrough of these lakes can be unpredictable and catastrophic floods.

H. *Monitoring of data and hydrology changes*

Water specialists should be able to track changes, and to develop and advise the implementation of appropriate responses. This requires tools to collect substantial amounts of data, analysis and interpretation, providing event planning and informing the public about their impacts.
At the national level, especially in many poorer countries, hydrological information systems have allowed to disintegrate under the pressure of the need to reallocate scarce resources to solve a larger number of pressing issues. When faced with budget constraints, hydrology, often, is one of the areas of activity that sacrifice in the first place. Unfortunately, as soon as the account is lost or is not in full, then it is very difficult to restore it. This is a problem not only in developing countries. Even in wealthy countries, the goal of monitoring was not achieved.
There are several reasons for the degradation of collection systems and data processing. In addition to internal conflict and budget constraints, there are cases where data are available, but because of the growing competition in the field of water resources, there is reluctance to share its information with other beneficiaries.

III. THE IMPACT OF CHANGES IN WATER RESOURCES FOR HUMAN DEVELOPMENT OF KURA BASIN COUNTRIES. CASE STUDY

Kura is the largest river of Transcaucasia. The length of the river is 1364 km, while the basin area is 188 km2. The basin is home to about 13 million people. There are five developing countries in the Kura river basin. They are Turkey, Armenia, Iran, Georgia and Azerbaijan. All of the countries belong to the group with a medium level of human development.
The main rivers that are flowing from the lesser Caucasus are Agstafachay, Tovuzchay, Asrikchay, Zayamchay, Shamkirchay, Ganjachay rivers, Kurekchay and Tartar. All of these rivers are going directly into the river or into reservoirs on the Kura River. In most areas of the river region – the only source of drinking water and water for irrigation and industry. This makes the water sector a top priority in the region. Water shortages and pollution, combined with problems of control (for example, does not apply integrated water resources management and integration of users) are the main obstacles to sustainable water supply in the region. In the report on human development 2007-2008 it was identified five key transmission mechanisms through which climate change can halt, and eventually reverse human development:

- Agricultural production and food security
- Water stress and lack of water security
- Sea level rise and the increased frequency of climate disasters
- Ecosystems and biodiversity
- Human health

None of these five factors is valid individually. They interact with wider social, economic and environmental processes that determine the possibilities for human development. Below are data about water resources and water availability of countries in the Kura basin (Table 1).

№	Country	Population (million)	Annual precipitation km3 /year	Water resources, km3/ year	Water resources per capita, m3/year	Total water use, %
1	Azerbaijan	8,447	400	30	5380	57
2	Georgia	5,074	1000	63	12480	6
3	Armenia	3,052	600	10	3450	28
4	Turkey	72,320	600	214	2950	18
5	Iran	69,788	200	138	1970	53

Table 1. Water resources and water management in countries of Kura basin

The main problems of the region associated with water are:

- Shortage of drinking and irrigation water
- Pollution of water resources
- Poor condition of wastewater treatment facilities
- Lack of progressive technologies of irrigation
- Excessive water loss during transportation

Priority transboundary issues in the Kura-Araz with the participation of representatives of Iran, Armenia, Georgia and Azerbaijan were identified as following:

- Change and reduction of water resources
- Degradation of ecosystems in the river basin
- Deterioration of water quality (pollution)
- Flooding and coastal erosion

Over the past 30 years in countries of the South Caucasus as a result of restructuring, major changes have occurred in industry and agriculture, which could not affect the issues of water use and water availability, the impact of processes of economic activities on hydrological regime and water resources.
It should be mentioned that the characteristics of water resources are very sensitive to even minor climate changes and immediately respond to them. Therefore, in the present there is a real opportunity to assess hydrological observational consequences of climate change that gives a good basis for prediction of these processes on the near future.
The worst-case scenario of climate change in the region by the end of the twenty-first century:

- Rise in temperature of 5-60oC
- Significant reduction in the amount of precipitation
- Reduction in river flow of up to 50%

In Iran, the increase in temperature from 2.0oC to 6.0oC will increase evaporation by 6-12%, resulting in a decrease in annual flow of rivers may be of 50.2 -50.3%.

