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Problems of Water Management in Agriculture in the World

Abstract. In connection with the frequent occurrence of water deficit in Central Poland and the growth of the phenomena of droughts and stepping formation (and desertification in southern Europe), the studies undertaken by hydrologists and representatives of agricultural scientists should be extended and stepping formation and desertification economics should be separated in these studies. Therefore, the evaluation of the management strategies in the conditions of water deficit, undertaken in agriculture, power engineering and other sectors of the economy as well as the search of suitable sources of water management financing should be brought to the forefront as they are specific in Poland due to functioning of ecological funds.

Key words: crisis of water supply, water deficit, retention of rainwater, irrigation of agricultural areas, overexploitation of water resources, risk of food crisis

Introduction

Water has always been, is and will be the most precious natural resource. Its lack, shortage of water resources, results in serious economic and social problems. Water resources include all rainwaters suitable for the use in the form of the annually renewable amount of water and its elementary element is *the permanent runoff*, which amounts to 36-39% of the total runoff of the rivers in the world (about 31% in Poland). It is the so-called blue water which can be used in the economy before it evaporates or flows to seas and oceans. However, 61-64% of precipitation is "green" water, which evaporates from plants and the surface of soil, i.e. evapotranspiration (Mioduszewski, Szymczak, Kowalewski, 2011). Water resources mean the total amount of water circulating in the environment in the given area and fed with the retention processes which is storing rainwater. While it is true that there is a lot of water in the world, and none of other resources exists in such abundance, but as much as 97% of water resources is salty water in seas and oceans, and 2/3 of fresh water is accumulated in icecaps. Thus, only 0.5% of the world's resources of water in the form of underground and deep waters as well as rivers and lakes. These waters, similarly to precipitation, are not distributed evenly due to the localization of lands, their relief and the differentiation of temperatures. The condition of water engineering infrastructure as well as water and sewage one has a big influence, which is connected with the level of the social and economic development of countries and regions. This factor prejudices that in practice the deficit of water resources does not occur more often but the crisis of water supply (Their, 2016). This especially refers to the developing countries with the high percentage of rural population.

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Water and its resources are, apart from the so-called the agricultural culture, the fundamental factor conditioning the agricultural and livestock production. The aim of the article is to present the significance of water management for the development of agriculture, and next the identification of the factors stimulating and hindering the use of water in the processes of irrigation of agricultural areas. This article is part of the unpublished in English A. Thier's dissertation. The originator of this article and its concept is the second author because of the importance of issues.

Water resources in the world

The average annual world's precipitation is 710 mm, 470 mm of which returns to the atmosphere as vapour and 240 mm makes up surface, ground and deep runoff. The average time of water retention in the atmosphere is 9 days, 1-2 months in soil (as humidity), 2-6 months in rivers, 50-100 years in lakes, 20-100 years in icecaps (20,000 years in Antarctica), 3,200 years in oceans, 10-100 thousands of years in ground waters. Thus, ground waters and icecaps in Greenland and Antarctica are a kind of reserve and strategic water resources, and their circulation in the nature is significantly slower.

Table 1. Renewability of water resources in the world per continents

Continent	Area million km ²	Population million 2005 and 2012	Renewable water resources (runoff from the surface in km ³ /year)			Water resources per 1 inhabitant in thousands m ³ /year in 2005 and 2012	Resources per 1 km ² of the area in thousands m ³
			average	max	min		
Europe	10.46	730 742	2900	3410	2254	3.97	277.2
Poland	0.31	38.5	61.9	86.9	49.7	3.91	198
North America (with Mexico)	21.8	392 466	7890	8917	6895	23.98 16.93	361.9
Africa	30.1	906 1084	4050	5082	3073	4.47 3.74	134.6
Asia	43.5	3921 4255	13510	15008	11800	3.45 3.18	310.6
South and Central America	20.5	373 496	12030	14350	10320	32.25 24.25	586.8
Australia and Oceania	8.95	33 38	2404	28080	1891	72.85 63.26	268.6
World	136	6470 7080	42785	44751	39775	6.61 5.42	314.6

Source: Kowalczak 2007; Poskrobko, Poskrobko, Skiba 2007 and own calculations.

Europe is inhabited by 11% of the world's population but it only has access to 8% of the global water resources. It amounts to 4-4,600 m³ per 1 inhabitant (almost 1,600 m³ in Poland) in comparison with the world's average 7,400 m³. Yet, this indicator is only about 1,000 m³/1 inhabitant in Northern Africa and in the Middle East. North America is the richest in water as its population amounts only to 5% of the population and the share in water resources is 26%. It is illustrated by Table 1.

