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Status of Agricultural Irrigation in Hungary

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Abstract. Some prediction models indicate climate change will have a more pronounced impact on Hungary than previously anticipated. Traditionally, Hungarian agriculture is based on dryland farming, with irrigated farming practiced in a few areas. Land degradation is a significant concern. However, the loss of arable land due to water scarcity could be more widespread. One potential solution is to irrigate, which could maintain soil fertility for decades. Utilizing modern irrigation techniques is a crucial approach to making irrigation as sustainable as possible while ensuring yield and quality. This study aims to provide an authentic picture of irrigation in Hungary, past and present. It also aims to provide suggestions for the near future, drawing on examples from abroad.

1 Introduction

Mosonyi identifies two significant challenges to effectively managing Hungarian water resources [1]. Firstly, in periods of drought, rivers with a low flow capacity, such as the Körös, could experience a reduction in flow to the extent that they may dry up. Secondly, the Danube will no longer be navigable, and it will be challenging to obtain water for irrigation. The high mountains are likely to experience greater runoff rates, with less snowfall than observed in recent decades, which will result in floods, although droughts are also possible in the same season. Furthermore, countries situated further upstream may implement measures to retain water resources for their use. In order to ensure the availability of water during critical periods. The upstream reservoirs will exacerbate the downstream water management issues.

The proportion of irrigated land in Hungary has never exceeded 6.5% of the total agricultural area. Since the 1980s, there has been a downward trend in the proportion of land under irrigation. During the socialist planned economy, these areas were more likely to be designated as potentially irrigated. On occasion, the irrigation system needs to be more adequately planned. In 2010, the irrigation intensity in Hungary reached the level observed in the 1950s [2]. Furthermore, including fish ponds within the scope of irrigated areas in statistical data introduces a further distortion.

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It is encouraging to note that stakeholders agree that more and better irrigated areas are needed. According to the Hungarian Statistical Office (KSH), the irrigated area has increased by 37% [3].

The year 2022, which was characterized by a strong drought season, provides a clear indication of the current situation. In 2022, land area legally permitted for irrigation will total 99,832 hectares. The area not registered is estimated to be between 20 and 30%, and about110,000 to 120,000 hectares are still irrigated according to the estimates provided by the government's irrigation experts [4].

In years of low precipitation, farmers tend to invest in irrigation. In contrast, even farmers concerned about climate change are uncertain whether they can recoup the cost of irrigation. Furthermore, 80,000 to 100,000 hectares will be rehabilitated over the next two years, with an additional 30,000 to 40,000 hectares being implemented as entirely new projects [5].

It is a common misconception that the only area that is measured is that which is irrigated. This is the only KPIs (key performance indicators) currently in common knowledge. The data can be used to gain insight into the current situation. It is well established that the profitability of irrigation is contingent upon a number of factors, including the technology employed, the crops cultivated and the energy sources utilized. In the early 1900s, Bulgarian gardeners (bolgárkertészet) with superior technology could generate significantly higher profits than Hungarian farmers. In certain instances, the initial irrigation costs were ten times higher for Bulgarian gardeners than for Hungarian farmers due to using the most advanced technology available [6].

In addition to the numerous incentives in place, implementing irrigation has been slower than anticipated. According to the National Bank of Hungary, the lack of irrigation will result in a 0.6% reduction in GDP in 2022 [7]. The proportion of agriculture in total GDP may appear relatively modest. When the data is analysed about agricultural-related sectors, the figure is found to be between 10 and 12 per cent on average. The 0.6% loss in GDP is, in fact, a 1.5-1.8% loss in GDP. This figure could potentially disrupt the growth trends observed during periods of economic downturn [8].

2 Materials and methods

2.1 Bibliometric analysis

The bibliometric analysis consisted of three phases, as we can see in Figure 1. The first was data collection. In this phase, relevant topics were searched using the Google Scholar and Elsevier and MDPI database. Specific keywords were used to obtain more specific results. The second phase was article selection. In this phase, the articles were selected on the basis of relevance based on quality and accuracy. Irrelevant and poor-quality articles were rejected. Interpretation and understanding of the articles. In this phase, the authors analysed each reference and tried to find trends and correlations between different sources.

