

DOI: 10.2478/v10025-010-0002-0

JOURNAL OF WATER
AND LAND DEVELOPMENT
J. Water Land Dev. No. 13b, 2009: 17–29

Expected development of irrigation in Poland in the context of climate change

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Abstract: Uncertainties as to how the climate will change and how it will influence the necessities and trends of irrigation development lead to a number of serious questions to be answered in the near future. How irrigation and water systems will have to adapt to climate changes is a challenge that planners, designers and O&M services will have to cope with.

It is widely accepted that air temperature in Poland will increase of 2–4°C, however a total yearly precipitation will not vary yet its pattern during the year may change towards higher in winter and lower in summer. Evapotranspiration and crop water demand may rise due to both an increase in temperature and duration of crop growth cycles.

Three main factors are expected to exert an accelerating influence on the development of irrigation: increased frequency and intensity of droughts and long-lasting precipitation-free periods with the high insolation and high air temperatures resulting from climate change; the intensification of agricultural production (e.g. in horticulture, orchards, seed crops), being forced by both domestic and European free-market competition; the necessity of reaching high level of quality for the majority of agricultural products.

To mitigate negative effects of climate change and extreme events, appropriate adaptation methods and adaptation strategies should be developed and implemented in existing irrigation and water control systems. A number of technological and organisational steps should be taken to improve operation, management, administration and decision making processes.

Key words: *climate change, drought, irrigation*

INTRODUCTION

An uncertainty as to how the climate will change and how it will influence the necessity and trends of irrigation development in Poland are the serious issues to be addressed in the near future since within the agricultural water management sector, it is the irrigation that is most likely to be affected by climate change. It is generally expected that irrigated agriculture will have to be extended in view of future climate conditions. It is not yet known how climate change will affect irrigation

water requirements, how many hectares of arable land will be irrigated, how much water will be needed, whether there will be enough water available for necessary irrigation. These questions should be dealt with on the regional scales, for example of Poland.

There are many works on the impact of climate change on agriculture, but the impact of climate change on irrigation has rarely been analyzed. There are some studies on the global scale, for example for Europe (DÖLL, 2002). Yet there are no studies available providing a computation of the change of irrigation requirements for Poland.

In this paper the projected trends of the development of irrigation in Poland are presented against the background of the expected climate change and its impact on crop water demand. The issues concerning irrigation management and performance that planners, designers and O&M services will have to face with are discussed. The viable and recommended steps to stimulate the development of irrigation and to adapt the existing irrigation systems to climate change are indicated.

PRESENT SITUATION IN IRRIGATION

Poland is situated in a transitory temperate climate zone, influenced by a mild oceanic climate from the west and a dry continental climate from the east. Climatic conditions in Poland are characterized by a considerable variability in weather during long periods of time (years) as well as short periods (days, weeks). In the vegetation period potential evapotranspiration in most areas of the country exceeds precipitation, resulting in water deficit, especially on light soils with low water-holding capacity. The driest regions of Poland are almost the entire central region, as well as the north-western and mid-eastern parts. These regions are most threatened by frequent and most severe droughts.

The irrigation in Poland is of a supplemental character, and it is used in short periods during the growing season, especially in regions with severe and frequent droughts. Statistically irrigation is needed once every three years. There are years when crops cultivated in Poland do not require irrigation during the growing season. In wet years the role of irrigation is marginal. Only in fruit and vegetable farming irrigation is essential every year.

In this country the irrigation plays an important role in mitigating the effects of drought on crop production locally, in areas of light soils with valuable crops, where dry spells are likely to occur, leading to substantial losses in yields. In extremely dry years (e.g. 1992 and 2000) up to 40% of the country was affected by drought (ŁABĘDZKI, 2006). Average decrease in crop yield is estimated at 10–40% as compared to the normal year.

The total area of irrigable land (equipped with irrigation systems is 415,000 hectares: 365,000 hectares of gravity systems on grasslands and 49,000 hectares of pumped systems in arable land (Rocznik..., 2008).