According to *the World Water Development Report*, for 180 countries, the poorest water resources characterize such countries and areas as Kuwait (where 10 m³ of water is per 1 inhabitant annually), next the Gaza Strip, Palestine (52 m³), the United Arab Emirates (58 m³), the Bahama Islands (66 m³), Qatar (94 m³), the Maldives (103 m³), Libya (113 m³), Saudi Arabia (118 m³), Malta (129 m³) and Singapore (149 m³). The following countries belong to the richest in water resources (excluding Greenland and Alaska): French Guiana (812 thousands m³), Island (609 thousands m³), Guyana (316 thousands m³), Suriname (292 thousands m³), Congo (275 thousands m³), Papua New Guinea (166 thousands m³), Gabon (133 thousands m³), the Salomon Islands (100 thousands m³), Canada (94 thousands m³) and New Zealand (86 thousands m³). According to the predictions in this report, these indicators may worsen until 2050³.

The presented data prove the known opinion that the distribution of water resources is uneven. It was influenced by the factors which played the central role in the evolutionary formation process of the current surface of our planet, including especially the hydrological and meteorological cycle. This cycle is present everywhere in the nature and decides on the incessant water circulation in the atmosphere, nevertheless it does not lead to the balance of its resources and streams.

Share of agriculture in water consumption

According to *the World Water Development Report* and other UN reports, agriculture is the biggest user of water in the world, which makes up 67-69% of the world's consumption, 40% in Europe, and only 10% in Poland. The water consumption for communal needs in the developed countries amount to 20%, in the less developed ones below 10%, and the world's average is 12% (The millennium..., 2015). It is recommended to consider where the consumption of water should be limited in Europe or where additional sources of fresh water should be provided. Although nowadays water resources seem to be abundant, one should realize the fact that the sources of clean water are definitely limited. The level of water is lowering every year and additionally the surface waters, among the others due to contamination, are more and more difficult to be recycled so that they could be used by a man and even for irrigation in agriculture.

There are special and specific difficulties in Africa and Asia since the percentage of water used in agriculture is generally even higher and amounts to over 85%. While the consumption of water for the living in the households in these countries is only 5-8%. The daily amount of water consumed by the inhabitants of the richest countries equals the monthly amount of water consumed by the inhabitants of the poorest countries (therefore, the first ones live beyond their means in terms of water). The use of water in some regions

³ *World Water Development Report* published by UNESCO, <http://www.unesco.org.2003>; the UN Information Centre published the discussion in the translation into Polish in: http://www.unic.un.org.pl/iyfw/raport_gwns.php

of Africa is below the minimum 25 litres/inhabitant/day which was defined by the WHO. The recommended indicator is 80-100 litres. Therefore, it is concluded that most of the countries in Africa die owing to the lack of access to fresh, clean water.

The main sector of the economy consuming water resources in Asia is agriculture. Table 2 depicts the exemplary comparison of water consumption in India, the USA and in Poland. Now, in India, the relatively poor country of the low industrialization, almost all the water is used in agriculture, and only its little part in the industry and the urban economy. In the USA the proportions are much more even due to the higher degree of industrialization of the country as well as owing to the bigger access to water and the well-developed urban economy. The structure of water consumption in Poland is similar.

Table 2. Structure of water consumption in the USA, India and Poland as well as in the world, in %

Items	Industry	Agriculture and forestry	Urban economy
USA	45	32	23
India	4	94	2
Poland	69	10	21
World	16	67	17

Source: UN Statistical Yearbook. The UN, New York 2015.

According to the report of the WDDR of 2003, the share of agriculture in the intake of water amounted to as much as 69%, and it exceeded 70% in some countries. It is concluded from the latest estimates that the share of agriculture in water consumption in the world amounted to as much as 71% in 2013, including over 90% in Afghanistan, India, Pakistan, Sudan and Turkmenia and about 70% in Saudi Arabia, Australia, Chile, Chad, Egypt, Indonesia⁴. Yet, this situation is changing. The biggest decrease in the share of agriculture can be observed in South America from 82% in 1950 to the predicted figure of 44% in 2025. Generally, it happens on all the continents in favour of the industry and the needs of the urban economy. For instance, the share of industry in water consumption in Asia in the studied period is increasing from 2.3% to about 10%. Europe is an exception where the share of industry in this structure is high, but it is decreasing. Besides, Europe (and also the USA and Canada), including especially Poland, is characterised by the different structure of water consumption than the world economy as in most European countries the share of the urban economy (fresh water) in the use in total amounts, according to the author's estimate, to 12-18% and the share of agriculture 3-12%, with the exception of Spain and Turkey where this indicator distinctly amounts to over 60% (Table 3). Therefore, competition in water consumption between the sectors of the economy has been increasing over time as so far its delivery for agriculture has been undisputed although often wrongly used, but – after the period of the increase in the urban economy and the industry - in the light of the needs for irrigation of crops, this issue requires the new strategy.

