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Assessing Irrigation Methods in National Relation

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1. INTRODUCTION

In this thesis, I endeavored to find answers to the following questions: Why did irrigation become such an integral part of society? What kind of issues did humanity have to solve relating to irrigation, additionally, in what ways did irrigation develop throughout history, how did our irrigational technology reach the state it is in now? I examined different solutions in Europe, comparing each region, and the role of the European Union along with its organizations, then I proceeded to document Hungarian irrigational methods throughout history up until our modern era. Furthermore, I pondered upon the solutions of the future, upon the possible directions, and upon how different world organizations, including the Hungarian State Administration, may attempt to conserve as much water as possible in agricultural irrigation, in an effective, and sustainable way.

In the contemporary world, extreme weather events, including frost, hail, heatwaves, variations in precipitation percentiles, and prolonged droughts, exert a significant impact on global food security. These events constrain the potential for crop production in both rain-fed and irrigated agricultural systems.

One of the big uncertainties of the future is how our agricultural and food industries will hold up against our planet's rapidly growing population in terms of maintaining an adequate level of production and supply. This very question in and of itself is difficult to tackle, however, pairing it with climate change makes it even more so. Since we cannot expect production areas to expand, we are forced to achieve the desired level of food production with the currently available area (which is in decline). This will certainly require the augmentation of our specific yields, in which irrigation plays a key role.

Food production is a process which requires a large amount of specific water consumption. All the meanwhile, we are seeing more and more temporary and permanent water shortages worldwide, which can lead to a potentially declining ecosystem service, and an increase in environmental impact. The water extraction used for agricultural irrigation makes up for 70 percent of the freshwater extraction. This puts an elevated level of pressure on us to reduce agricultural water consumption, and to increase efficiency. The need to adapt to climate change pushes professionals around the world to find economically, socially, and environmentally acceptable and sustainable methods of water consumption.

2. EUROPEAN IRRIGATION

Europe comprises diverse climates, landscapes, and agricultural practices. The water management principles of the European Union are also - in general - characterized by promoting efficient water consumption; however, the different member states demonstrate widely differing levels of advancement in irrigation. There are already certain countries which possess vast irrigational capacities, in these cases the goal is increasing the efficiency of their existing systems, while achieving economical water management. In other member states agricultural irrigation is less widespread, less advanced, meanwhile climate change necessitates it more and more for them. The latter - including Hungary - are in the process of increasing their irrigational capacities, and ameliorating its infrastructure. Naturally, the newly realized capacities should also fit into the aforementioned aspects of efficiency, in terms of water consumption, and agricultural profitability.

Irrigation has been a longstanding practice in European agriculture, dating back thousands of years. Naturally, the majority of irrigated agricultural areas are concentrated in the southern regions, particularly in Spain and Italy. However, irrigation-equipped areas can also be found in other parts of Europe, with the Netherlands being a notable example. Agriculture accounts for over 40% of the European Union's total water usage, and in several countries such as Greece, Spain, and Cyprus, the majority of freshwater abstraction is dedicated to agricultural purposes. Prolonged drought periods experienced in many parts of the EU, the impacts of climate change, environmental pollution, and competition for water use further exacerbate the pressures on European water resources. The challenge of food security in the context of climate change makes it necessary to improve water management capabilities. This includes promoting greater responsibility among users, particularly farmers, in their water usage practices (Rossi, 2019).

The European Union has introduced various policy initiatives to tackle the issue of sustainable water use in agriculture. These initiatives include adopting a more comprehensive approach to water management, encouraging water reuse, promoting research and innovation, and enhancing the environmental objectives within agricultural policies. Effective policy coordination between different EU policies and actions is considered crucial for the successful and sustainable protection of European waters.

2.1. Mediterranian Region

In Southern Europe, irrigated agriculture stands as the most significant consumer of freshwater resources. Despite this, there remains a notable absence of consistent and comprehensive information regarding irrigation water usage within the European Union (Wriedt, 2009).

In Spain, under Mediterranean climatic conditions, irrigation water requirements are expected to increase between 40 to 250%, depending on the crop type by 2100 (Rusu & Simonescu, 2016).

In reality, for a specific combination of soil type and crop, both the annual and seasonal fluctuations in rainfall play a crucial role in determining a predictable water stress profile that can be addressed. Take, for instance, rain-fed winter wheat (Triticum aestivum L.), a significant crop cultivated in the Mediterranean region. Variations in rainfall patterns are expected to have a detrimental impact on the phenological behavior of this crop, resulting in reduced yields. This is particularly challenging because agricultural water demand is often inflexible, while the available supply is already stretched to its limits, limiting the ability of crops to cope with fluctuations in water availability. The modernization of irrigation practices can significantly enhance the efficiency of water application. Transitioning from traditional surface irrigation methods to closed pressurized pipe network systems can result in substantial water savings, with potentially reaching up to 90%, as is the case with trickle irrigation (Nikolaou, Damianos, Christou, & Kitta, 2020).

Therefore, to alleviate poverty, the World Bank has provided financial support for the implementation of enhanced irrigation systems in low-income countries. In the European Union, upgrading irrigation systems is considered a priority under the European Water Framework Directive, which is aimed at ensuring the sustainability of irrigation water usage. Nowadays, approximately 40% of the world's food supply is derived from the 18% of cropland that is irrigated, with high water application efficiency irrigation systems being utilized in more than 95% of the total irrigated land, as exemplified by Cyprus. In Mediterranean countries, the irrigated area accounts for less than 40% of the total cropland, while in Germany, only 2% of cropland is irrigated (Nikolaou, Damianos, Christou, & Kitta, 2020).

2.2. Central and Eastern region

The importance of traditional irrigation in Southern Europe is widely recognized, its contribution to the ecological history of rural landscapes in other parts of Europe is often underestimated or disregarded. This points out that long before the industrial era, irrigation had played a pivotal role in agriculture for many centuries. It was applied widely in the environmental regions across Europe, which often shows differences and contrasts.

Given the intricate nature of how historical irrigation systems operated, comprehending the processes and long-term effects scientifically can be challenging. Nonetheless, it remains evident that the fundamental goal of all irrigation farming endeavors was to boost crop yields (Leibundgut, 2014).

Between member states of the EU, there are wide variations in terms of irrigation need and implicitly the irrigable agricultural areas.

In Central European countries, irrigation plays a crucial role in compensating for the yearly fluctuations in moisture levels, which often fall short of the requirements for productive agriculture. These countries include France, Romania, England, Germany, Holland, Belgium, Austria, and Hungary. They are witnessing a growing trend in the development of the irrigation sector, primarily aimed at mitigating risks and improving yields, especially for crops that are particularly sensitive to drought (Rusu & Simonescu, 2016).

Regarding the countries of Eastern Europe, since 1961 we can notice an increasing trend of irrigable agricultural areas that nearly overlaps with that of western European countries until the 1990s.

Analysis of the European Union's irrigation sector reveals a notable pattern of expanding irrigated areas in Southern and Western Europe over the past five decades. In Eastern European countries, there was an upward trend in irrigation until around 1990, which was subsequently followed by a decline. This decline can be primarily attributed to the collapse of communist regimes, which brought about significant social and economic transformations. Between 1961 and 2011, there was a substantial increase in the irrigated area within the European Union (Petersen & Hoogeveen, 2004).

In the arid and semi-arid regions of the European Union, irrigation plays a vital role in enabling agricultural production in areas where water is a limiting factor. In wet and temperate zones, irrigation serves the purpose of adjusting local water supply to meet the specific needs of agriculture, reducing the risks of unexpected events that could harm crops. Agricultural policies should promote European agriculture's ability to adapt to climate change by encouraging flexible crop irrigation. In this context, it's essential to acknowledge the multifunctional role of agriculture, which involves striking a balance between economic, social, and environmental considerations in various European regions and countries.