In general, taking into account the whole agricultural area in the country, the role of irrigation in agriculture is marginal, as only a very small part of it is irrigated. Due to changes in the national economy and the transformation of the Polish agriculture after 1989, irrigated area diminished by 75% since the beginning of the nineties (ŁABĘDZKI, 2007; ŁABĘDZKI *et al.*, 2006). At present, on average, 0.5% of the total agricultural land in this country is irrigated (Ochrona..., 2008). In the driest region of Poland – the Kujawsko-Pomorskie province – 1.1% of agricultural land area is irrigated. Sprinkling irrigation of arable lands for field production covers only 5,000 hectares and subirrigation of permanent grasslands – 75,000 hectares (Tab. 1) (Ochrona..., 2008). In the official government publications there is no data on microirrigation but total area microirrigated in Poland may be estimated at about 20,000 ha. Water withdrawal for irrigation is about 99 hm³ and it has decreased by 80% since 1990 (Tab. 1). The decrease in water use since the nineties has been caused by decrease in irrigated area.

Table 1. Irrigated area and water withdrawal for irrigation in Poland (Ochrona..., 2008)

Year	Total	Irrigation method				
		subirrigation	sprinkling	microirrigation	flood irrigation	border irrigation
Irrigated area, ha						
1990	301,500	284,950	10,300	–	2,550	3,700
2007	79,991	75,222	4,653	20,000*	96	20
Water withdrawal, hm ³						
1990	519	–	–	–	–	–
2007	99.1	93.8	5.5	–	0.07	0.02

„–” no data available; * estimated.

At present, three types of irrigation systems are in use. Systems of gravitational irrigation are used on permanent grasslands in river plain areas in which subirrigation is applied. Such systems consist of a network of ditches and control structures, supplemented with a network of drain pipes in some irrigation units. Three techniques for maintaining groundwater level in these systems are used: controlled outflow, subirrigation with a constant water level, subirrigation with a regulated water level (groundwater level management). Systems with pressure irrigation include sprinkler and all types of microirrigation, i.e. drip, microsprinkler and subsurface irrigation of intensive root, industrial and greenhouse crops, horticultural crops in open air and orchards. Sprinkler irrigation is concentrated chiefly in the western and central part of the country, in regions with relatively low precipitation and with fertile soils. Microirrigation systems are developing faster than

any other type of pressure irrigation in Poland. Flood and border irrigation is used to a very small extent because of great water demand and low irrigation effectiveness.

Under the economic conditions of the Polish agriculture, irrigation of most field crops is an unprofitable measure, only irrigation of potatoes, vegetables and orchards brings profits (GRUSZKA, 2004; JANKOWIAK *et al.*, 2006; JANKOWIAK and RZEKANOWSKI, 2006; RZEKANOWSKI, 2000). That is why the existing irrigation systems and facilities are only used to a small extent. Irrigation facilities undergo degradation. Economic situation in agriculture and lack of funds by farmers, farmers' associations and local governments responsible for amelioration in the catchments are the main reasons of the disregard for an appropriate use of the melioration systems and facilities, for a cessation of irrigation systems maintenance and conservation, and for a controlled water management. Reduced interest in the use of water facilities is observed. Large areas of agricultural land are abandoned because of a dwindling interest in fodder production and its market prices.

The effects of irrigation are related to the quality of management of these systems. Where management of facilities is appropriate and water uptake is provided, negative effects of droughts may be avoided and even higher productivity obtained. To achieve a high efficiency of irrigation systems during a drought, systematic O&M of the systems is necessary in the period preceding drought. A lack of modernization and inappropriate use of the systems and facilities restrict competent water management and result in decreased crop production while their proper allows an effective water management on irrigated areas and greater crop yield stability.

At present, an increase in the area of irrigated land, especially in vegetable and fruit farming using drip irrigation, has been observed. It is assumed that the development of this type of irrigation will run parallel to the development and intensification of agriculture.

PROJECTED CLIMATE CHANGES AND THEIR IMPACT ON SOIL WATER REGIME, EVAPOTRANSPIRATION AND CROP WATER DEMANDS

According to the most probable scenario of climate change (A2), the global temperature will increase by 4°C by the end of the 21st century (ALCAMO *et al.*, 2007; RANDALL *et al.*, 2007; The Fourth Assessment..., 2007). It is acknowledge that air temperature in Poland will increase by 2–4°C. According to the GISS scenario it will increase by 2.8°C (www.giss.nasa.gov, 2009).

