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IRRIGATION CHANGES IN THE MARITSA RIVER BASIN: A CASE STUDY FROM THE PLOVDIV REGION

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Abstract

In the context of the policy of securing and protecting water resources for growth and sustainable development, agriculture must, through adequate planning of land use, cultivated crops and water infrastructure and taking into account climate changes and the needs of ecosystems, have a responsible managing role. The changes in Bulgaria after 1989 have brought for agriculture many risks and challenges. Therefore, the present study aims at making a general overview of the state of irrigation in the region of Plovdiv, as an example of the Maritsa River watershed.in the period 2017-2021. On the basis of the obtained results, major problems and their possible solutions for agriculture and irrigation will be defined, such as recommendations for improving the agricultural policy and integrated water management in Bulgaria.

Key words: *irrigation system (IS), river water intake (RWI), water source.*

INTRODUCTION

Bulgaria, as a country, rich in diverse and fertile soils and relatively significant water resources, has its traditions in irrigation, with a well-developed hydro-meliorative fund, amounting at 1.2 million ha irrigation area at the end of 1980s. Political changes after 1989 led to various but still not entirely successful reforms in the agricultural sector. The introduced in 1991 private ownership of the agricultural fields and not sufficiently clear vision of the agricultural development completely changed the organization of the irrigation process, the size of the irrigated areas and the water supply. Thus, a large part of the existing large-scale irrigation infrastructure lost its purpose and suffered a significant decline in the last 30 years.

Meeting the demand for irrigation water depends on the type of crops, the size of the arable areas, the climatic factors and the good technical condition of the irrigation systems. Therefore, this paper aims at evaluating the irrigation changes, including the crops, grown in the period 2017÷2021 in Plovdiv region, in the Maritsa River basin (the main unit for water management in the East Aegean Sea region).

Based on the obtained results and on previous water balance assessments, the main problems will be marked, and recommendation will be made for the development of agriculture and irrigation in Bulgaria.

MATERIALS AND METHODS

Study area

The basin of the River Maritsa (with a length of 524.6 km and an area of 53 000 km^2, of which 21 083.5 km^2 on Bulgarian territory, i.e., almost half of this is the Aegean sea watershed) occupies the central part of the Aegean drainage area (Hristova, 2012). The river takes its source from two high-mountain lakes in Marishka circus and after the town of Belovo enters the Upper Thracian lowland, covering the middle part of its watershed. The Thracian lowland is the most extensive and fertile lowland in Bulgaria with an area of 6032 km^2, an average altitude of 168 m and a transitional continental to Mediterranean climate on its southern slopes. The morpho-hydrographic and physical-geographic features of the lowland determine its division into two sub-regions – Western (Pazardzhik - Plovdiv field) and Eastern – (Stara Zagora field).

The Pazardzhik-Plovdiv field (with a length of up to 105 km, a width in the middle part > 50 km and an altitude of 300 m at the town of Belovo to 100 m at the town of Parvomai) is a plain in southern Bulgaria, covering the territory of the districts of Pazardzhik and Plovdiv. The average annual temperature in the field is 12.5°C (for Plovdiv 12.2°C). The winter season is relatively mild and warm with an average January temperature of 0°C to 1°C (for Plovdiv 0.2°C), and the summer is hot with an average July temperature of 23-24°C (for Plovdiv 23.6°C).

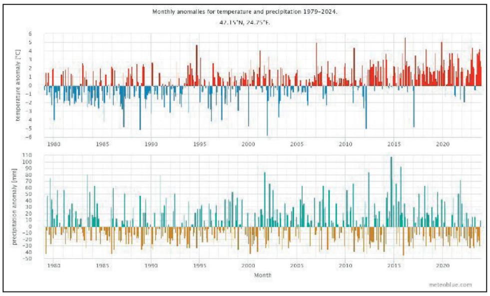

Figure 1. Monthly deviations from the 30-year average climatic value of temperature and precipitation for the Plovdiv City in the period 1979÷2021, https://www.meteoblue.com