2.3. European Legislative Frameworks and Policy

To achieve sustainable agricultural water use, a reform can be pursued through various means, such as regulating water use in agriculture, which may include implementing water charges. Additionally, addressing subsidies that can have a positive impact on water resources is crucial. This reform should be guided by comprehensive research, educational initiatives, and effective governance efforts. These strategies are vital in preparing for and maximizing the opportunities for reform in agricultural water usage, ultimately contributing to the sustainable management of water resources.

In recent years, the European Union has introduced several initiatives aimed at tackling the issue of sustainable water management, particularly in agriculture. The EU's water policy process is characterized by a relatively loose and open network of stakeholders and actors, as opposed to a closed and exclusive policy community. Nevertheless, it is still possible to identify a central core of key actors within this broader and more flexible configuration (Richardson, 1994).

The European Irrigation Association (EIA), headquartered in Brussels, is a non-profit organization established in 1996. It serves as a representative body for irrigation professionals in both the agricultural and landscape sectors across Europe. The primary goal of the EIA is to be the primary advocate for the irrigation industry within the European Union institutions and committees. It is dedicated to promoting best practices, knowledge transfer, and discussions related to water management. The EIA's mission involves fostering the ongoing advancement of irrigation products, practices, and services, while advocating for sustainable industry standards and water management policies. Their aim is to create a stable legal environment for irrigation professionals to operate within (Kallis & Nijkamp, 1999).

The EU Water Framework Directive *(Directive 2000/60/EC)* was adopted in 2000, resulted from a comprehensive reevaluation of European water policies. It ushered in a new, holistic strategy founded on river basin water management and the integration of objectives across all types of waters (EU, 2000).

The European Water Framework Directive has mandated the introduction of water pricing policies, and these policies have the potential to incentivize farmers to make investments in technologies aimed at enhancing water management. The directive has established specific objectives to be achieved by 2015 and 2027. For surface water, the directive sets qualitative targets for protection, while for groundwater, the emphasis is placed on safeguarding against contamination and over-abstraction. To achieve a good quantitative status for groundwater, the directive imposes limits on abstraction, allowing only the portion of annual recharge that is not required to support aquatic ecosystems (Kallis & Butler, 2001).

Reflecting on the progress made in the past, the Commission's 2012 blueprint for safeguarding Europe's water resources highlighted the necessity for additional efforts in addressing the root causes of adverse impacts on water quality, which encompass factors like climate change, land use, and economic activities. The blueprint emphasized the importance of more effectively integrating water policy and proposed specific actions to achieve this integration. While the blueprint's objectives are not legally binding, they can provide valuable benchmarks for evaluating the implementation of EU water legislation (Commission, 2012).

The European Water Association (EWA) is an independent, non-governmental, and non-profit organization dedicated to the management and enhancement of the water environment. It stands as one of the prominent professional associations in Europe, encompassing the entire water sector, which includes wastewater, drinking water, and water-related waste. EWA's membership includes associations from nearly all European countries, encompassing most European Union Member States. This includes all countries from Central and Eastern Europe that became EU members as of June 1, 2013. The primary objective of EWA is to serve as a platform for the discussion of critical technical and policy issues in Europe and its regions. It also aims to promote and showcase advanced technologies for water conservation, innovations in irrigation efficiency, and best practices in water conservation. These goals are pursued through activities such as conferences, workshops, meetings, special working groups of experts, and the dissemination of information via publications and web-based media.

The European Innovation Partnership on Water is an initiative that was launched in 2013. Its primary objective is to promote the development of innovative solutions to tackle various water-related challenges. This initiative fosters collaboration by forming action groups and by providing opportunities for innovative solutions to enter the market, both within and outside of Europe. Additionally, it serves as a platform for the exchange of ideas and discussions on how innovation can effectively address water-related issues.

The EU Taxonomy – *Regulation 2020/852* – is the first international classification system established by the European Commission that defines which economic activities can be defined as sustainable. The goal is to enhance transparency and improve the quality of information accessible to investors, enabling them to make well-informed decisions regarding sustainable investments (Commission, 2020).

In practice, the EU Taxonomy comprises a list of economic activities that can contribute to the attainment of six key environmental objectives. These objectives encompass climate change mitigation, climate change adaptation, sustainable utilization and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems (Malecki, 2022).

In accordance with the Regulation, an economic endeavor can be considered "sustainable" when it meets the following criteria:

- Demonstrates a substantial contribution to at least one of the six environmental objectives by adhering to the technical criteria specified in the Regulation.
- Avoids causing significant harm to any of the other environmental objectives by satisfying the technical thresholds and regulatory prerequisites outlined in the Taxonomy.
- Ensures the observance of basic social safeguards, primarily encompassing compliance with international standards regarding human rights and labor conditions.

Given the challenges posed by persistent water scarcity in specific EU regions, extended drought periods across the Union, and the impacts of climate change, it is essential for researchers to investigate novel and eco-friendly approaches to agricultural water management. EU funding is actively backing a variety of initiatives focused on crafting sustainable adaptation strategies, which include optimizing water and energy utilization in irrigation, as well as embracing multidisciplinary and integrated water management methods (Dubini, 2023).

3. HISTORICAL OVERVIEW OF IRRIGATION IN HUNGARY

The development of drainage irrigation and civilization has been closely intertwined throughout history. Approximately 8000 years ago, both the Ubaid and later the Sumerians in Ancient Mesopotamia played pivotal roles in the inception of civilization and the widespread adoption of intensive irrigated agriculture. They ingeniously designed regional canals that facilitated the transportation of water from the Tigris and Euphrates rivers to support large-scale irrigation systems and farms. Cities in this region thrived, housing populations ranging from 50,000 to 80,000 people, with nearly 90% of the population residing within these urban centers. Approximately half of the populace was engaged in the labor-intensive work on the extensive irrigated farms that encircled each city. In contrast, modern agricultural practices have evolved to the point where just 1% of the population can now produce enough food to sustain the entire population. The historical significance of regional canals in Mesopotamia is underscored by a statement made by the renowned Babylonian king Hammurabi around 1750 BC (Thenkabail, Lyon, Turral, & Biradar, 2009).

The Egyptians adopted advanced agricultural practices from the Sumerians, particularly the concept of intensive agriculture. Their irrigation system was closely tied to the annual flooding of the Nile River, which followed a more consistent and predictable pattern compared to the Tigris and Euphrates. The annual Nile flood would typically inundate the Nile floodplain with about 1.5 meters of water in September, persisting for approximately one month. After the fields had dried out by November, farmers sowed winter wheat crops, which they subsequently harvested in April and May. In case the need arose, they constructed basins to retain water until the fields were thoroughly saturated, after which they would permit the excess water to drain away.

The Yellow River in China stands as another historical epicenter of civilization and water management. The hydraulic engineer Zheng-Guo played a pivotal role in creating a highly effective irrigation canal network, which drew water from a tributary of the Yellow River. This irrigation system facilitated the cultivation of 200,000 acres of irrigated land in Qin province in 246 BC. The network featured a primary canal alongside numerous lateral distribution canals. Simultaneously, during the Qin Dynasty, the Dujiangyan irrigation system was developed, and it remains in operation to this day, irrigating an expansive area of 5,300 square kilometers (Waller & Yitayew, 2016).

