CLIMATE CHANGE IMPACTS ON WATER RESOURCES

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ABSTRACT. – Climate change impacts on water resources – The most recent scientific assessment by the Intergovernmental Panel on Climate Change (IPCC) [6] concludes that, since the late 19th century, anthropogenic induced emissions of greenhouse gases have contributed to an increase in global surface temperatures of about 0.3 to 0.6^{o} C. Based on the IPCC's scenario of future greenhouse gas emissions and aerosols a further increase of 2^{o} C is expected by the year 2100. Plants, animals, natural and managed ecosystems, and human settlements are susceptible to variations in the storage, fluxes, and quality of water and sensitive to climate change. From urban and agricultural water supplies to flood management and aquatic ecosystem protection, global warming is affecting all aspects of water resource management. Rising temperatures, loss of snowpack, escalating size and frequency of flood events, and rising sea levels are just some of the impacts of climate change that have broad implications for the management of water resources. With robust scientific evidence showing that human-induced climate change is occurring, it is critical to understand how water quantity and quality might be affected. The purpose of this paper is to highlight the environmental risks caused by climate anomalies on water resources, to examine the negative impacts of a greenhouse warming on the supply and demand for water and the resulting socio-economic implications.

Keywords: climate change, environmental risk, water resources, GHG.

1. INTRODUCTION

The rapid changes in the environment are caused by rising world population, the growth rate of consumption of resources by human society and by technology changes. The most important component of global change is climate modification due to the amplification of the natural greenhouse effect, caused by anthropogenic emission of greenhouse gases (GHG), which will have an important impact on the environment and on social-economical activities.

The present climate change felt more strongly in recent years in Romania and all over the world represents the trigger of an endless chain of consequences that affects all four environment components, the social-economic activities and quality of life.

Currently, the dominant theory concerning the causes that led to present climate change lies with the UN Intergovernmental Panel on Climate Change (IPCC), which argues that global warming had resulted from increasing concentrations of anthropogenic GHG in the twentieth century.

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The conclusions of the Global Environmental Change"The Threat to Human Health", published by the World Watch Institute and United Nations Foundation [2] asserts that the changes the are taking place in the climate and ecosystems threaten the very foundations of human health (access to adequate food resources, clean air, clean water and safe housing) and are, at this point, the biggest challenge of the XXI century, with regard to public health.

2. THE IMPACTS AND POSSIBLE SCENARIOS OF CLIMATE CHANGE

The effects of climate change are already being felt, with impacts across bioceonosis spaces, human life and many economic sectors. While there will clearly be some gains from climate change, most of the impacts will be negative, and gains and losses will not be evenly distributed. [3]

Table 1.***The impact of climate change on critical areas*[3]**

Water	Rising global temperatures will lead to an intensification of the hydrological cycle, resulting in dryer dry seasons and wetter rainy seasons, heightened risks of more extreme and frequent floods and drought with significant impacts on the availabi-lity of water, as well as the quality and quantity of water that is available and accessible. Melting glaciers will increase flood risk during the rainy season, and strongly reduce dry-season water supplies to one-sixth of the World's population.
Agriculture	Declining crop yields are likely to leave hundreds of millions without the ability to produce or purchase sufficient food supplies, especially in Africa. Agriculture in some northern regions should increase in productivity due to a rise in temperatures, but will decline at higher levels of temperature change.
Ecosystems	Ecosystems may shift – forests, land types and plant species will dieback in some areas as temperatures rise, but increase in other areas. In many cases, the pace of change in temperature may be too fast for ecosystems to adjust, resulting in the loss of forests and species.
Health	Higher temperatures expand the range of some dangerous diseases, such as malaria, which already kills one million people annually, most of whom are children in the developing world. Heat waves associated with climate change, and increases in water borne diseases, will result in increased health problems.
Coastlines	Melting ice and thermal expansion of oceans are the key factors driving sea level rise. In addition to exposing coastlines, where the majority of the human population lives, to greater erosion and flooding pressures, rising sea levels will also lead to salt water contamination of groundwater supplies, threatening the quality and quantity of freshwater access to large percentages of the population.

In Romania, projections of global scenarios, namely the period 1991-2099 compared to 1961-1990, shows a rising average of air temperature of about 2° C in winter and 3.5 - 4.3° C in summer season (3.5° C in northern, 4.3° C in southern territory).

In terms of precipitation changes are significant; deficits during summer surpluses in winter, light surpluses in the north-west part and deficits in south-western regions of our country.