2.2 Exclusion criteria

Topics that were not logically constructed, had few references, had poor methods for monitoring research. Excluded: scientific structure of the topics. Were rejected.

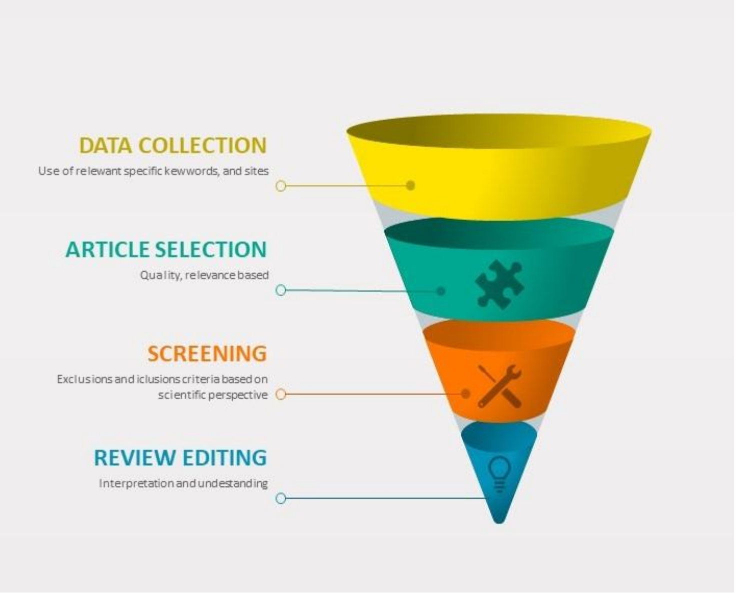

Fig. 1. Methodological framework process flow for conducting systematic literature review.

2.3 Inclusion criteria

Issues were selected to represent the best available information of the periods mentioned. Preference was given to new articles. The search objectives were to find relevant sources for the specific questions.

3 Results and Discussion

While economic figures are useful, they are not sufficient to enable an understanding of the broader context. As demonstrated, global supply chains are susceptible to disruption and breakdown more rapidly than anticipated. Globalisation is demonstrating the potential for a return to growth. In periods of economic downturn, the value of goods and services that are no longer accessible increases. Regarding water resources, Hungary is a wealthy nation, with an average of 12,000 m^3 per capita per year. The criteria indicate that a rate of 1,700 m^3 per capita per year is optimal [9].

Consequently, the water security of Hungary is experiencing a decline as a result of climate change. The observed increase in surface temperature indicates that thermal stress will persist, resulting in the continued occurrence of droughts. About water security, irrigation clusters represent a local solution. Furthermore, it is recommended that a minimum of 8-10 km^3 of water be retained within the Hungarian water circles. The use of cover crops and limited tillage methods is recommended. This approach can be employed to reduce stubble temperatures. Conversely, it is necessary to enhance the capacity of reservoirs within Hungarian river basins that are managed intelligently [10].

It reveals that in the 1950s, 1 tonne of maize used 91 mm of water. Today, this figure is down to 34 mm [11]. This fact shows that intensified production is more vulnerable to climate change. Although yields have increased, water security: "society's capacity for livelihoods, prosperity, socio-economic growth and enough water to sustain these goals" is decreasing based on all trends [12]. Fertiliser accessibility increases exposure through increased leaf area.

Increased evaporative leaf area can become a negative production component in dryland or under sufficient irrigation [11].

It should be noted, however, that even if we want to save our yields by investing in irrigation, money is no guarantee of success. The return on irrigation investment is based on optimised use of the equipment, taking into account the economic and climatic environment. In addition, irrigation management as a concept must take place after the investment to make production profitable and intensive [13].

Poor planning and investment can result in such a long payback period that it can dampen the enthusiasm of both investors and local farmers. In the case of irrigation development, the most important planning issues should be considered. What should be the government's and the market's share of the investment? What system should be used to produce in the invested areas? For example, should there be a second crop? How much land can we supply with the available water base? If this limit is not applied, the water will not be used optimally in the area. And from the government's point of view, it may not be cheaper to simply pay producers a certain amount when they are affected by drought. In addition, determining the size of economic clusters can also have a significant impact on profitability [14].