The upper graph in Figure 1 shows the temperature anomaly, while the lower one illustrates the precipitation anomaly for each month from 1979 to 2021 for the city of Plovdiv. i.e., the corresponding deviations from the 30-year average climate values of temperature and precipitation for the period 1980÷2010. The months in red are warmer, in blue – colder, in green – wetter and the months in brown are drier than the climatic norm for the period. The increase in the number of warmer and less humid months over the years confirms the climatic trends in Bulgaria towards warming since the late 1970s and increasingly milder winters since the second half of the 20th century. This will compromize to a certain extent the production of the main agricultural crops by lowering their yield (Veselin, 2020). Therefore, the change in multi-year precipitation totals is an important regional indicator for various economic sectors, and especially for agriculture (Shopova et al., 2022).

The fertile soils and the relatively good water resources and climatic conditions in the Pazardzhik-Plovdiv field, and more specifically in the region of Plovdiv, are decisive for the development of vegetable farming, viticulture, fruit-growing, and above all rice production (which dates back to the 14-15th century), and, respectively, are decisive also for the large irrigation systems in Bulgaria.

The demand for irrigation water in the studied region is mainly satisfied by surface waters – rivers and the 11 dams, built on them, which almost always guarrantee the water needs. Three of the dams (Vacha, Topolnitza and Pyasachnik) are complex and significant according to Annex №1 to the Water Act (2000), and the rest are managed by "Irrigation systems" EAD.

The irrigation systems Plovdiv and Stryama – Chirpan receive water through river water intake (RWI), respectively Polatovo and Manole from the Maritza River and Chernozemen and Ivan Vazovo – from the Stryama River. Water reaches the irrigated fields through the main irrigation canal (MIC) Eni Ark for the first system and through the main irrigation canal "Stryama-Chirpan" - for the second one. The main water sources of the remaining irrigation systems are the dams, given in Table 1.

Table 1. Irrigation systems (IS) in The Region of Plovdiv

Location IS	Water source	Constructed area, ha
IS Vacha - Parts of the Stara (Peshterska) River and Vacha River, Stamboliiski and Krichim municipalities	Dam Vacha	15456
IS Topolnitza - Part between the rivers Piasachnik and Stryama, Maritsa, Kaloyanovo and Saedinenie municipalities	Dam Topolnitza and Dam Pyasachnik	36586
IS Plovdiv - Part of the Maritza River basin, Maritsa and Saedinenie municipalities	Maritza river	6857
IS Asenitza - Part of the Cherkezitza River catchment, Asenovgrad municipality	Dams - 40-te isvora and Shushitza	15456
IS Stryama - Chirpan - Part of the Stryama River catchment, Kaloyanovo municipality	Stryama River	13280
IS Domlyan - Part of the Stryama River catchment, Karlovo municipality	Dam Domlyan	7082
IS Dondukovo - Part of the Stryama River catchment Srebra river catchment, Brezovo municipality	Dam Dondukovo	42
IS Karavelovo - Part of the Stryama River catchment, Karlovo municipality	Dam Kliment and Dam Sinyata reka	1955
IS Parvomai - Part of the Mechka River and the Kayakliika River catchments, Asenovgrad and Parvomai municipalities	Dams - Ezerovo, Lenovo, Mechka and Bryagovo	12597

The only irrigation system, not considered in the studied region, is the IS Rosino, the 720 da built irrigation areas of which on the Stryama river catchment, are not functional in practice. In the years of change, smaller farms increasingly use underground water sources for irrigation.

Data and methodology

Basic data on the irrigated areas, used water masses and cultivated crops for the period 2017÷2021 have been provided by "Irrigation systems" EAD for the ongoing project "Research on the security of water needs in the Maritsa river basin" carried out by the author. For performing a statistical analysis of the data, concerning the irrigated and built areas, the cultivated crops and the used water volumes, as well as for establishing trends, the program MS EXCEL was used. Summarizing spreadsheets were created to analyze the mentioned data. Calculation procedures were carried out on an annual basis for the period 2017÷2021, regarding: the size of the arable areas; the share of the irrigated from the total of the built areas; the sewn areas by types of crops out of the total of the irrigated areas; the used water volumes from the total volume by irrigation systems; the used water volumes by irrigation systems and types of crops. The results are graphically represented and analyzed, taking into account the dynamics and the trend.