In the twentieth century, the effects of global warming reveals increase in mean annual temperature of 0.3° C, almost in the entire country, being more pronounced in southern and eastern areas. In terms of seasonality, there have been significant warming during winter and summer (the most pronounced being recorded in Bucharest-Filaret, with 1.9° C), and cooling during autumn more significant in the western regions of the country. [7]

3. CURRENT IMPACT OF CLIMATE CHANGE ON WATER RESOURCES IN ROMANIA

Observations and measurements made in the world and in Romania on some climatic parameters and the effects of climate on water resources show certain signs that support the hypothesis of climate change. Among the signals produced in Romania, worthy of consideration, are [7]:

- Over the last 100 years has been proved the global warming trend in Romania, with the largest increases of up to 0.4° C in industrial areas;
- Aridity phenomenon of climate and increased frequency of occurrence of extreme values of temperature and precipitation:
- Record of extreme temperatures in Romania: 44.5^{o} C at Râmnicelu (10.08.1951), 44,3^{o} C at Calafat (24.07.2007);
- Intense rain falling on the small areas that produce catastrophic effects: (e.g. 120 mm/m^2 rain that fell in 40 minutes near Buzau, Cuculeasa, June 22 1999 and 285 mm/m^2 rain that fell in 30 hours in Bucharest 21-22 September 2005, which represents 60% of annual rainfall);

The emergence of non-specific weather climate in Romania (the Făcăieni tornado);

Increased frequency of catastrophic floods

Chroniclers recorded regularly over time, catastrophic floods: 10 the sixteenth century, 19 in the seventeenth century, 26 in the eighteenth century, 28 in the nineteenth century and 42 in the twentieth century.

Six catastrophic floods occurred in Romania in 2005 with a probability of producing between 1% and 0.5%: in April, Timiş and Bega river; June, Argeş, Vedea and Olt river, July, lower Siret and Trotuş basins, August, higher Siret basin; September Ialomiţa river, Dambovița and coastal area, December, basins of Banat area.

Increase of the maximum annual flow of the Danube. In the last 166 years is a tendency to increase the maximum flow at Baziaş with 1200 m^3/s due, mainly, to the climate changing and of impoundment on upstream Danube and its tributaries.

Increase by 34 cm of sea level during 1860–2004.

4. THE QUANTITY AND DISTRIBUTION OF WATER ON EARTH

For decades there have been made great efforts to determine the amount and distribution of water. The total amount of water present on our planet is estimated at about 1.4 billion cubic kilometers. Estimates suggest more accurate figure of 1357.506 x 1015m^3 [11].

Europe's water resources is estimated at 1015 m^3 groundwater, 2580 x 109 m^3 surface water (131 x 109 m^3 in rivers, 2027 x 109 m^3 natural lakes, 422 x 109 m^3 in artificial reservoirs) and 4090 x 109 m^3 in glaciers. Average flow (runoff = precipitation minus soil absorption and evaporation) is 304 mm/year, estimated about 3100 x 109 m^3 for a territory of 10.2 million km^2.

Compared to the European population (680 million inhabitants), this is theoretically 4560 m^3/capita/year at a current total capture of 700 m^3/capita/year. [7]. Existing water distribution in Europe is uneven. Northern European countries have per capita, 8.6 times more resources than others. It is estimated that close to urban centers in all European countries except Ireland, surface and groundwater resources are overexploited.

Compared with the rest of Europe, Romania is a country with limited water resources. Despite the completion of many reservoirs, the volume of surface water is modest with relatively small rivers flow.

In figures, Romania's total water resources are estimated at 40 x 109 m^3/year, of which only 5 x 109 m^3 in rivers per year and 3 x 109 m^3/year of groundwater. The hydro potential is approximated at 1750 m^3/inhabitant/year comparing the European average which is 4800 m^3/inhabitant/year.

5. WATER NEEDS OF HUMAN SOCIETY

Ensuring adequate public water is a problem everywhere, although in principle it is a declared priority over other needs for water (industry, agriculture, etc.). Water consumption has continuously increased worldwide three times since 1950 and the definitive loss of surface and groundwater has increased more than sevenfold in the last century.

Thus in 1980 the water consumption per capita was 1980 m^3 in the U.S., 1172 in Canada, 962 in Egypt, 946 in Finland, 836 in Belgium, 460 in China, 423 in Poland, only 60 in Malta, in 1990, industrial water consumption reached 250 million tons for iron and steel industry, 30 million tons of aluminum industry, 21 million tons for chemical fertilizer industry, 14 million tons for food industry, 47 million tons for pulp and paper industry, 50 million tons for textile industry, 75 million tons of oil refining industry, 15 million tons in other industries, a total of over 500 million tons of water.[8]

In Europe, water use by category of use is very different from one country to another. Thus, in Germany, Belgium, Finland, Lithuania, over 80% of abstraction is used in industry, in Greece, Italy, Denmark, Spain, the industry consumes less than 30%.