Sprinkler head precision is perhaps the most important remaining factor that can significantly reduce the risk of wind drift, evaporation and runoff on the ground. As early as the 1970s, Hungarian researchers demonstrated that the droplet energy of sprinklers' droplet energy significantly affects soil infiltration [15].

The quality of irrigation is determined by the hydraulic and operating characteristics of the sprinkler. During the design and selection of sprinklers, the primary consideration is the need to irrigate the plant. The structure of the soil and its rate of water absorption can be just as important [16].

A similarly important factor in irrigation planning is pressure management, which can ensure that an irrigation plant uses only the necessary energy to operate the system [17]. In addition to the utilisation of contemporary sprinklers, pressure management methods encompass the operation of water pumps with the aid of variable frequency drives (VFDs), namely frequency converters. These pumps can modify their frequency in response to a pressure signal, thereby optimising energy consumption by implementing a constant feedback loop. This results in a reduction in the financial expenditure associated with irrigation [18].

The selection of appropriate pipe diameters and materials represents a pivotal concern in the period preceding the investment, which also encompasses the selection of an appropriate pressure range. In addition, many factors influence the long-term success of a design. Accordingly, the pipe system must be capable of withstanding at least twice the designed pressure. It is also necessary to consider the impact of temperature fluctuations in the environment and UV exposure [19].

As a consequence of the irrigation revolution, the irrigation districts in the US state of Nebraska and the university context represent one of the most advanced and experts in the world [20]. Consequently, it is beneficial to compare the situation in Hungary with that in Nebraska and to draw conclusions regarding the most promising avenues for the development of a successful irrigation culture. In the context of Hungarian irrigation communities, there is a need to enhance efficiency. Since the concept's recent launch, more than 204 irrigation communities have been established in Hungary [3, 21-22]. The government sought to establish irrigation communities on the model of Austrian irrigation cooperatives. The membership of these communities is comprised of the land users of the areas surrounding the irrigated area. These communities are constituted from below and comprise market participants [23]. The application funds are available to the irrigation communities for three years, after which they must be self-supporting by the draft [22]. This is likely to present challenges. The development of irrigation communities was also motivated by financial considerations, as the proportion of successful applications from irrigation communities increased to 70% [24-25].

The state of Nebraska has the largest area of irrigated land of any US state. A total of 3.4 million hectares are irrigated, with 98% of these being centre-pivot systems. In a manner analogous to the circumstances in Hungary, the necessity for human resources was found to be the least pressing concern; while the size of the irrigable area constituted the two principal factors influencing the selection of pivots. Furthermore, the University of Nebraska Institute of Water Sciences plays a pivotal role in irrigation support, in addition to the irrigation districts [26]. The designation of irrigation districts was based on the division of water bodies at the state level. The Nebraska Department of Natural Resources (NDNR) is responsible for the equitable distribution of water resources. In order to achieve the equitable distribution, it is necessary to implement a monitoring system that covers the widest possible area, which should be accessible to all relevant actors in order to facilitate decision-making. This objective can be met by utilising a multitude of sensors. Groundwater wells are subject to mandatory registration. Furthermore, the licensing process also applies to surface water sources. Additionally, the NDNR is tasked with the recording of real-time water flows. The NDNR provides users of well water with access to sophisticated modelling tools. Consequently, users are able to ascertain the quantity of water available during a given year. In the event that the demand for a specific water source is greater than the supply, the irrigation district (NRD) and the NDNR collaborate to redistribute the resources through negotiated agreements. In consideration of the results of models above, the establishment of these irrigation districts was linked to the moment when more and more actors wanted to use the available resources [27].

The districts were established by a law enacted in 1972. Should irrigation remain a profitable enterprise in Hungary, it is likely that similar evolutionary processes will ensue. The districts are overseen by elected representatives. Prior to the election, candidates must collect recommendations from relevant stakeholders. The irrigation districts convene on a monthly basis to deliberate and reach consensus on matters pertaining to irrigation. In doing so, they consider the recommendations of the local university, which are duly taken into account [28].