In Hungary, the development of agriculture cannot be delineated with a straightforward, unbroken curve. Because of this lack of smoothness and directness, experts in general separate the country’s agricultural history into multiple historical periods.

3.1. Ancient Times and Middle Ages

In ancient times, Hungary's climate and fertile soil facilitated agriculture without the need for extensive irrigation. However, some rudimentary irrigation methods might have been employed near rivers and lakes. Archaeological findings suggest that simple channels and ditches were used to direct water to fields for irrigation purposes.

In regions where water availability was more challenging, communities may have employed techniques like bucket irrigation, where water was lifted manually using buckets and then poured onto fields (Ferenczi, 2006). These methods would have been labor-intensive and limited in scale.

In the Middle Ages, surface irrigation methods would have been prevalent. This could include furrow irrigation, where shallow trenches were dug along the contours of fields to allow water to flow through them, irrigating the soil. Basins might have been used to hold water and allow it to slowly infiltrate the ground.

Some historical accounts suggest that dams and small reservoirs were built to capture and store rainwater during wetter seasons. This stored water could then be released and directed to fields during drier periods for irrigation. These reservoirs might have been made of earth or stone.

We have records of wells as early as the 11th century, but they appear more prominently in the 14th to 15th centuries, with references found in place names in historical documents. Citing Werbőczy István's Tripartitum, István Szabó pointed out that there was generally a well in villages, which often served as a communal well and was typically located in the center of the village (Ferenczi, 2006).

Given the limitations of technology and transportation, communities likely relied on localized water sources for irrigation. Fields situated closer to rivers or other water bodies might have been favored for irrigation due to easier access to water.

3.2. Ottoman Rule (16th-17th centuries)

The 150-year Turkish occupation not only impeded the progress of Hungarian society in terms of its social structure and economy but also had a profound impact on the geographical landscape of the Carpathian Basin. The formation of the present-day Great Plain, commonly referred to as the Puszta, was largely influenced by the period of Turkish rule (Nagy, 2008).

This period, that lasted until the middle of the 18th century, can be regarded as the first substantial era of development. Agriculturally relevant areas could be divided into three distinct categories (pasture, rice and vegetables). Irrigation carried out on Turkish controlled land can be linked to the gastronomic tradition of the culture. A key part of Turkish cuisine was rice, which was not imported, but grown in place. The center of rice cultivation was the Temes river region.

In the Middle Ages, floodways were considered to be the breaks on the bank of a river through which the water could break out onto dry land, and then retreat through during flood periods. The shape and size of these openings varied, however their thresholds, for example in the Central-Tisza region, were around 4-5 meters above the water level. It is in this basic sense that we can say that floodway farming became the basis of ancient flood-based farming systems. The definition of a floodway is also connected to the idea of a created opening, an artificial furrow, the function of the ditch, and its purpose.

The artificial floodways were the waterways created to utilize the floodplain in an economic manner, which lead the water in two directions; to the deep of the floodplain during flood, and toward the river bed during recession. The most important characteristic of the water system structured in this way is that it links the stagnant and flowing water of the floodplain.

3.3. 18th-19th Centuries

The beginning of this period is characterized mainly by the naturalization of rice in Hungary. Rice farming, and the irrigation linked to it did not cease to exist in the Temes region after the Ottomans’ departure from the territory. The officially recognized year for the rice plant’s naturalization in Hungary is 1780, and it peaked in 1794 (Museum, 2023).

In the Middle Ages people's concept of irrigation was restricted essentially to the irrigation of their fields and their rice crops, and fit nicely into the farming systems of the era. The developmental provisions of the councils at that time were motivated in quite a large part by the changes in climate of the period. The end of the Turkish occupation also represented the simultaneous end of a period of cold and rainy weather which had lasted several centuries (also known as the ‘Little Ice Age’ amongst experts of the field). This was replaced by a long stretch of dry and rainless climate, during which the need to augment natural water sources. According to a report originating from the period, there were a total of twenty occasions between 1686 and 1836 of drought and extraordinary dry spells (Brian, 2019).

The implementation of field irrigation in the Tiszántúl region of Hungary was first conceptualized by Sámuel Tessedik in a study of his published in 1786. They managed to practically double their yields using irrigation.

An outstanding figure of the history of irrigation in the country is Wittmann Anton, the leader of the Magyaróvár ducal estate, who established a large irrigational system measuring 1200 acres, out of these, 254 were equipped with modern surface irrigation systems. The special part of Wittmann’s initiative is that he utilized multiple irrigational methods in a large agricultural area – surface irrigation, furrow irrigation, flood irrigation – were all attempted. Amongst these, the one method that received the most attention, as it was considered new at the time, was the surface irrigation process (the farmers of the time were familiar with the ‘bakhátas’, or ‘Baden method’, and the ‘sided’, or also known as the ‘Lombard method’).

The idea of spreading irrigation around the entirety of the Hungarian Great Plain only appeared seriously later down the line, in the 1840’s, seeing as it was a crucial part of István Széchenyi’s initiative to regulate the river Tisza. The aforementioned project utilized the talents of other famous figures such as the respectively Italian and Hungarian architects Pietro Paleocapa and Pál Vásárhelyi. This was also the first time that the question of the utilized water’s quality, and the possibility of simultaneous fertilization and irrigation arose as relevant issues. Regarding the latter, experts of the time attempted to mix the water with certain substances used for fertilization such as lime, salt, and ash, and distribute it onto the agricultural land (Museum, 2023).

Around the years 1867-1868 was when, on the initiative of the Central Tisza Regulation Office, the first serious plans for the construction of irrigation canals were born: placing canals between the Tisza and the Körös rivers, between the Maros and the Tisza, and one parallel to the Arad-csanád irrigation canal.

The appropriation of Bulgarian horticulture represented a serious development for horticultural irrigation. The first Bulgarian horticulturists appeared in the Tiszántúl region in 1890. Their early activity was characterized by an unknown intensity of water and organic fertilizer usage. Bulgarian technology began a period of dynamic improvement from 1896 onwards: the horticulturists in Gyula, Doboz, and Békéscsaba all received an increasing amount of requests from their Hungarian counterparts to use their irrigative water supplies. The Bulgarians used the so-called ‘spade irrigation’ method (which was the primitive precursor of sprinkler irrigation) and furrow irrigation (Király, 2001).

During the argument surrounding Act no. XXX in 1900. on the creation of irrigation canals the members of parliament already began to articulate the importance of the State’s financial support, and the significance of the regulation works in the construction of the canals (Wolters Kluwer, 1900).

One of the most prominent chapters in the history of water management in Hungary is associated with the waterworks initiated during the Reform Era. Like many other great initiatives, this period of water management is attributed to the name of Széchenyi István. Even by that time, they had realized that the way forward for the project would be paved by companies formed independently for this exact purpose. Thus, the predecessors of modern water companies were born (Szerényi, 1997).

3.4. Early 20th century

However, horticulture experienced a boom in the Körös region during the war years. The spread of the form of farming on a wide scale increased between 1920 and 1930 parallel to the decline of rice irrigation. Thanks to Bulgarian horticulture, irrigation that was only present in large plants beforehand, managed to find its way into plants with smaller estates as well. If we examine the period between 1919 and 1930 we see that the irrigated area still only rose by 6512 hectares with, amongst others, the creation of 138 new irrigation plants. The split of the types of irrigation expressed in percentage was the following: meadow made up for 48%, arable lands constituted 39%, rice 2%, and horticultural irrigation accounted for 11% (Museum, 2023).

In terms of the irrigational methods in 61% of cases surface irrigation was used, sprinkler irrigation accounted for 20%, and subsurface irrigation is equal to 19% as it can be seen in Figure 1.