In Armenia, with the increase in air temperature by 1.5–2.0oC and the decrease in annual precipitation by 10-15% it is expected the reduction in total annual river flow by 15-20%.
In Azerbaijan, it was concluded that the effect of global warming water resources will be reduced as well by 15-20%.
The key effects of the changes in water-climatic conditions on the factor of human development in the Kura basin:

- Lack of water in everyday life and its poor quality has a negative effect on people's health, their life expectancy.
- Lack of irrigation water leads to a decrease not only in total agricultural products, but their yield per hectare. And this, in turn, can lead to forced migration of the rural population and will not reduce the level of poverty.

Excessive temperature increases in the summer months will adversely affect population health and labor productivity (change comfortable body temperature by 10 °C leads to a decrease in performance of 4%). High temperatures will create conditions for the spread of various diseases and epidemics such as malaria.
In conditions of modern climate change has dramatically increased the frequency of threat (extreme) hydrological events (floods, mudslides, droughts, etc.). If the drought is mainly affecting agriculture, floods destroy infrastructure, got demolished the house, etc.
Reduced water resources will reduce the amount of power generated in hydroelectric power stations, which also will adversely affect the quality of life of the population pool.
Key barriers to effective factoring climate change into water management strategies:

- Inadequate examination and incorrect assessment of changes in water resources under climate change;
- Lack of will and competence to implement adaptation measures to climate change;
- Lack of funds for the implementation of the planned measures because of the economic difficulties.
- Humanity will not be able to avoid climate change without drastic mitigation measures.
- Effective planning for adaptation to water and climate change can be summarized in four main areas:
- Information for effective planning
- Infrastructure to withstand water and climate change
- Insurance for social risk management and poverty reduction
- Institutions for managing the risks associated with natural disasters

IV. MITIGATION TECHNIQUES THROUGH WATER RESOURCE MANAGEMENT

It is noted that as soon as the climate begins to change, the water sector will be the first among the sectors that are most susceptible to impacts. It is important to pay equal attention to the impacts of rapidly changing climate (adaptation), and the driving forces of these changes (mitigation).
Some of the impacts of climate change will simply reflect the role of water in all of our lives. For example, will require adaptation of rainfed agriculture to the new situation arising from changes in the amount and timing of rainfall. Health systems will need to cope with changes in the structure of the spread of diseases such as cholera and malaria, due to changes in the environment. Will require changes in infrastructure, including roads and buildings, and of course the layout of the villages to adapt to changes in precipitation and river flow regime. It may also affect many industries and a large part of agriculture, which become very vulnerable if their water supply is unstable.
Since climate change impacts manifest themselves strongly in the aquatic environment, there is also the danger that they can spread beyond the water sector. If the relationship between climate change and water resources has not been studied, the strategies for adapting to climate change developed in other sectors, can only exacerbate the problems and increase the vulnerability of populations and their habitat from natural and anthropogenic disasters.
Therefore, water resources will be a key aspect of risks and responses adaptation to climate change. Not to say that water management provides the answers to all the questions because of the need to find solutions in many sectors. In addition, water resources are both part of the problem and partly the solution.

A. Hydro-dams

Approximately 75% of water reservoirs in the world were built for irrigation, flood management and urban water supply. Greenhouse gas emissions vary depending on locations of reservoirs, the power density (power per area flooded), flow velocity and type of stations – based on the dam or run-of-river reservoir. Recently, the fact of emissions from reservoirs of hydro power plants questioned. Significant methane emissions were registered in the shallow plateau-like tropical reservoirs where the natural carbon cycle is most productive, while deep-water reservoirs are characterized by lower emissions. The methane from natural floodplains and wetlands may be blocked if they are flooded by a new reservoir since the methane is oxidized as you rise in the water column. Methane formation in freshwater includes a by – product carbon compounds (phenolic and humic acids) that effectively bind the participating carbon. For small tropical reservoirs it is necessary to conduct further studies to determine the extent to which they can increase methane emissions.
Emissions of greenhouse gases from reservoirs due to rotting vegetation and carbon input from the catchment area are recently established impact of dams on ecosystems. This is not consistent with the conventional view that hydropower has only a positive impact on the environment (e.g., reducing CO_2 emissions and oxides of nitrogen) when compared with conventional sources of energy.