With the aim of assessing the degree of securing the irrigation in the Maritsa river basin, various balance methods have been applied, generally based on a comparison between the inflow and the water consumption in certain nodes of the water management system (WMS). For example, with the help of the imitation (simulation) model SIMYL, transforming the physical scheme of the WMS into a directional graph, and solving the network flow problem, a scientific team from the Bulgarian Academy of Sciences assessed the security of water consumption by volume, months and years, and by the presence of water shortage (WPI-BAS, 2000). Currently, this assessment, with an already upgraded model, is being updated, including for irrigation under the above-mentioned project.

Another example of a balance method is the modeling system MIKE 11, which, through the rainfall/runoff module (MIKE 11-RR) determines the quasi-natural runoff for the hydrographic unit (NAM-catchment) and through the hydrodynamic module (MIKE 11-HD) simulates the change of the river runoff from the water intake (JICA Project, 2006-2008). And in the second river basin management plan (RBMP) for the East Aegean District, the assessment of the water intake pressure, including from irrigation at the water body level in a 6-level classification system, is also based on a balance method (calculated by the National Institute of Meteorology and Hydrology - RBMP, the East Aegean District, 2016-2021).

RESULTS AND DISCUSSIONS

Statistical analysis of the irrigation in Plovdiv District for the period 2017÷2021 - Irrigation Systems Analysis

The size of the irrigated areas in Vacha IS during the studied period has a downward trend with a sharp decrease in 2018 compared to 2017 by 49.6% and a subsequent smooth decrease by 14.9% in 2021. The irrigated areas of Topolnitza IS as of 2018 decreased by 37.1% compared to the first year of the period, then increased by 31.1% as of 2020, and, compared to this year, decreased by 89.7% at the end of the period (Figure 2).

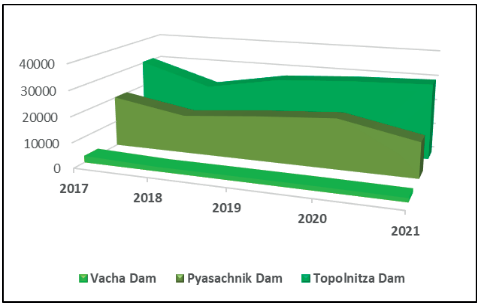

Figure 2. Irrigation Systems Vacha and Topolnitza - Irrigated Area (da)

The change for the IS Asenitza and IS Parvomai is similar but with more pronounced peaks of decrease. The first peak of decrease is in 2018, with almost 20 times for IS Asenitza and 57.3% for the IS Parvomai, compared to 2017; and the second peak is in 2021 with 61.5% for the first irrigation system and twice for the second one, compared to 2020. A growth of 12.7% and 4.5 times for the entire period marked the irrigated areas, respectively, of the IS Plovdiv and IS

Karavelovo (Figure 3). For the irrigation system Stryama-Chirpan and the irrigation systems Dondukovo and Domlyan considered combined, an increase in the size of the areas after 2019 is reported - 2.5 times for the first system and by 56% for the other two systems combined (Figure 4).