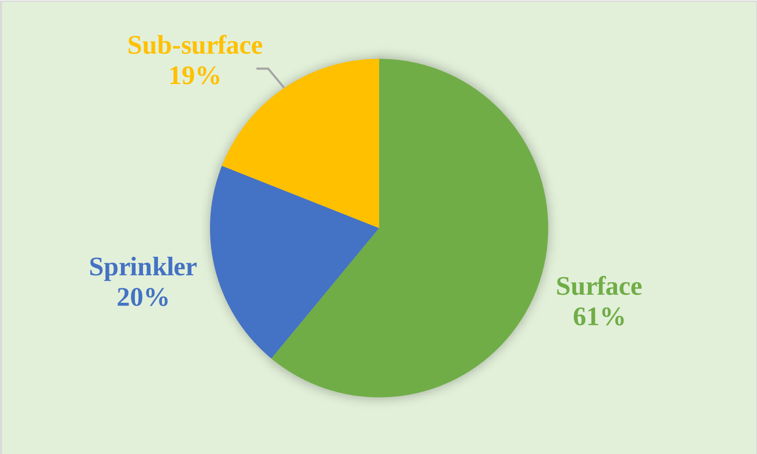

Figure 1: Distribution of irrigation methods 1919-1930
(Source: Museum of Irrigation)

In conclusion, we can deduce that this period oversaw a massive turn in technological and structural development in irrigational engineering, however small the percentage of actual growth of crop yields might have been.

It is worthy of note, that 73.6% of areas transformed accordingly for irrigation were located in the Transdanubia, while 6.3% were located in the vicinity of Budapest. The lands on the Great Plain which were suitable for irrigation only made up for 20.1% of the nation's irrigated lands. The differences between the region west of the Danube and that which lies to the east of it, were proportional to the differences in the standards of regions' respective agricultural practices.

In 1934 and '35, there were two consecutive years of catastrophic drought, which wrought havoc on the country, pushing many farmers into a state of financial crisis. The shortage which followed the drought could only be resolved with resources within the country, meaning that, for example, the water shortages in the Plains became a national issue. Despite the urgent nature of the conundrum, the situation changed for the better at only a slow pace: Under the 15 years of this era, the Hungarian Great Plain managed to increase its share of the total irrigated territories by only 4.5% (from 20.1% to 24.6%). (Museum, 2023).

One of the most important events of the era was the establishment of the National Irrigation Office in 1937 through legislation, which centralized the management of irrigation development. The law envisioned the creation of approximately 170,000 hectares of irrigated land along with the necessary facilities. As a result of these efforts, just before the outbreak of World War II, the irrigated land had reached 24,000 hectares (Katz, 1997).

Despite the increasing financial burdens of the war, tax benefits were provided to farms that installed irrigation equipment. However, strict conditions, such as the existence of a drainage system, were imposed. The proportion of horticultural irrigation continued to increase during this period, and this is when the first irrigated orchards also appeared.

For the purpose of researching the quality aspects of irrigation, the first irrigation and soil laboratory was established in Sarkad. Between 1930 and 1944, the actual irrigated land area increased from 14,620 hectares to 28,000 hectares. Within this expansion, the proportion of rice cultivation also significantly increased, reaching 8,500 hectares (Museum, 2023).

3.5. Socialist Era (mid 20th century)

After the war, there was a strong development in the reestablishment of damaged irrigation facilities. By 1949, the irrigated land area had reached pre-war levels in terms of quantity. There was a significant structural change as well: instead of the previous predominance of irrigation facilities in the Transdanubian region, 80% of the irrigation facilities were developed in the Great Hungarian Plain, primarily for the expansion of monoculture rice cultivation (Museum, 2023).

In the 1950s, in line with the economic policies of that time, significant rice fields were established mainly in the place of marshy, waterlogged areas (Gazdag, 2009). The rapid territorial development often occurred without thorough consideration from both a technical and agronomic perspective. The majority of the rice fields in the Great Hungarian Plain were established on poor-quality, saline soils. In these rice-growing areas, the groundwater levels dangerously increased.

From the 1960s, once again, driven by another period of drought, irrigation development saw a resurgence. However, the increased demand for establishing traditional surface irrigation systems could not be met at the level of planning, execution, and manufacturing. Consequently, in 1962, there was an import of irrigation equipment, marking a significant technological advancement. As a result of these measures, between 1960 and 1965, the area equipped for irrigation increased by nearly 210,000 hectares, more than tripling the total to reach 369,000 hectares.

There was even more significant technological progress. The ratio of surface/overhead irrigation, which was 73.6%/26.4% in 1960, nearly reversed by 1966, reaching a ratio of 30.2%/69.8%. The area that could be irrigated in a manner similar to rainfall reached 291,368 hectares. However, the intensive period of irrigation development stalled in 1964, following the end of a relatively short period of drought.

The National Water Management Authority was established in the late 1960s with the goal of preparing agricultural enterprises in need of irrigation for the reception of irrigation water. In the late 1960s (between 1967 and 1969), the distribution of irrigation by sector was as it can be seen in Figure 2.

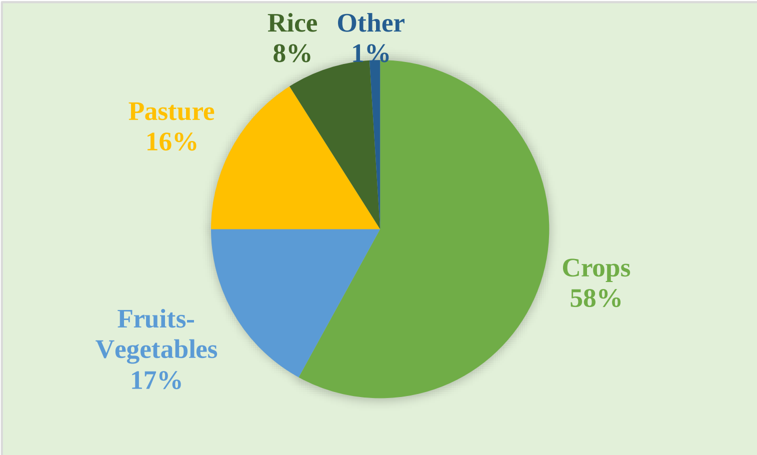

Figure 2: Distribution of irrigated plants at the end of 1960s
(Source: Museum of Irrigation)

The numbers clearly indicate that during this period, the significance of rice cultivation significantly decreased. The least territorial variation was observed in the fruit and vegetable sector.

Starting in 1970, targeted investment structures began to emerge. As a result, by 1975, approximately 24,000 hectares of modern irrigation facilities were built. These facilities featured underground pipe networks, hydrant operation, and machine-transferred lateral pipelines.

The industrial background of irrigation development also saw intensive growth during this period. Modern rain gun irrigation equipment with increased water-carrying capacity, utilizing foreign experiences, became available, and domestic nozzle production improved.

In the later years of this period, again drawing on foreign experiences, drip irrigation systems began to appear in many places. In Hungary, the production of micro-irrigation products, such as mini-sprinklers and drip hoses, started in 1987. The mini-sprinkler irrigation equipment used predominantly originated from Israel. There were attempts to manufacture these products domestically, but the quality was not satisfactory, and production ceased in 2003.