The development of agriculture, industry and services also contributes to the increase in water consumption as it is a resource needed in the production and service processes, and some of them are very water-inefficient. While it is true that the technological development results in the decrease in water consumption per unit in the production processes, but in

⁴<http://wdi.worldbank.org/table/3.3> and <http://data.worldbank.org/indicator/SH.H2O.SAFE.ZS>

spite of this fact the development of the economy influences the increase in the total demand for this resource in the developing countries.

Table 3. Water intake for the use in agriculture in the chosen European countries

Countries	Water intake in total m ³ per inhabitant		Share of agriculture in the intake in total in % from 2012 to 2013 ^{b)}
	2010	2013	
Belgium	580	462.0	0.6-0.8
Bulgaria	805	750.7	16
Czech Republic	186	157.0 ^{a)}	2.1-2.7
France	495	457.7	about 12
Spain	710	797.7	about 60-70
Holland	645	641.0	0.7-1.1
Germany	390	310.1	0.5-0.8
Poland	300	293.9 ^{a)}	9.7-10.1
Rumania	320	320.6	17.8
Slovakia	146	103.3 ^{a)}	3.2-4.1
Slovenia	460	609.4 ^{a)}	0.5
Switzerland	333	252.0	about 3
Sweden	290	287.9	about 4
Turkey	625	676.0	about 70-80
Hungary	540	508.6	7-13

a) Year 2014

b) Estimated data owing to the differences in the classification

Source: Eurostat database. Environmental protection. GUS, Warsaw 2016, 471-472 and own calculations.

Agriculture and industry in numerous countries suffer from the more and more difficult hydrological conditions. The shortage of water is a frequent problem, but it does not concern everybody. For example, in these parts of India which are affected by the lack of access to water, irrigation pumps pump water from water-bearing layers to the farms of rich farmers all the time, whereas small farmers depend on changeable precipitation. Here, the reason of the shortage of water in most cases is not its quantitative lack but the wrong policy of the authorities. The shortage is the consequence of the economic policy of the state in a lot of countries which led to the excessive consumption of water with subsidies and the decrease in prices. However, the poor are constantly devoid of access to water owing to the limited rights and the underestimation of the issue of access to the sanitary and water infrastructure by the state. Therefore, the shortage of water results from the different actions discriminating poor people, which has already been, or at last, criticised.

Social aspects of water management

If water is to be the cause and the main engine of development of the social and economic life, one should change the political and economic structures, and first of all, the way of thinking of the man. One should realize in the first place that the right to water is an

indispensable condition of social security in the rural areas. The sudden loss of water or the limitation to the entitlement to water can threaten the human life and effectively contribute to the increase in poverty, which consequently leads to the loss of security. The right to water is more important for the poor than for the rich for the obvious reason, poor people do not have sufficient resources or political influences in order to defend their position sufficiently enough. The reforms of the hydrological economy teach us how essential is justice in the field of the rational management of water resources. Contrary to the reforms of the land use, the fair division is not paid such attention to in the plans of the reform of the water management. It is a serious mistake of the structural character, which contributes to the non-sustainable social and economic development. The good example of the influence of the water management on wealth or poverty is the irrigation system. The research showed that the degree of the poverty distribution is by 20%-40% lower in the areas with the irrigation network, however, there are big fluctuations here (Sen, 1982). Irrigation favours the decrease in poverty to a large extent in some countries, but in others does not help so much anymore. The uneven access to soil is a vital factor here. The countries where big inequalities exist (among others India, China, the Philippines) are less effective and fair than the countries with less significant inequalities.