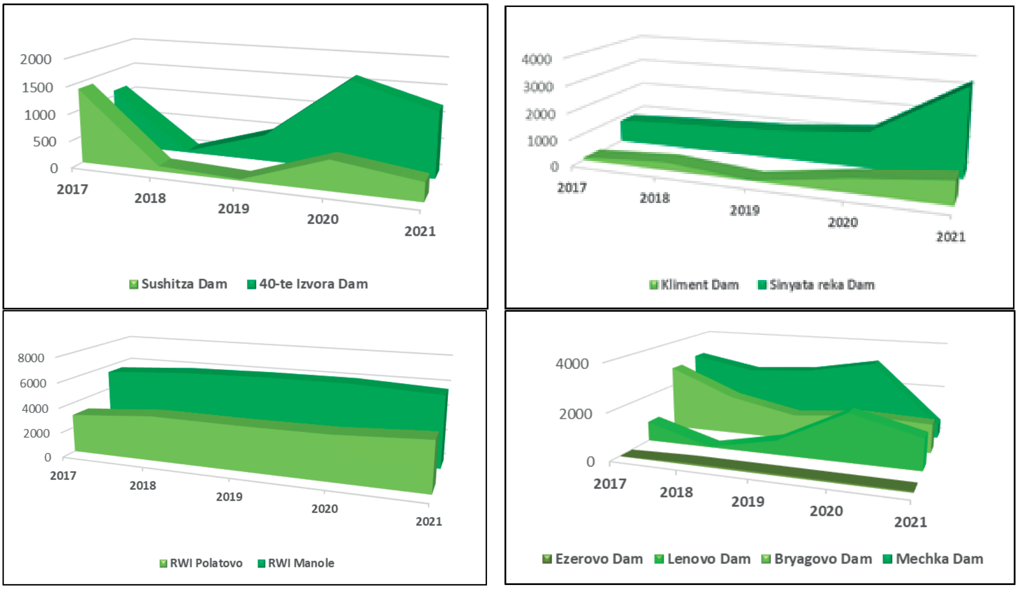

Figure. 3. Irrigation Systems Asenitza, Plovdiv, Karavelovo and Parvomai - Irrigated Area (da)

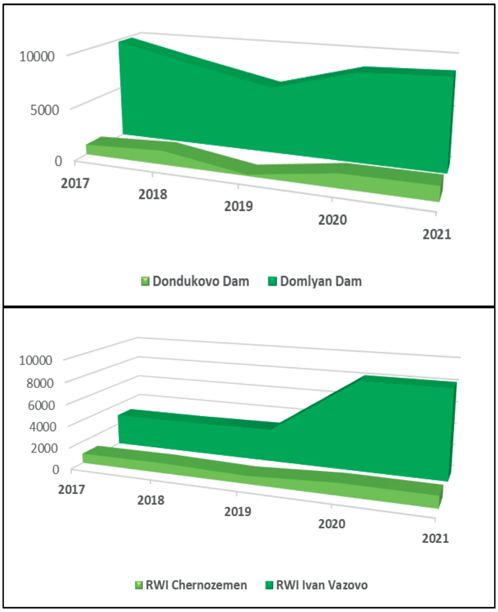

Figure 4. Irrigation Systems Stryama-Chirpan, Dondukovo and Domlyan - Irrigated Area (da)

Given what has been stated about the dynamics of the irrigated areas in the region of Plovdiv during the studied period, the following generalizations can be made: a downward trend for Vacha Irrigation System and a general upward trend for the irrigation systems of Plovdiv and Karavelovo; growth in the middle of the period and decline at its beginning and end for the irrigation systems Topolnitza, Asenitza and Parvomai; two clearly expressed trends – a downward trend as of 2019 and an upward one as of 2021 for the IS Domlyan and Dondukovo and alternating upward and downward trends for the IS Stryama-Chirpan.

The share of the irrigated areas out of the built-up ones, presented in Figure 5, reached only 17% for the IS Vacha in 2017. And on average for the period 2017÷2021, the largest share of 13.6% belongs to Plovdiv IS, followed by the irrigation systems of Domlyan and Dondukovo with 13.1% and the irrigation systems Topolnitza and Vacha with 12.3% each, whereas the smallest share of 0.9% belongs to Asenitza IS.