4. RECENT IRRIGATION METHODS IN HUNGARY

The proportion of irrigated territories in Hungary is quite small, expressed in percentage it is overall 2,4 (2015), in the EU it is 8, and it is above 13 percent in the USA. The low spread of irrigation can be traced back to, for example, the shattered property structure, the lack of cooperation between the farmers, short term lease agreements, the complexity of the water law permission system, the hardly accessible, sub sufficient amount of irrigational water, and the lack of resources to improve these systems. Local professionals agree that irrigation holds many beneficial possibilities for the country's agricultural production. Due to climate change, we too experience extreme weather conditions, out of which the most drastic is the increasing occurrence of dry seasons. It is possible to mitigate the negative effects of the dry seasons by expanding upon irrigational farming. One precondition of this is to ensure that the farmers have access to a sufficient amount of a sufficient quality of water, which requires improvements from both the state, and the farmers (Tóth L. L., 2020).

The practice of water replacement has become more and more widespread in the past few decades, this is mainly due to meteorological shifts, the expandability of returning yield, the favorable changes in the expenses related to irrigational equipment, increases in miscellaneous production expenditures, and reaching a larger economic potential. In order to achieve the proper growth in our plants, they require sufficient levels of air, light, heat, nutrients, and water. Out of all these, farmers are most capable of influencing the latter two.

When it comes to promoting growth, too much or too little water can be equally detrimental to this process. In cultures where natural precipitation is utilized for irrigation, cultivation is successful if the farmers are able to supplement their rain at an optimal time, to an optimal degree through artificial means. If the minimum water requirement can't be reached even when supplemented with irrigation, then the venture will yield no economic profit, which in turn means an unnecessary rise in expenditures. The only condition in which we can expect an economic result from irrigation, is if it is integrated into crop-growing technology.

Today, in order to receive our desired economic result, and to minimize negative effects on the environment, the supplying of water to our crop must be carried out while managing a stable supply of nutrients simultaneously.

Depending on whether we supply water by routing it to the surface of the soil, by distributing it through the air, or in a subterranean manner, we can distinguish between the following irrigational methods: Surface irrigation; Sprinkler irrigation; Subirrigation; Micro irrigation.

Within certain irrigational methods, especially in the case of surface irrigation, the irrigative equipment can be modified in multiple ways, therefore multiple further variations of water dosing exist.

The volume of water required is defined by the method we are using, the moisture retained by the soil, and the water needs of the crop. The selection of an irrigation system is based on soil, crop, economics, water quality, and management considerations.

To accommodate the fluctuation in weather and to satisfy the plants' water demand, we possess not only our natural water reserves, but also irrigational farming. Having discerned the importance of irrigation, we must now decide which methodology to implement. To support our decision-making, I have compiled the most relevant irrigational methods, and their characteristics.

4.1. Surface Irrigation

Surface irrigation accounts for the largest share of irrigated land globally. Traditional surface irrigation techniques, such as furrow, basin, and border strips, exhibit a field water application efficiency estimated to be as low as 40%. This is due to significant deep percolation losses and poor water distribution uniformity, as depicted in Figure 3. Nonetheless, in countries with extensive irrigated areas, these methods continue to be prevalent primarily because they are cost-effective and straightforward to implement.Water is applied by gravity across the soil surface by flooding or small channels (i.e., basins, borders, paddies, furrows, rills, corrugations).

Figure 3: Furrow irrigation
(Source: Waller & Yitayew 2016)

Surface irrigation – specifically flooding irrigation – is one of our most ancient tools for water replenishment. In this case the soil is submerged in a homogeneous layer of water, where the water then seeps into the ground by way of gravity. It is important to note, that surface irrigation is exclusive to soil which is only minimally water permeable, otherwise one will face erosion and a large waste of water.

Surface irrigation is the most widespread method of irrigation in the world, however there is no practical example of its use in Hungary, mainly due to the following reasons.

- low effectiveness (large water loss)
- uneven distribution of water
- unsuitable for good quality irrigation
- necessitates landscaping beforehand

4.2. Sprinkler Irrigation

Water is distributed to the desired location through a network of nozzles, which can be impact and gear-driven sprinklers or spray heads. This water reaches the sprinkler heads via both above-ground and underground pipelines. Sprinkler irrigation laterals can be categorized as either fixed, periodically moved, or continuously self-moved systems. These systems encompass various types, such as solid set, hand-move laterals, sideroll (wheel) laterals, center pivot, linear move (lateral move), as well as stationary and traveling gun varieties.

Rain-like irrigation is the most popular method of irrigation in our nation, mostly used in Arable cultures. This kind of irrigation involves sealed pipes, using pressure to direct water that is in turn distributed by nozzles, delivering the water through the air, in the form of small particles, simulating the effect of real rain.

Advantages:

- Low labor requirements.
- Capable of irrigating various kinds of reliefs and various sized fields.
- Easy to operate and easily automatized (The released water can be smoothly regulated and measured).
- The sealed piping prevents the chemical and physical pollution of the water.
- It makes the release of nutrients and chemicals, the regulation of the microclimate, the cooling of the environment and protection against frost possible.
- The design of the nozzles and their wide range of sizes facilitates water replenishment in different reliefs and fields.

Disadvantages:

- To ensure the full operation of the system, a generally high pressure of 2-8 bars is required, which requires a lot of energy to generate.
- The pressure resistant pipes, shapes, and fittings are expensive.
- The irrigational distribution is greatly impacted by wind velocity, the small droplets are carried far by these gusts. Any wind above the speed of 5 m/s (18 km/h) means we must cease irrigation (Tóth Á. , 2008).
- The evaporation loss of the process is high (around 25 %), a certain portion of the water evaporates in the air, while another portion vanishes from the surface of the plants (Tóth Á. , 2008).
- Irrigation originating from above the plant stock can result in the spread of pathogens, and removes plant protectants from the foliage.
- Irrigation water of poor quality and high salt content can scorch the leaves.
- If the intensity is not adjusted to meet the requirements of the specific soil, this can cause erosion.

In our nation's natural climate, large crop field irrigation across a large surface is easily automatable in a way that saves water and energy, using high performance front-moving (linear) or cyclical (pivot) automatic sprinkler systems (Csomor, 2018).

These crop fields between 20 and 400 hectares, or multiple neighboring small fields each accessible from the other are suitable for joint irrigation. The sprinkler mechanisms themselves are made up of towers which revolve on small wheels. It is on these towers, separated by 25-55 meters each, that the pipeline is located. The sprinkler can be moved with a unique hydraulic motor, or an electrical one, the velocity of which can be regulated, which in turn makes regulating the intensity of the irrigation possible (the amount of water delivered onto a given unit of soil, within a given time interval). Its sphere of use is unaffected by the type of the soil. The water requirements and the irrigative capacity of the equipment differs from type to type. The modern mechanisms can be used up to a slope of 15 percent (Kemény, Lámfalusi, & András, 2018).

Water is supplied to the cyclical sprinkler mechanisms from a drilled well or hydrant located in the middlepoint of the sprinkling radius of the mechanism. The length of a piece of equipment such as this one can vary from 200 to 600 meters, this number is also equal to the area of effect of the sprinkler. The rain-like dispellment of the water is performed by sprinkler nozzles placed along the connecting piping of the towers at different heights, which can be supplemented with a high radius nozzle at the end of the wing duct (Figure 4.).

Figure 4: Center pivot irrigation system
(Source: Waller & Yitayew 2016)

The most important advantages of linear irrigation:

- The permanent nature of the installment and low intensity means it can be used on sandy and hard ground equally.
- Their operation can be fully automated, is easily controllable, and requires minimal manual labor. The most modern equipment is equipped with positioning systems (GPS) and can be remotely controlled or monitored via GSM or internet-based data transmission.
- They can help mitigate atmospheric drought because they can quickly pass over the area with small water doses.
- The latest types of these devices can be seamlessly integrated into the technological sequence of precision agriculture.