It is believed that a total yearly precipitation will not vary but its pattern during the year will change towards high in winter and lower in summer (Assessment..., 2000; KUNDZEWICZ, 2003; 2007; The Fourth Assessment..., 2007). According to the studies conducted by JAWORSKI (2004), taking into account the GFDL scenario, precipitation may increase by 20–60 mm·year⁻¹. The other scenario (GISS) predicts much higher precipitation increase of 100–160 mm·year⁻¹.

The climate changes are known to alter the hydrological cycle components such as evapotranspiration rate, crop water demand, soil moisture storage, runoff, groundwater recharge.

An increase in winter precipitation may cause excessive soil moisture in spring and a need for drainage. A decrease in summer precipitation may result in over-drying of soil and a need for irrigation. Long-lasting periods without precipitation combined with a high temperature and insolation seem very likely.

The studies done by SOMOROWSKA (2008) for the second half of the 21st century show, basing on the simulations with the ECHA-M5 and GFDL climate models, an increase in extreme stages of soil moisture and a decrease in available soil water content in summer.

According to the studies conducted by JAWORSKI (2004), taking into account the GFDL scenario, an increase in areal evapotranspiration may occur in all the months and give an annual increase of 50–80 mm·year⁻¹. The GISS scenario predicts much bigger evapotranspiration increase of 70–100 mm·year⁻¹ (JAWORSKI, 2004). For example, crop water demand for maize may increase by 2–4% and for potatoes by 6–10% (Impacts..., 2008; OLESEN and BINDI, 2002; The Fourth Assessment..., 2007).

Moreover, evapotranspiration and crop water demand may increase due to increased temperatures and the duration of growing season. Combined with the precipitation decrease, crop water deficits will increase. Thus soil moisture may deplete more quickly during the growing season, and both surface runoff and groundwater recharge would decrease.

Although the use of water for irrigation is negligible now in Poland, agriculture is already a large consumer of water resources taking into account the use of water through evapotranspiration. The effects of climate change may boost water demand in agriculture by 30–50% in the next 20–30 years, increasing the competition for water between rural and urban as well as industrial areas. Much of this increased demand for water in agriculture will come from irrigated agriculture. Moreover, more water will be required per unit area and probably for unit crop productivity, decreasing crop water productivity. The possible increase in water shortage in agriculture may reinforce the current trends of an increase in local water resources and their availability, intensification of irrigation and increase in water use efficiency.

An impact of climate changes on agricultural water resources is also predicted. Direction and intensity of the impact vary for different scenarios. Basing on the GFDL and GISS scenarios, projected river flows in the Warta and Wieprz river catchments will not change significantly until 2050 (KACZMAREK, 2003). According to GFDL water resources may be depleted by 17–25% and according to GISS they would grow. Possible increase in water resources deficits would be caused by increased demand for water in agriculture, mainly due to irrigation development. According to GFDL, significant increase in agricultural water demand may be ex-

pected. According to JAWORSKI (2004), on the basis of studies carried out in the Wilga river catchment, projected climate changes might cause a significant reduction of the filtration into the direction of groundwater table by 6–20% in a year and by 20–28% during the growing season. Because of the reduction of the filtration process, the river flow conditions will be disadvantageous from agricultural point of view (the low flows will be much lower than under present conditions).

While considering irrigation development one has to take into account the impact of climate changes on soil. It is more than likely that the impact will be adverse due to soil over-drying and depleted organic matter content. It will worsen the physical-water characteristics of soils and reduce the ability of soil water retention.

Due to climate change, extreme meteorological and hydrological events may be expected to occur more frequently, among which droughts are considered most dangerous. It is important to determine the consequences of expected regional climate changes caused by global warming in agriculture and whether they will result in increasing irrigation needs.

FUTURE DEVELOPMENT AND PROSPECTS FOR IRRIGATION IN THE CONTEXT OF CLIMATE CHANGES

Climate change will affect not only water availability but also the demand for water in agriculture. In drier and warmer regions dwindling water resources availability may be combined with an increasing demand for water. How to solve this problem and mitigate this conflict is a serious task for water management planners and politicians.