B. Irrigation

Approximately 18% of the world's arable land is currently receiving additional water through irrigation. Expanding this area (where allow the water supply) or using more effective irrigation measures can enhance the storage of soil carbon by increasing yields and plowing of crop residues. However, some of these benefits may be offset by the carbon dioxide resulting from energy use for delivery of this water, or by N_2O emissions due to higher humidity and the formation of nitrogen from fertilizers, although the influence of the latter has not been evaluated quantitatively in broad terms. The extension of the area of wetlands for rice cultivation can also cause increased emissions of methane from the soil.

C. Plowing remains of plants

Competition of weeds for water is an important cause of crop failure crops or reduce crop yields worldwide. The latest achievements in methods of weed control and agricultural technology presently make it possible to grow many crops with minimal tillage (limited tillage) or without tillage (zero tillage). These methods, which lead to the preservation of the remnants of crops on the soil surface, allowing, thus, to avoid wasting water to evaporation, is currently increasingly used worldwide. The use of limited or zero tillage may also influence N2O emissions, but the cumulative effects are inconsistent and not always well defined quantitatively in the global plan. The effects of limited tillage on N2O emissions may depend on soil conditions and climate: in some areas, limited tillage promotes N2O emissions; in other areas it may reduce emissions or not to exert any measurable effects. In addition, systems with zero tillage may reduce carbon dioxide emissions resulting from the use of energy. System, there are remnants of cultures also tend to increase the content of soil carbon because these residues are the source for organic matter is the main carbon stock in the soil.

D. Drainage of arable land

Drainage of arable lands in humid regions can promote productivity (and hence the conservation of soil carbon) and perhaps also inhibits N2O emissions, thus improving aeration. Any loss of nitrogen through drainage, may, however, also occur in the form of loss of N2O.

E. Wastewater treatment

For CH4 generated in landfills - the largest source of GHG emissions in the waste sector, emissions continue several decades after waste disposal, and thus estimation of emission trends requires models which include temporal trends. CH4 is also emitted during wastewater transport, sewage treatment processes and leakages of anaerobic digestion of waste or sewage sludge. The main source of N2O is the purification of sewage and wastewater.

In developing countries due to rapid population growth and urbanization without concurrent development of infrastructure for wastewater treatment emissions of CH4 and N2O from wastewater in General higher than in developed countries. Open sewers or informal, sedimentation tanks in developing countries often result in uncontrolled discharges to rivers and lakes causing rapid growth in the volume of wastewater occurring simultaneously with economic development.

Overall, the quantitative indicator of collected and treated wastewater is increasing in many countries to maintain and improve the quality of drinking water, as well as other benefits to health and environment. At the same time, GHG emissions from wastewater will be reduced in comparison with the future increase of the collection and treatment of wastewater.

F. Desalination

In regions with water scarcity, water can be (partly) by desalination of salt water. This process requires energy and this implies the formation of GHG emissions in case of use of fossil fuels.

G. Geothermal energy

The use of geothermal energy for heating purposes is not associated with the formation of GHG emissions, as is the case with other methods of energy production.

V. CONCLUSION

Thus, changes in rainfall and river flow parameters will affect all water users. Increased uncertainty and change in water consumption by crops are threatened, especially for poor farmers, who seeded rainfed land. Intensification of droughts, floods, typhoons and monsoons will further increase the vulnerability of many people. There also might be quick increase of risk and uncertainty associated with epidemics of diseases transmitted by water and melting of glaciers, floods, breakthroughs of lakes of glacial origin or increase of level of World Ocean. A particular concern is that these impacts of climate change will more likely affect the poorest segments of the population who are less able to resist them now and in the future. Although the nature and degree of these impacts cannot be predicted with absolute certainty, long-term management of water resources dictates the need to prepare responses now. However, that is good that management of water resources also contributes to the control of current climate variability and shocks, which are fundamental problems that are today hindering the development of the poorest countries in the world.

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