It is notable that 85% of Nebraska's irrigated land is fed by groundwater, a figure that contrasts with the domestic structure. To prevent any permanent damage to water bodies, the construction of wells is subject to strict regulation. A separate permit is required if the recommended distance between two groundwater wells is not observed. The board members appoint internal auditors who must maintain the utmost respect for neutrality when conducting their audits. Consequently, inspectors and subjects are more aware of the regulations and their purpose. They can comprehend and adhere to the regulations more effectively. One finding indicates that the most significant challenge facing irrigation districts is securing adequate funding, and this is how they can develop and educate. In the United States, local taxation is permitted by law. The tax rate varied between 1.9% and 6.9% of income, with an additional tax levied on irrigated land at $25 per hectare. Furthermore, the irrigation districts are entitled to apply for state funds in the same manner as the Hungarian irrigation communities [29]. Nevertheless, further financial resources would be required to facilitate the constant innovation of the infrastructure. In light of the factors above and numerous others, Nebraska system represents exemplary practice. This is exemplified in Table 1.

In table 1, a well-structured irrigation investment necessitates the implementation of appropriate management, the provision of excellent education, the establishment of close cooperation with government institutions, and the establishment of an appropriate legal and instrumental background. In other words, a very complex set of questions must be successfully solved by those decision-makers and planners advocating national irrigation development in Hungary today.

Table 1. Historical economic effects of irrigation in different dimensions, Nebraska state, USA.

Change between: 1976-2011	
Irrigated acres	+50%
Land Values	
Center Pivot Irrigated	+300%
Non-Irrigated Cropland	+250%
State Corn Yields	
Irrigated	+4,5 t/ha
Dryland	+3,75 t/ha
Value of Irrigation Water	
Net Farm Income	+290%
Fertilizer Use	-25%

As the field of irrigation investment continues to evolve, it will become increasingly necessary to incorporate a wider range of information and regulations. Those communities and individuals who are open to innovation will be able to disseminate, sustain, and develop these innovations within a given irrigation community. Introducing an innovation in the Hungarian countryside requires, on average, 53% of the time that elapses between its inception and its successful implementation, some form of continuing education [30]. It follows, therefore, that the training of irrigation apprentices, vocational secondary schools, and higher education related to irrigation must flourish once more after the irrigation investments have been made. This training must be able to stand its ground both theoretically and practically. Furthermore, it is recommended that regular training be conducted every three years, as was the case before the introduction of the innovation [31]. There has been a paucity of discourse in recent times concerning the necessity for significant infrastructural investments. Unfortunately, the construction of a centre pivot irrigation plant in a specific location to extract suitable water is not a solution that can be applied nationwide to address the problem. It would be prudent to consider the potential of reservoirs for the capture of rapidly draining waters, the construction of rainwater reservoirs, and the agricultural use of monitored purified water produced during wastewater treatment. Furthermore, introducing precision water management and digital monitoring systems can be an important element in this context [32].

Unfortunately, the current network of canals dates from the socialist era, as they are highly conductive irrigation canals and their water resistance is inadequate, making water retention and management questionable without new investment [33]. Furthermore, it would be particularly important in the development of irrigation to replace the concept imposed in the fifties, where we did not plough everything that we could. Changing the cropping pattern of the typical inland water areas can create reservoirs suitable for irrigation and at the same time improve the chances of small rainfall events in the hydrological cycle. "Most of the former floodplain lowlands that are severely and moderately threatened by inland water, and the zone that is severely threatened by drought, overlap [34]." In developed western countries, by properly establishing environmental water level standards, the increase of biodiversity, the revitalisation of habitats and the reservoirs for irrigation can be achieved simultaneously [35].