The shortage of water is the reason of the lack of possibility of the agricultural production in the dry and semi-dry zones, which is often the effect of the unfair division of water resources when the poor are generally losers. The polarization of the social classes exists especially in the developing countries. The bigger percentage, as much as over 65% of the poor population, is in the areas with the deficit of water resources in such countries as China or India. The consequences of such a division of society are surprising. Namely, in the 1970s and the 1980s there was famine owing to the long drought in the countries of the Sahara Desert in Western Africa, but in spite of that there were sufficient amounts of water to cultivate cotton, vegetables, peanuts intended for the export to Europe and the USA. These products were transported to Dakar by the same vessels which brought food aid for starving people. The similar situation occurred in Ethiopia in 1985 where a large part of the country was affected by the drought, causing the death of 300,000 people, but at the same time the satisfactory crops of sugar cane and cotton were obtained in the state farms in other regions of the country, intended for export. These facts illustrate that the polarization of the society pushes one group into poverty and leads to the disaster through the failure to help.

According to the reports, water consumption has already tripled in the last 50 years together with the increase in the population in some regions of the globe (Water..., 2003). This tendency will still be intensifying because the research shows that the population growing by about 80 million every year is increasing the demand for water by 12 billion m³. The demand for agricultural products is increasing together with the fast population growth, and 67% of water consumed in the world is used in various forms of agriculture. Currently, a lot of countries maximally use their water resources, which is caused by the natural increase and the needs generated by it, especially concerning irrigation. The growing demand for water increases the risk of food crisis. The best example is again Africa where the droughts and the decrease in water resources bring about constant problems with famine. As a consequence, every year millions of people's health deteriorates and they even die. Thus, access to water will be one of the key problems of security in the future.

According to the predictions of the UN, in 2025 about 8 billion people will live on the Earth which is about 38% more than nowadays. Therefore, it is estimated that the increase in the cereal yield by 40% will be necessary. This will in turn be connected with the

development of agriculture and the acquisition of new water resources. It is estimated that the irrigated area will have to be enlarged by about 30%, which is connected with the growth of the demand for water by 17%. It is evaluated that overexploitation of water resources both surface and underground ones already exists in India, Pakistan and even the USA (Spring, Brauch, 2011).

Fight against droughts

Due to the increasing global warming, the phenomenon of drought is more and more common in numerous states. In some regions, such as Syria (2006-2011), Australia ("the drought of the millennium" 1995-2009), India (54% of the area of the country suffers from water stress and in Punjab and Rajasthan there is a threat of the collapse of the agricultural production), northern China (due to the drought people emigrate to Siberia), California, south-eastern Brazil, Spain, the drought has been there for several years. The depletion of deep water resources has been noticed in Saudi Arabia. The processes of steppe formation and desertification are recorded also in Europe, especially in its southern part where there are permanent periods of drought. In 2003 the drought affected 53% of the area of the European Union and brought about the losses in agriculture at the amount of 12.5 billion Euro (then there were violent floods). The steppe formation affects especially the regions of Wielkopolska (Great Poland) and Kujawy (Kuyavia) in Poland, where the indicator of *the climatic water balance*, as a difference between the amount of precipitation and the amount of evaporation from the air, soil and plants, is very unfavourable and amounts to minus 200-250 mm. The use of the potential possibilities of crop productivity of arable crops is evaluated in Poland as only about 62% - from 30% in the south-eastern part to 80% in Western Pomerania owing to the shortage of water (Jankowiak, Bieńkowski, 2011).

The influence of the drought on the yield in agriculture is still insufficiently examined in Poland and more work in this field was undertaken after 2000, and since 2007 this system has been run by the Institute of Soil Science and Plant Cultivation in Pulawy. Since 2009 the European Union has been assessing the range and the consequences of the water shortage and drought every year. The European Union has established the Centre of Drought Management entitled *Drought Management Centre for South-Eastern Europe and European Drought Centre* (the virtual centre of knowledge and coordination operating in Holland). Five research centres were created in this field in Great Britain. Since 1999 the National Oceanic and Atmospheric Administration has been functioning, using the satellite data on vegetation, climate and geophysics. Next, the Global Drought Monitoring at the University College London offer monthly reports on the spacious composition of weather phenomena, etc. (Kręgiel, Jarośnińska, 2006). Similar climatic centres were opened in Australia, China and other countries and such reports for Africa are prepared, among others, by the Princeton University (New Jersey, USA).

A lot of actions have already been taken to fight against drought apart from the monitoring of climatic and weather changes, enumerating for instance, retention of rainwater and water from rivers, modernization of irrigation systems (losses in water transport and distribution often amount to 40-60%), the use of recycled sewage to irrigate arable farming (in Cyprus and the Canary Islands it is 20% of water to irrigate the fields), the changes of the financial aid system for the projects concerning water management.

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