During the recent years, as well as in the years to come, three main factors are believed to exert an accelerating influence on the development of irrigation:

- increased frequency and intensity of droughts and long-lasting precipitation-free periods in Poland, with the high insolation and high air temperatures as a result of climate changes; in case of water retention deficit in an area, as a result of dewatering, it leads to dramatic deficit of water in the soil, which, in turn, may cause a significant lowering of crops and creates an uncertainty in economic planning of the activities of farms,
- the intensification of agricultural production, being forced by the domestic and European free-market competition; its stabilization is necessary annually because, among other things, only then it is possible to conclude various contracts with the users of agricultural crops,
- the necessity of reaching high quality of the majority of agricultural products; one of the examples may be the consumable potato, especially for public catering needs; its indispensable qualitative standard (size, shape, equality) may be reached only under the conditions of sprinkler irrigation, i.e. in the conditions of stable optimal humidity of soil.

Projected climate changes and an increase in frequency and intensity of droughts in our climate zone are likely to result in an increase in crop water demand, irrigated areas and irrigation water requirements. In 2020 in south-east England, net irrigation water requirement will grow by 70% compared to 1995, and in north Germany – by 40% (DÖLL, 2002). Similar increases may be expected in Poland. Under conditions of climatic and economical changes, the irrigation area will increase up to 2.1 million hectares, of which 1.6 million hectares on permanent grasslands and 0.5 million hectares on arable land and in orchards (NYC and POKŁADEK, 2007). According to MIODUSZEWSKI (2007) 3–4% of arable land (without subirrigated areas) would be irrigated in the near future. RZEKANOWSKI (2000) states that till 2025 pressure irrigation ought to be used on 1 million hectares, mainly on very light and light soils in central Poland.

At present, a slow grow of irrigated areas has been observed, especially in vegetable and fruit farming using drip irrigation. Microirrigation systems have become more common because of their high efficiency. This trend is expected to dominate in the Polish agriculture. There is no need, except for financial subsidies, to undertake any special steps to stimulate development of this type of irrigation. It is believed that an increased use of groundwater for this type of irrigation may cause unfavourable changes in the environment. However, it might become necessary to limit groundwater uptake.

Gravitational subirrigation systems will continue to be used on permanent valley grasslands, which are a source of fodder offering a healthy way of cattle feeding. They also have a great role in the preservation of biodiversity and organic soils in river valleys.

There is an urgent need for the improvement and modernization of irrigation systems to make possible the use of modern energy- and water-saving methods and techniques of irrigation, and to increase the effectiveness of irrigation and water use efficiency.

The long term irrigation research and practice have demonstrated that water use is much more efficient in pressurized irrigation than in surface irrigation. Therefore, the following innovative technologies, equipment and accessories have been developed for irrigation:

- micro sprinkling with low-discharge sprayers and minisprinklers,
- drip irrigation (surface and subsurface into the root zone),
- compensated drippers,
- automatic valves and controllers,
- automatic filtration.

These irrigation technologies and tools should be recommended for use. Besides, fertigation should be a routine in most of the irrigated areas. Highly soluble and liquid fertilizers have to be used which are compatible with this technology. Irrigation ought to be controlled by automatic valves and computerized controllers.

At this point in time, modern irrigation technologies and equipment are available in Poland and can be obtained from numerous companies, both domestic or foreign (e.g. from Israel, USA or Italy). These companies offer a full investment process, from counseling and design to advisory service and control at every stage of operation and management. The only barrier of implementation of a modern irrigation equipment remains its price.

The ratio between the investment and operation costs of irrigation and profits deriving from irrigation seems likely to improve. On one hand a reduction in prices of irrigation equipment can be expected, and on the other, the market prices of agricultural products should make irrigation profitable for farmers.

At present and in the near future there are following challenges in the area of irrigation for the Polish government, self-governments, local councils, local administration of amelioration and water management, farmers' associations and farmers themselves:

- restraint of decapitalization of irrigation systems,
- improvement and modernization of irrigation systems,
- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation,
- implementation of modern energy- and water-saving methods and techniques of irrigation,
- improvement in the efficiency of irrigation,
- optimization of water distribution and water management in irrigation and agriculture water systems,
- implementation of various measures to increase good quality and availability of local water resources.