In Romania, water use is very diverse, with a number of peculiarities: price is still very low, with low consumption efficiency.

Table 2. ***Development of Water requirements in Romania*****[6]**

YEAR	WATER DEMAND [m^3/an]	IRRETRIEVABLE [billions m^3/an]
1975	14.4	9.7
1980	22.4	15.3
1990	35	25.6
2000-2010	46	36

5. SOURCES AND SITUATION OF ENSURE NECESSARY WATER SUPPLY

Specific water availability of the continents (in cubic meters/per year) of water that fall on 1 km^2 of area and per one person is presented in Table 3.

Table 3. ***Renewable water resources and water availability by continents*** **[9]**

Continent/ Area, [billions.km^2]	Population, billions	Water resources, km^3/year			Potential water availability, 1000m^3/year	
		Average	Max	Min	per 1km2	per capita
Europe [10.46]	685	2900	3410	2254	277	4.23
America N [24.3]	453	7890	8917	6895	324	17.4
Africa [30.1]	708	4050	5082	3073	134	5.72
Asia [43.5]	3445	13510	15008	11800	311	3.92
America S [17.9]	315	12030	14350	10320	672	38.2
Australia and Oceania [8.95]	28.7	2404	2880	1891	269	83.7
The World [135]	5633	42785	44751	39775	317	7.60

Due to a rapid Earth's population growth in the last decades the potential water availability of Earth's population decreased from 12.9 down to 7.6 thousand m^3 per year/person. The greatest reduction of population water supply took place in Africa (by 2.8 times), Asia (by two times), and South America (by 1.7 times), and only with 16% per Europe.

On Figure 1 the specific water availability (thousand m^3 per year per capita) of every region is designated with shading by the following gradations: < 1 catastrophically low; 1.1 - 2.0 very low; 2.1 - 5.0 low; 5.1 - 10 average; 10.1 - 20 high; > 20 very high.[7]

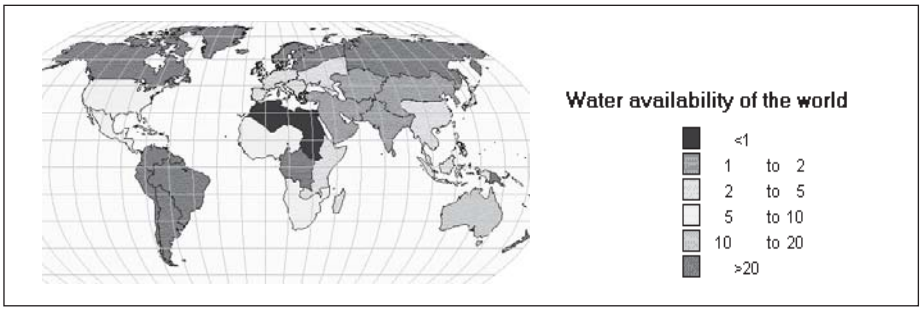

Fig. 1. ***The specific water availability (m^3/year/capita) around the world*** [8]

Table 4 shows the dynamics of water use by the continents for the current century and a forecast till 2025 obtained on the basis of the above initial data and methodological approaches.

Table 4. ***Dynamics of water use in the World by continents (km^3/year)*** **[9]**

Continent	Assessment						Forecast
	1900	**1950**	**1990**	**1995**	**2000**	**2010**	**2025**
Europe	37.5	136	482	455	463	535	559
	13.8	50.5	198	189	197	234	256
America N	69.6	287	653	686	705	744	786
	29.2	104	221	237	243	255	269
Africa	40.7	55.8	203	219	235	275	337
	27.5	37.8	150	160	170	191	220
Asia	414	843	2114	2231	2357	2628	3254
	249	540	1315	1381	1458	1593	1876
America S	15.1	49.3	152	167	182	213	260
	10.8	31.7	81.9	89.4	96.0	106	120
Australia/ Oceania	1.60	10.4	28.5	30.4	32.5	35.7	39.5
	0.58	5.04	16.4	17.5	18.7	20.4	22.3
Total	579	1382	3633	3788	3973	4431	5235
	331	768	1982	2074	2182	2399	2764

Note: First line - water note: withdrawal, second - water consumption

To see more clearly the distribution of specific water availability values by natural-economic regions of the world, it is presented on global charts for 1950, 1995, and 2025.