Disadvantages of linear irrigation:

- High initial investment cost.
- High maintenance costs.
- Significant energy requirements depending on water supply.

Among these operating irrigation systems, the most common is the hard hose reel irrigation machine (Figure 5.). These devices are available in a wide range of sizes and are produced with various technical configurations and control systems.

Hose reel irrigators are set up in one area and allowed to run for a certain amount of time, then moved to water a different area. Hard hose systems work with sturdy plastic hoses that are reeled onto a large hose reel, pulling the sprinkler cart along the irrigation lane where watering is necessary (Tóth Á. , 2008).

Advantages of hose reel irrigation:

- The wetted width can be up to 100 meters or more.
- Application rate and depth is controllable.
- Auto shut off at the end of a pumping session.
- Large volumes pumped at one time.
- Generally good uniformity.

Disadvantages of hose reel irrigation:

- Heavy equipment to shift (tractor required depending on size).
- High standard of competence required to operate.
- Medium to high capital outlay.
- Large versions can be affected severely by wind (spray drift).

Figure 5: Hard hose reel irrigation system

Irrigation systems are commonly employed to distribute substances such as fertilizers, soil fumigants, or insecticides to crops. There may be instances when the crops need nutrient supplementation even when irrigation isn't necessary, such as after heavy rainfall. The recommended fertilizer injection schedules, determined by soil test results, are outlined in each crop production section of this guide. It is advisable to commence fertigation only after the irrigation system has been pressurized. At the end of a fertigation or chemigation event, it is highly recommended to conclude with a brief flushing cycle using clean water to prevent the buildup of fertilizer or chemical residues in the irrigation system (Dukes, Zotarelli, Liu, & Simonne, 2021).

4.3. Micro Irrigation

Water is applied to the point of use through low pressure, low volume discharge devices (i.e., drip emitters, line source emitters, micro spray and sprinkler heads, gravity and low pressure bubblers) supplied by small diameter surface or buried pipelines.

Micro irrigation is the most frugal method, which is most widely used in arable vegetable plantations: this collective term signifies irrigational methods where the water dispensing elements, using low pressure, under a given interval, deliver the water in a dot-like formation across the marked area.

Drip irrigation, as we can deduce from its name, involves delivering water to the surface of the soil in controlled drops. The water demand of the vegetation is constantly being addressed, which, in practice, means that water being transported under low pressure is distributed in small amounts through the different dispensary elements.

The characteristic of micro-irrigation is that it does not irrigate the entire surface; the emitters are fixedly installed, and water movement in the soil is unidirectional. Fertigation, which is the application of nutrients through the irrigation system, is part of micro-irrigation. Micro-irrigation can be used regardless of the terrain's slope, making it possible to achieve uniform distribution even on sloping terrain. It can be effectively implemented on areas of any size and shape. It can also be applied to soils with poor water management, provided that the design takes into account the soil's water-carrying and storage capacity.

Continuous dosing allows for intensive production even on low water-holding capacity sandy soils, and irrigation can also be successfully implemented on heavy clay soils due to its low intensity. It can use water with a higher salt content compared to other irrigation methods because the frequent application prevents the soil solution from drying out. With a slight surplus of water, salts can be leached below the root zone. Leaves do not come into contact with the irrigation water, preventing scorching. However, salt deposits and impurities can easily clog the narrow passages of the drip emitters, so water purification and filtration are essential. For subsurface drip irrigation, treated wastewater can also be used.

4.4. Sub-irrigation

Water is made available to the crop root system by upward capillary flow through the soil profile from a controlled water table. Each irrigation method and irrigation system has specific site applicability, capability, and limitations.

In the case of subsurface irrigation, the irrigation water is transported and distributed by underground pipe systems, in a layer of soil which remains untouched, from where it drenches the cultivated soil. Its advantages are that it does not hinder surface-level cultivation and its evaporative loss is low. However, it is expensive to install and it is difficult to follow the path of the water in this system.

4.5. Sustainable Irrigation Practices

Sustainable irrigation practices are methods and techniques employed in agriculture to ensure efficient and environmentally responsible water use while maintaining or increasing crop productivity. These practices aim to address the challenges of water scarcity, soil degradation, and the need to minimize the environmental impact of agriculture. Sustainable irrigation practices are essential for meeting the growing global demand for food while safeguarding water resources and minimizing the ecological footprint of agriculture. When it is applied to the management of water resources in agriculture, sustainability is considered to be a series of practices that increase crop yield and minimize water losses. These practices aim to strike a balance between agricultural productivity and environmental stewardship, ultimately contributing to a more sustainable and resilient food production system (F. Velasco-Muñoz, 2019).

Conservation tillage practices, such as no-till or reduced tillage, help improve soil structure and reduce water runoff. These practices minimize soil disturbance and maintain crop residues on the field, which can help retain moisture and prevent erosion.

Applying organic or synthetic mulch to the soil surface helps conserve soil moisture, reduce evaporation, and suppress weed growth. Mulching can be particularly beneficial in arid and semi-arid regions.

Rotating crops and diversifying plant species can improve soil health and reduce the risk of soil degradation. Different crops have varying water requirements, allowing for more efficient water use when they are strategically planted.

Collecting and storing rainwater for irrigation can be a sustainable practice, especially in regions with seasonal rainfall. Rainwater harvesting systems can range from simple rain barrels to more complex storage and distribution networks.

Well-maintained and properly designed irrigation infrastructure, including canals, pipelines, and reservoirs, is essential for minimizing water losses due to leaks and evaporation.

Poor irrigation practices (i.e. insufficient water application, use of saline water, limited provision for field drainage), combined with low rainfall, high evapotranspiration rates and limited inherent soil drainage characteristics accelerates salinization. Globally, about 10 Mha of agricultural land is lost annually due to salinisation, of which about 1.5 Mha is in irrigated areas (Shahbaz & Rana, 2006).

Implementing best practices in agriculture, such as integrated pest management (IPM) and optimal planting density, can reduce the need for excessive irrigation and minimize environmental impacts.

Each of these sustainable irrigation methods has its advantages and disadvantages. The primary drawback of implementing a more efficient method often relates to the time or financial investments required. For instance, redirecting a stream or channeling pre-collected groundwater into fields with furrows is a cost-effective approach. Water flows through these furrows, temporarily flooding the field without causing harm to seeds or crops, known as flood or furrow irrigation. However, this method tends to consume more water than necessary.

On the other hand, adopting a sprinkler system to collect groundwater or lifting it from underground sources represents a more sustainable irrigation technique compared to flood irrigation. This approach allows for precise water direction and control, resulting in reduced water usage. Nonetheless, there are upfront costs involved in installing these pumps, as well as ongoing expenses for maintenance, including fuel and replacement parts. When acquiring any farming equipment, it's important to consider these financial aspects. Fortunately, the United Nations, in collaboration with various global organizations, is working to provide rural farming communities with solar and mechanical pumps.

Sustainable irrigation methods hold significant importance for farmers worldwide, as they offer various options tailored to the resources available in different regions. What is important is ensuring a water supply so that farmers in arid regions can continue to grow and profit off of their crops.

5. FUTURE STRATEGIES

In order to satisfy the ever more prosperous human race, we must increase global food production twofold by the year 2050, while additionally reducing food waste, and changing our diets. The constant development of agricultural practices has successfully diminished the rates of hunger on a global stage, however, this development has also contributed to issues such as climate change, biodiversity loss, and degradation of land and water resources. Therefore, securing sufficient and equitable access to sustenance while decreasing agriculture's environmental effects is perhaps the most magnificent challenge for society of the 21st century (Lorenzo, 2022).