Various steps to be taken to stimulate the development of irrigation include among others:

- maintenance and adequate use of the so called “basic land reclamation facilities” like reservoirs and canals maintained by the state,
- organising training for farmers to promote and help implementing modern irrigation systems and water-saving technologies,
- establishment of legal, financial and institutional basis for regional water supply systems for irrigation,
- stimulating farmers' participation in the planning of irrigation development and water resources management, emphasising the protection of water-dependent ecosystems and improvement of ecological status of surface waters,
- preparing new regulations for co-operation between agencies responsible for irrigation,
- establishing boards (organizations) responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems.

It must be noted that the success of irrigation projects is highly dependent on operation and management. There is a growing recognition that systems operated by water users seem to be more successful than those public operated.

A variety of measures for making irrigation effective and environment-friendly, should be taken. Some of the most important are: development of irrigation systems as an element of integrated water management system in a catchment; development and usage of the technology of subirrigation to protect wetlands and organic soils using regulated run-off; improving the operation of irrigation systems through automation and mechanization; development of appropriate irrigation systems and practices under different soil, plant and climatic conditions in order to achieve optimum yield at high water use efficiency; improving the quantity and quality of yields through improved agrotechnologies and the introduction of new varieties; conserving water and fertilizers through the scheduling and monitoring of irrigation and fertilization; optimization of using pesticides and nutrients adequately to the natural pedoclimatic conditions of the area and water supply; fertigation.

Farmers must realise that water is a precious and limited resource and should be conserved and handled carefully in the most efficient manner. Modern irrigation equipment will enable better control and monitoring of irrigation, which will translate into higher water use efficiency. Regional network of agro-meteorological stations should deliver real-time weather data to farmers in conjunction with the recommendations regarding real-time irrigation demands. Besides weather monitoring, soil-moisture monitoring should be applied using tensiometers, pressure chamber patterns, electrical resistance sensors for more precise specific local adjustment. Vegetal indicators such as leaf water potential, stomatal resistance, infra-red canopy temperature may be used to achieve further precision in water use.

Irrigation is and should be perceived as an element of integrated water management in a river catchment. So the problems, objectives, options and vision on irrigation must be considered in the context of water management. In Poland, the range of problems to be solved to upgrade the management of water resources to the required standards (taking full account the principles of sustainable development) has been fully acknowledged.

NECESSARY ADAPTATION OF IRRIGATION AND WATER SYSTEMS TO FUTURE CLIMATE CONDITIONS

How irrigation and agriculture water systems will have to adapt to climate changes is the challenge that planners, designers and O&M services will have to cope with. In Poland, as elsewhere, most of irrigation and agricultural water systems were designed to last long life (30–50 years) on the assumption that climatic conditions would not change in the future.

Because an increase in extreme meteorological and hydrological events (droughts, floods) due to climate change is very likely, it is crucial to review planning principles, design criteria, operating rules, contingency plans and management policies for water infrastructures and to stress the role of irrigation and agricultural water management in order to control these events.

The extreme events cannot be prevented or eliminated. To mitigate their negative effects and to minimize losses, appropriate adaptation methods and adaptation strategies should be developed and implemented in existing irrigation and water control systems. A number of technical and organisational steps should be taken to improve operation, management, administration and decision making.

Proposed adaptive measures include:

- modernization of irrigation and water distribution systems to increase their effectiveness for supply and out-flow of water,
- improvement of O&M of irrigation and water systems,
- usage of modern energy- and water-saving methods and techniques of irrigation,
- improvement in the efficiency of irrigation,
- improvement of crop water use efficiency,
- improvement of existing infrastructure for storage and distribution of water,
- increasing available water resources (in soils, streams, reservoirs),
- improvement and implementation of water distribution procedures towards dynamic and flexible water resources management with the use of multi-criteria optimization and modern automatic systems for monitoring the status of water systems (groundwater table depths, stream water stages and stream flow discharge, monitoring of water structures),
- adjustment of water system control algorithms to changing climate conditions and extreme weather events,
- development of regional (local) systems of climate monitoring for the needs of water system management,
- development of telecommunication systems,
- usage of remote-sensing methods and GIS in water system control.