6. THE IMPACT OF WATER ISSUES ON HUMANS LIFE

Climate change is one of the major challenges of our century - a complex area in which we should improve our knowledge and understanding for taking immediate and correct action to adapt to future climate conditions.

Drought (excessive lowering of the groundwater) and desertification (reduction of soil surface covered with vegetation and considerable depletion and soil erosion) is, as pollution, the second biggest problem facing the world, affecting all regions of the globe.

Worldwide, 3.6 billion hectares of the 5.2 billion hectares of arable land, is prone to drought. Annually, desertification is expanding at 50 000 hectares of land in the world. Desertification, present in over 110 countries, is affecting approximately 1 billion people and it's causing annual damage of 42 billion dollars. [9]

Drought and desertification affect sustainable development through interrelated social problems that it generates and enhances: reducing water supplies, the potential for food production, hence food security of the population, poverty as the worst dysfunction in the areas affected by these phenomena and deteriorating health due to inadequate food consumption, resulting in anemia and malnutrition.

In Romania there is a clear trend of intensification and extension of droughts and desertification of natural causes, but also from anthropogenic causes (deforestation, destruction of irrigation systems, etc). Of the 14.7 million hectares of farmland, about 7 million hectares (48%) are affected by drought for long periods in consecutive years. [10] Currently in our country, the phenomenon of desertification manifests on approx. 350 000 hectares. Some experts say that unless action is taken in time, it is likely that the population in southern Romania is forced to migrate over the next two decades, in the northern areas.

The most affected areas are south and south-west of Oltenia, the south-east of Banat, southern Moldova (sandy area of Hanul Conachi) and Dobrogea. In extremely dry years, the phenomenon of drought may comprise almost the entire territory of our country, as happened in more recent years, 2000 and 2003. Large precipitation deficits occurred in 1907, 1924, 1928, 1934, 1945, 1946, 1948, 1953, 1982, 1983, 1992, 1993 and more recently, in recent years, namely, 2000 2001, 2002 and 2003. [2]

Floods are the most destructive natural phenomenon of high frequency worldwide. Annually, floods occur on Earth more than 20 000 deaths and 100 million people are affected, to varying extents, the consequences of this phenomenon.

In Europe, flooding is also the most common type of natural disaster. Floods have caused about 43% of all natural disasters during 1998-2002, when there were approx. 100 serious floods, which caused about 700 deaths, displacement of about half a million people, economic losses of at least 25 billion, about 1.5% of Europe's population being affected. The European countries that were hardest hit frequent floods in recent years include United Kingdom, Romania, and Germany etc [7].

Flood risk map shows that most of our country is vulnerable to this type of disaster. Areas most at risk are located, particularly in basins of large rivers (Mureş, Someş, Criş, upper Olt, Siret), in areas along the Danube and its Delta as well as smaller rivers in central part of Moldova, which regularly suffers the consequences of flooding. [4]

For Romania, meteorologist's studies indicate an increase in mean annual temperature of 0.5^{o} C per country in the last century, with some differences by region. A more pronounced warming (0.8^{o} C) was observed in south and southeast, where the average annual temperature reached 11^{o}C.[5]

The population of Romania was confronted with large eco-climatic special events over the past two decades, but it seems that they have become more frequent after 2000: heat and drought (2003, 2005 and 2007), catastrophic rainfall and floods (in 2005 and 2006), extreme weather phenomena (tornado type, in 2002), and not at least the changing of the main features of seasons.

Year 2007, for example, was the warmest of the last 107 years in Romania, with maximum over 44^{o} C and greater persistence of hot days.

7. CONCLUSION

Climate change - a phenomenon clearly and widely recognized by scientists - generate heated arguments around explaining its causes, as recognition of one or other potential causes involve incurring huge costs for some operators.

Climate changes can lead to robust growth in poverty and undermine sustainable development, especially in less developed countries. Efforts to mitigate the effects of global climate change can strengthen the prospects for global development partly by reducing the risk of negative impact of climate change.

Global efforts against climate change have been initiated over 20 years ago (1988), when it was established the Intergovernmental Panel on Climate Change in the UN, that assesses the risks of climate change induced by these potential effects and options for adaptation and climate mitigation.

Available water amount is $1500m^3$ per capita and it is expected to decline to 1000 m^3 in 2050 as a result of population growth and impact of climate change.

In this study the authors evaluate global climate change and its impact on world's water resources.

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