Figure 5. Share of the irrigated areas from the total amount of built-up areas, by irrigation systems, in %

Cultivated crops

Regarding the cultivated crops: rice is characteristic of the irrigation systems Topolnitza (80.9%), Plovdiv (67.9%), Domlyan (53%) and Stryama-Chirpan (5.5%); corn - of all systems without the IS Plovdiv, with a share of 62.7% belonging to Asenitza IS; tobacco is typical for five irrigation systems, of which the IS Parvomai has the largest share of 52.6%; and permanent plantations are present in all systems except for the irrigation systems Plovdiv and Stryama-Chirpan, with the IS Vacha having the largest share of 24.3%. Vegetable production is the least represented, with a share of 17.5% for Vacha IS, followed by 2.3% to 5% for the irrigation systems Asenitza, Parvomai, Domlyan/ Dondukovo and Karavelovo, and only 0.3% for the irrigation system Topolnitza.

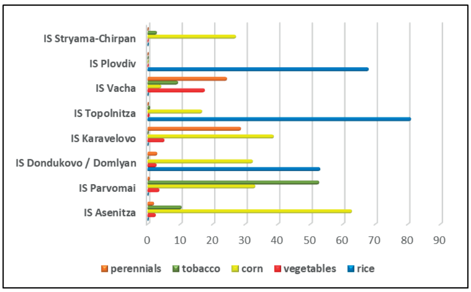

Figure. 6. Share of the areas, sown by crops, from the total amount of irrigated areas, by irrigation systems, in %

Water volumes used for irrigation

The volume of the water used for irrigation is determined by the size of the irrigated areas and cultivated crops, and therefore their dynamics is similar. The share of the main water sources for the irrigation systems, comprising more than one water source, is presented in Table 2.

Table 2. Share of the main water sources for the irrigation systems, in %

IS Asenitza		IS Plovdiv	
40-te Izvora Dam	65.06	RWI Manole	62.35
IS Parvomai		**IS Topolnitza**	
Mechka Dam	47.33	Topolnitza Dam	61.30
IS Karavelovo		**IS Stryama-Chirpan**	
Sinyata reka Dam	81.23	RI Ivan Vazovo	84.32

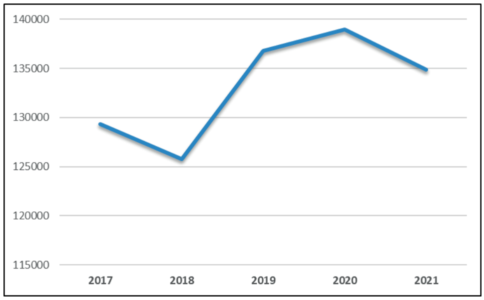

Figure 7. Total used water volume in the period 2017-2021

In the period 2017-2021, the total consumption of water for irrigation (reported by invoice) amounts to $665724*10^3$ m^3 with a minimum in 2018 and a maximum in 2020 and compared to 2020 it decreases by 3% as of 2021 (Figure 7). The largest share of this expenditure belongs to the irrigation systems Topolnitza and Plovdiv, with 67% and 17%, respectively (Figure 8).

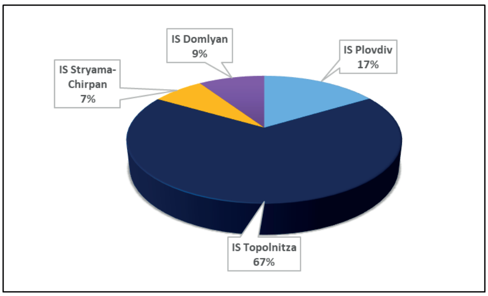

Figure 8. Share of used water volumes for the more significant irrigation systems out of the total volume (%)

Regarding the distribution of the water volume, consumed by crops, cultivation of rice takes the largest share - 95.9%, while vegetables and perennial plants are with the smallest share of 0.1% each.

Modeling and Impact Assessment

The results of the experimental study with the SIMYL model, according to four scenarios - basic, pessimistic, realistic and optimistic, with the inclusion in the latter of the areas constructed for irrigation, show the presence of a water deficit in the catchments of the rivers Stryama and Chepelarska due to the lack of regulating volumes (WPI-BAS, 2000).