Farming now is responsible for nearly a quarter of our total global greenhouse gas emissions, and takes up about 70 percent of all our freshwater use. These trends are likely to become exponentially stronger in the coming decades, as more and more people join the middle class as a result of general growth in humanity's population (Searchinger, et al., 2014).

Supplementing concurrently underperforming rainfed crops with irrigation is vital to matching future global food demand without further expanding the crop area. Global warming has affected agricultural productivity in the past, and will certainly affect global food security in the future. Those rural communities that rely on rainfed agriculture will be gravely influenced by climate change since rainfed farming is largely dependent on climatic conditions and sustains the majority of global food production. Due to the increase of water- and heat-stress events caused by global warming, establishing irrigation can be a potential climate adaptation solution which alleviates heat- and water-stress to crops and reduces climate variability and extremes. Areas being irrigated have increased in number twofold during the past 60 years, these lands presently account for about 22 percent of croplands across the globe. The swelling population will be a key motivator for irrigational expansion initiatives in the times to come, and according to recent predictions, the proportion of irrigated land on a global scale could double by the year 2050, passing the 800 million hectare mark, further heightening the water demand for these projects. Nevertheless, water and land availability are restricted by natural biophysical limits, especially alongside climate change (Lorenzo, 2022).

Agriculture of this type produces higher yields than rainfed agriculture and is undoubtedly vital for food security, since it sustains 40% of global food production, despite the fact that only 22% of total cultivated land is handled this way. Sadly, approximately half of the current water consumption is unsustainable, in other words, the consumption of water in these cases exceeds the regional renewable water capacities, which leads to the depletion of rivers and freshwater sources.

There are multiple examples of unsustainable irrigation practices, such as the extraction of antediluvian water from groundwater, the pumping of well water at the rate required to mine an aquifer, or the draining of river flows, bringing about disastrous conditions for aquatic animal life and ecosystems. These practices have over the years successfully degraded countless local and downstream river flows all around the globe. Therefore, our drastic reliance on unsustainable irrigation practices imperils security of water and food on a global, and local level equally. Lands utilizing these ecologically unbeneficial methods grow crops that satiate the nutritional demands of 1.3 billion people. However, a sizable proportion of food produced this way does not actually contribute to local food security, but instead becomes a part of the international food trade. Globally speaking, 15% of unsustainable irrigation volumes produce agricultural commodities for the export market. Amongst the major importers of these goods are countries like China, and the European region, while the major exporters include India, Pakistan, the USA, and Mexico. The majority of remunerative crops such as sugar cane, fruits, vegetables, and cotton constitute two thirds of the global unsustainable irrigation water consumption used to grow crops to then export. For that reason, there are major trade-offs to take into consideration between the economic benefits and environmental impacts of these aforementioned practices (Lorenzo, 2022).

Burdened with the situation of our present-day precipitation and ambient temperature patterns, we are in possession of enough local water to increase the proportion of sustainable irrigated lands by 35%, in turn pushing food production to be able to sustain 1.4 billion additional people without substantially draining water resources or violating natural areas. We are able to implement sustainable irrigation through making use of locally available water resources which do not influence freshwater ecosystems or degrade rivers, lakes, reservoirs, or groundwater.

In implementing sustainable irrigation under global warming, two approaches exist. The first of these involves nature-based methods in reducing crop water stress and in turn thicken soil moisture by easing evaporation, and enhancing filtration. Contour stone bunds, pitting, and terracing are agricultural methods that boost soil moisture levels by decreasing surface runoff and improving the process of infiltration. Agroforestry, mulching, and no-till farming have the potential to enhance soil water retention and minimize evaporation by reducing sunlight exposure through shading. The removal of weeds can additionally decrease unproductive evaporation and boost the availability of water for cropsAn alternative strategy involves the implementation of engineered solutions that aim to decrease water demand and increase water availability (Shahbaz & Rana, 2006).

To mitigate evaporation and reduce irrigation water demand, the installation of photovoltaic panels over croplands can be employed to provide shading. A method for increasing water availability to crops involves the adoption of rainwater harvesting techniques, which capture and store rainwater for supplementary irrigation. Sustainable irrigation solutions like solar-powered drip irrigation systems are actively promoted by the European Union and United Nations.

Meeting the future potential for sustainable irrigation expansion necessitates the development of increased water storage capacity to address temporal discrepancies between water availability and crop water requirements. In a warmer climate, there is a demand for significant water storage infrastructure to safeguard sufficient water reserves required to sustain current possibilities for expanding irrigation. The scarcity of such infrastructure is likely to persist and continue to affect the economics of agricultural water resources The introduction of water storage infrastructure introduces additional challenges on social, economic, and ecological fronts in the context of future food systems. This poses a significant gap in our understanding of the economic and environmental consequences of expanding irrigation. The construction of large dams and reservoirs has been a prominent feature of infrastructure development in the 20th century. In fact, man-made reservoirs have played a crucial role as a water source for irrigation.

Furthermore, irrigated agriculture and water storage are expected to play integral roles in climate adaptation and mitigation strategies aimed at achieving carbon neutrality, such as bioenergy coupled with carbon capture and storage the rising demand for bio-energy crops to facilitate carbon dioxide removal is anticipated to lead to an expanded cultivation of irrigated croplands, intensifying the strain on water resources (F. Velasco-Muñoz, 2019).

5.1. Climate Change Adaptations

Over the past 10,000 years, Earth's climate has maintained a remarkable stability, enabling the advancement of modern civilization and agriculture. Our way of life has been designed to align with this consistent climate, rather than the significantly warmer conditions expected in the coming millennia. As our climate undergoes shifts, adaptation becomes imperative. The speed at which these changes occur will significantly impact the challenges we face in adapting to them.

As global warming persists, there is a projected increase in its adverse effects on irrigation water, potentially impacting food security. Rising temperatures lead to an accelerated rate of evaporation from both land and oceans. This is expected to result in increased precipitation in tropical and high-latitude regions, but a decrease in arid and semi-arid mid-latitudes and continental areas (FAO, 2015).

Although climate change is a global concern, its impact is experienced at the local level. Local governments are thus on the front lines of climate adaptation efforts. Cities and communities worldwide are actively addressing their specific climate challenges. They are undertaking initiatives to construct flood defenses, prepare for heatwaves and increased temperatures, implement improved drainage systems in pavements to manage floods and stormwater, and enhance water storage and utilization.

The effects of climate change are clearly evident in recent years' data for Hungary as well. According to the data from the Hungarian Central Statistics Office (KSH), the trends indicate that it is getting warmer, but less precipitation is expected, and it will fall on fewer days (Table 1.). It is necessary to prepare for the increasing occurrence of drought periods, which will require more irrigation to maintain sustainable crop yields.

Table 1: Annual meteorological statistics
Source: Hungarian Central Statistics Office, *(KSH, 2023)*

Year	Avarage annual temperature in C°	Annual precipitation in mm	Number of rainy days	Number of frosty days	Number of heat days	Number of heat waves
2016	11	700	144	78	23	3
2017	11	616	127	83	40	11
2018	12	605	151	80	37	7
2019	12	630	141	72	41	8
2020	12	613	140	72	29	2
2021	11	514	134	96	41	16
2022	12	497	126	88	46	16

The objective is to mitigate the risks arising from the adverse impacts of climate change while simultaneously harnessing any potential advantageous opportunities that may come with it, such as extended growing seasons or enhanced crop yields.