These activities aiming at the adaptation of existing irrigation and water systems, together with all other steps taken for counteracting negative effects of the climate change in agriculture, will improve the adaptive capacity of these systems and reduce their vulnerability to extreme events.

CONCLUSIONS

1. Due to global climate changes air temperature is believed to increase by 2–4°C in Poland. A total annual precipitation will not vary but its pattern during the year would change: rising in winter and lowering in summer. Evapotranspiration

and crop water demand would increase due to a higher temperature and an extended duration of growing season. Thus soil moisture may diminish more quickly during the growing season, and surface runoff and groundwater recharge may decrease.

2. Due to climate change and related extreme meteorological and hydrological events (droughts), the scenario predicting an increase of both the irrigation water demand and irrigated areas is most likely.

3. Nowadays the role of irrigation in agriculture is marginal because of very small irrigated area (0.5% of the total agricultural land area). During the recent years, as well as in the years to come, three main factors exert an accelerating influence on the development of irrigation: increased frequency and intensity of droughts; the intensification of agricultural production (e.g. in horticulture, orchards, seed crops), being forced by the domestic and European free-market competition; the necessity of obtaining high quality of the majority of agricultural products.

4. A variety of steps should be taken to stimulate the development of irrigation and to adapt the existing irrigation systems to climate change. Measure aimed at the adaptation of existing irrigation and agricultural water systems, together with other steps taken to counteract negative effects of climate change in agriculture, will improve the adaptive capacity of these systems and reduce their vulnerability to extreme events. A number of technological and organisational actions should be taken to enhance operation, management, administration and decision making.

5. It is essential to review planning principles, design criteria, operating rules, contingency plans and management policies for water infrastructures and to stress the role of irrigation and agricultural water management to control extreme meteorological and hydrological events due to climate change.

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STRESZCZENIE

Przewidywany rozwój nawodnień w Polsce w kontekście zmian klimatu

Słowa kluczowe: *nawodnienia, susza, zmiany klimatu*

Zmiany klimatu będą wywierać silny wpływ na rolnictwo. Przeważa pogląd, że w skali ogólnej spodziewane zmiany, polegające na globalnym ociepleniu, przyniosą korzystne efekty w gospodarce rolnej, bowiem zwiększy się potencjał produkcyjny rolnictwa. W Polsce należy się spodziewać wzrostu temperatury o ok. 2–4°C. Konsekwencją tego wzrostu będą sezonowe zmiany ilościowe opadów atmosferycznych i natężenie ekstremalnych zjawisk pogodowych. Większość scenariuszy dla Polski nie przewiduje wzrostu sumy opadów w ciągu roku. Można natomiast spodziewać się wzrostu opadów zimowych, a zmniejszenia opadów letnich. Spowoduje to nadmierne uwilgotnienia gleby w okresie wczesnowiosennym i potrzebę odprowadzenia tej wody przez systemy drenarskie oraz przesuszenie gleb w okresie letnim i potrzebę nawodnień.

Przewidywany wzrost natężenia i częstotliwości występowania susz może spowodować wzrost deficytów wody w rolnictwie. Susze stają się w ostatnich latach coraz bardziej dokuczliwe, a przesuszenie wielu obszarów jest wyraźne. Jednocześnie dopuszcza się do bardzo głębokiego kryzysu nawodnień w Polsce. Obecnie nawodnienia w Polsce odgrywają znikomą rolę zarówno w produkcji rolnej, jak i gospodarce wodnej. Są stosowane zaledwie na ok. 0,5% powierzchni użytków rolnych (łącznie wszystkie rodzaje nawodnień).

Możliwe zwiększenie deficytów wody w rolnictwie w wyniku zmian klimatu może utrwalić obecne trendy rozwoju nawodnień. Znaczenie nawodnień w polskim rolnictwie powinno się zwiększać wraz z intensyfikacją rolnictwa i negatywnymi skutkami zmian klimatu.

Received 12.05.2009

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