The results obtained from the study with the modeling system MIKE11 show a possible risk for the irrigation in the watersheds of the rivers Stara reka (Peshterska) and Pyasachnik after the dam (JICA Project, 2006-2008).

The assessment of the pressure from the water intakes in the RBMP (2016-2021) ascertains a significant pressure of more than 30% in the Maritsa River basin from intakes for irrigation, of which in the studied area are: Kayakliika River – 67%, Pyasachnik River – 78% and Stara (Peshterska) River – 61% (RBMP, the East Aegean District, 2016-2021). Individual sections of the irrigation systems Vacha, Topolnitza and Parvomai are generally at risk of water shortage as of 2021.

Main problems and possible solutions

The main problems and their possible solutions for the "Agriculture" sector and for the irrigation in Bulgaria, are:

– uncertainty due to the lack of a strategy with clear objectives for the development of the sector, including for irrigation, in compliance with the objectives of the Common Agricultural Policy of the European Union (EU). The "General Strategy for the Management and Development of Hydromelioration and Protection from the Harmful Effects of Water" developed by a World Bank team and approved by the Council of Ministers in 2016, remained without application and currently needs updating;

- legal uncertainty - the multitude of regulations in the sector create difficulties for the farmers, and in the field of the hydromelioration activities there is a need for new ones, for example, development and adoption of a Law on Hydromelioration and a methodology for determining the price of the service for supplying water for irrigation;

– management uncertainty based on unclear demarcation of the management levels and responsibilities, lack of inter-institutional coherence and poor infrastructure management and water supply service quality. What is needed is a new model for management of the hydromelioration fund and new activities, reforming both the management and the operation of the networks and facilities;

– uncertainty in achieving the goals of integrated water management through the RBMP, overcoming which is possible through targeted sectoral coherence and activities such as: re-evaluation of: - the water sources; - the irrigation standards; - the permitted water intakes and the irrigation systems in terms of their water supply, size of irrigated areas and irrigation techniques and technologies with determination of the priorities for reconstruction. In addition, the presence of monitoring and effective control of water use, including in real-time, water balance assessments and the promotion of organized irrigation through irrigation associations are important for the water provision for consumers;

– climate uncertainty, i.e. agricultural production will be increasingly affected by climate change - a decrease in the amount of precipitation leads to a decrease in the river runoff and hence to a water deficit in the agricultural areas. In addition to the measures mentioned above, the following could be listed: - new genomic techniques for selecting drought-resistant agricultural crops; - introduction of water-saving irrigation techniques and compilation of irrigation options, adequate to the different climate scenarios, while protecting the water resources and the environment;

– uncertainty for the regional planning related to determining the type of the grown crops and the relevant irrigation infrastructure to provide water. The restoration and modernization of the irrigation systems should be linked to a methodically justified prioritization to determine the significant ones for the sector by classifying them according to certain criteria. For example, in the strategy mentioned above, the following four criteria with different weights are proposed: - system/technical priority; -

regional priority; - and a criterion according to the type of water source;

– uncertainty for the small and medium-sized farms, growing, for example, vegetables and orchards, which negatively affects irrigation and the infrastructure, related to it. This is due to the incorrect subsidy model, determining the creation of large conglomerates for the cultivation of grain crops, competing for the consolidation of the agricultural lands.

CONCLUSIONS

Regarding the cultivated crops, the tradition of rice production is preserved, though on a smaller scale, on the one hand, and vegetable production and fruit growing are too poorly developed. The differences in the irrigated areas and used water volumes are mainly due to the lack of maintenance and absence of measuring equipment for reporting the actual water consumption.

The defined problems provide insight into the state and the challenges facing the agriculture and irrigation, and the proposed measures for their overcoming are important for policy reform and support of decision makers. In conclusion, the present paper proposes a way of studying other regions as well, which will expand and clarify the issues and improve the recommendations for irrigation development, including the infrastructure, in the context of the productive agriculture in Bulgaria, resilient to the changing climate and water resources.

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