The Intergovernmental Panel on Climate Change (IPCC) of the United Nations believes that in areas already suffering from water scarcity, we can expect a 10-30% decrease in water resources. In some places and during certain seasons, the changes may deviate from this annual pattern. The extent of areas affected by drought is likely to increase. The frequency of intense heavy rainfall events is likely to increase, which will raise the risk of flooding (Kapronczai I. B., 2011).

Mitigating the impacts of climate change on irrigation water will increase the need to evaluate the current irrigation strategies to maximize the utilization efficiency of available water.

To address this, it is important to construct more reservoirs to ensure that rainwater is available during dry periods, thus reducing the reliance on natural water sources.

Hungary could be in a more advantageous position because it is abundantly supplied with both surface and groundwater resources. However, it has not fully utilized these advantages. Current conditions are marked by the fact that more surface water leaves the country each year than flows into it, while in some years, the agricultural sector is severely affected by drought. If Hungary were to exploit the irrigation potential from surface waters alone, it could engage in much more stable and intensive agriculture (Kapronczai, 2014).

5.2. Future Policy and Regulation in Hungary

Irrigation development is a strategic issue in Hungary. The country receives an average annual precipitation of 500-750 mm, but there are significant variations in the amount of annual precipitation between regions. In theory, the amount of precipitation could be sufficient for most of the crops currently grown; however, due to the uneven distribution of rainfall, irrigation is essential to achieve high and quality yields (Tóth T. , 2021).

In order to make irrigation sustainable and effectively cope with the impacts of climate change, the Hungarian government has issued various regulations and policies such as the Hungarian Government Decree no. 1744/2017. (X.17.) On the creation of an irrigational development scheme lists certain goals to achieve by the year 2030, to appropriate the spread of effective irrigational farming. The government declares the following preconditions to bring this about: the necessary technological and infrastructural conditions for this development must be defined, parallel to the necessary human and financial needs; it also proposes creating a professional program which outlines the necessary infrastructural and water supply management development in the near and distant future.

To achieve this, real-time water supply management is a must. The program also includes the role of local communities, alongside that of the state; such as water damage prevention, internal water protection, and other tasks which are within the purview of the local council.

The state pledges (Act CXIII., 2019 on irrigational farming) 17 billion HUF annually between the years 2020 and 2030 to increase the size of irrigated areas nationwide, to increase the number of farmers involved in irrigation, further improving the efficacy of agricultural production. Irrigational farming is supported by the new Act passed by the Hungarian Parliament, which declares that irrigation should be a part of the public interest (Kolossváry, 2019).

The goal of the agricultural ministry is, by way of new legislation, to aid our farmers in flexibly adapting to challenges affiliated with extreme weather changes, and further improve agricultural efficiency. Irrigation is an essential component of a competitive agriculture, the amelioration of which is an economic issue, while the national food supply component is in fact a national strategic issue. In this past year, we witnessed the creation of the center of administration for agricultural irrigation, and we saw how the Rural Development Program accommodated irrigational development.

With the conversion of the cooperation of our professional authorities, water rights permit procedures will become much simpler and faster.

Due to changes in legislation, the types of areas permitted for irrigation, and the conditions, including technological ones, connected to this are now precisely defined by irrigational development plans. With these new government measures, the Ministry of Agriculture has accepted a large role in keeping irrigational investments within the space defined by environmental protection regulations.

Irrigational systems in Hungary must be improved, new canals and machines must be constructed, the cost of which will realistically be between 105 and 120 billion HUF according to professionals. These very professionals also warn us that the irrigational needs of our agriculture greatly exceed our irrigative capacity, these numbers are 800 hectares and 300 hectares respectively. Out of the area dominated by irrigable plants measuring 2.696000 hectares in total nationwide, only 68.000 hectares are irrigated, even though it would be possible to irrigate another 330.000 in an economic manner (Tóth L. L., 2020).

In the interest of achieving this, the creation of a so-called Irrigation Bureau was proposed in the past, which would have been responsible for planning complete investments in irrigation, and would have performed administrative duties, up until the acceptance of the permit.

Hungary experiences 28 years of drought in the course of 100, but we must prepare for the effects of ‘period of drying’ in terms of space, and of time. Already, a great proportion of agricultural land today is arid land, but current climate projections show that our summers will become warmer, and precipitation will drop. Defining the whole country as arid leads us to the obvious conclusion that the demand for irrigable land will rise exponentially. This signifies a growth of 638.000 hectares more than what the concurrent climatic conditions require. The irrigational funding is best directed towards land that possesses favourable conditions for irrigation farming, because these are the types of lands that we can expect to be profitable. According to the calculations made in this matter the profitable solution would be to utilise 701.300 hectares of surface waters, and 102.700 hectares of underground waters for irrigation. 96 percent of the irrigational development achievable through the employment of surface waters would support plant growth on arable lands, also increasing the area of irrigated vegetable plantations by 7200, fruit plantations by 9800, and vineyards by 5300 hectares. All in all, the irrigated lands of arable cultures, which is currently 50.700 hectares, could grow sixfold with the help of irrigational development (Tóth L. L., 2020).

6. SUMMARY

My goal throughout this thesis was to brush upon the different factors and changes which influenced European, but mostly the Hungarian development of irrigation. I examined the differences between the different European climate zones, their irrigational uniquities, and their varying histories. I then proceeded to list all of the legislative bodies which play an important role in designing the laws and system of rules for irrigation in the EU. We can ascertain that all through the years countless organizations were created to protect our waters, and to decide how to utilize the resources that we still possess in an effective and sustainable manner.

I studied the development of irrigation from numerous sources, going back all the way to ancient times, then eventually moving on to its emergence and evolution in Hungary. I delved into the methods and techniques that characterized the different eras, their progression through history, the changes that they went through. I deduced that the major changes came as a result of wartime or periods of drought, and i observed how different irrigation methods adapted from separate cultures were first implemented, then how they became an integral part of the country's irrigation. The role of the local nobility, scientists and politicians is undeniable, whose visions shaped the constant and dynamic improvement of the nation's irrigation plan during the decades.

I also perceived that the state had, and still has an all important role in using their legislative capabilities to shape the direction of change, whether it be negative or positive.

Arriving to our times, I enumerated the methods which are still in use to this day. Furthermore, I inspected what technology and machinery was used in aid of ameliorating the efficacy and simplicity of irrigation systems, and their precise benefits and drawbacks.

Toward the latter part of my thesis, I pondered upon, then dissected the problems and issues that the future may hold. The conclusion that I drew from the wide variety of studies I read was that irrigation is absolutely vital in the conservation of our society, since a rapidly growing population in turn requires a rapid growth of agricultural yield. We must push ourselves to utilize our modern methods in the most efficient way possible, while supporting our farmers in the best way possible.

I find that using the natural resources at our disposal is of utmost importance. By this I mean, for instance, satisfying our irrigation needs efficiently, or even using storing rainwater in containers for later use. It is critical that we, as a species, learn how to adapt to the situation generated by climate change, like sudden increase in temperature, low and uneven precipitation, and from this, drought periods that last longer than before.

In my opinion, the most that we can do is to preserve our already vanishing water sources, on the level of the individual, on an industrial level, and on a state level all around. Using the knowledge that the human race has accumulated throughout the centuries, paired with the cutting edge technology of the 21st century, we must prepare for the difficult times that lie ahead, and ensure stable food safety for the generations to come in our ever changing world.

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9. ANNEXES

DECLARATION

the public access and authenticity of the thesis

Student's name:	Szabó Bence
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Year of publication:	2023
Name of the consultant's institute:	Institute of Agronomy
Name of consultant's department:	Department of Agronomy

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