Irrigation pivot capacity is also an issue for Hungarian irrigators. In the 1970s, the daily capacity was 80 mm gross with a return period of 18-21 days, meaning a capacity of 4.4 mm/day. This capacity worked with the more reliable and useful (seasonal) rainfall [36]. Nowadays it is more and more 9.5-10 mm/day [37]. Demand and rainfall do not overlap as they used to. In addition, farmers should plan for less than 24 hours of operation. Because of operational problems, the cost of a night shift, and the extreme weather conditions when it is not wise to irrigate. So, if we calculate with 16 hours of operation, a 10 mm/day pivot can only apply: 6.7 mm gross/day. Meanwhile, crop evapotranspiration (ETc) for cereals could reach ETc of 3.57-7.90 net mm/day [38] at flowering periods. This means that if a farmer wants to get all the water he needs for his crops, 10 mm/day capacity for a pivot system is becoming more and more necessary, even in Hungary. On the other hand, pipe sizing is based on this figure, so if this is not considered at the beginning. Changing from 4-5mm to 8-10mm is usually impossible without a new investment [39]. According to crop modelling research in Texas: "As irrigation capacity increased from 4 to 8 mm d-1, the irrigated fraction that maximised net returns increased from 0.5 to 0.9. Concentrated water produced higher net returns due to higher irrigation water productivity and lower seed and fertilizer costs. Investing in larger pipe diameters is a long-term investment [40]. According to Spanish research where the net daily water requirement was 7.65 mm/day for maize. The results show that for 30 ha plots, the recommended pipe diameter is 127 mm; for 30-40 ha, 168 mm; for 75 ha, 219 mm; and 100 ha, 254 mm [41].

Between the gross and net irrigated mm/day, there are losses that we should be aware of. Practically every drop of water that does not make it to the root zone is considered to be a loss. Losses include air loss, canopy loss, soil evaporation and deep percolation. The occurrence of these losses is dependent on the time of day. For example, canopy loss is greatest between 12 and 16 h [42], which supports the idea that 24-hour operation is not something we can calculate in reality.

After all the water-related elements discussed, one important thing to consider is using nitrogen and other fertilisers in agriculture. Combing input with low efficiency leads to environmental causes, soil degradation, eutrophication, groundwater pollution and ammonia emissions. In addition, N supply should match N demand in time [43]. In practice, Hungarian farmers apply nitrogen twice in a season, and these applications rarely meet the plant's needs. Fertigation, a method of applying fertiliser through the irrigation system, is a key solution for reducing the use of nitrogen and other fertilisers [44]. In the near future, fertigation will be a solution to reduce nitrogen use in Hungarian agricultural production. Some things should be considered before designing pivot pumping stations to make fertigation possible. With fertigation, nitrogen can be applied at any growth stage. According to specific design recommendations, 4 fertiliser pumps are needed to allow variable fertiliser application. The fertiliser injectors must have inverter-driven motors to allow for different flow rates. In addition, these pumps must be intelligently controlled and remotely monitored to prevent backflow and environmental damage [45].

4 Conclusion

The issue of agricultural water management is becoming increasingly problematic. The country is susceptible to both floods and droughts in the same season due to the limited capacity of water reservoirs and the inadequacy of water level control in Hungary. The Hungarian irrigated area is significantly below the economically positive investment size of 6.5% [37], with current levels at approximately 2-2.5%. The level of irrigation science and practical knowledge has experienced periods of advancement, which provide a valuable opportunity to renew academic knowledge, education, planning and operation. The use of key performance indicators (KPIs) would be a valuable means of more accurately representing the actual status of efficiency.

The potential GDP is being lost each year as a consequence of the failure to utilise the water resources for the purposes of water security and intensified production. In 1950, the amount of rainfall required to produce one tonne of maize was 91 mm. This figure has since decreased to 34 mm, a reduction that has been accompanied by an increased vulnerability to droughts as a result of intensified production. The wise and economic use of irrigation systems is contingent upon the implementation of effective irrigation management.

The planning of irrigation systems is a complex task that requires a combination of practical and academic knowledge, software support, and specific knowledge of the area where the installation is to be made. Faulty sizing can result in an increased return on investment (ROI) and net profit loss. The potential for reducing the use of fertilisers through fertigation must be incorporated into any investment in irrigation. Furthermore, it is crucial that scientific research in Hungary be expanded to serve as a model for investors.

The Nebraska state Irrigation Districts could serve as a model for Hungarian irrigation communities. Their uninterrupted history from the 1970s evidences a democratic evolution, self-sustaining finance, and a state-of-the-art monitoring and self-auditorial system for maintaining water bodies in optimal condition. Compared to dryland farming, irrigated land has experienced a greater increase in price and a decrease in fertilised use, while yields have increased to a greater extent.

There has been a paucity of discourse on the necessity for substantial infrastructural investments in recent times. Considering the potential benefits of capturing rapidly draining waters in reservoirs would be prudent. This could be achieved by installing water intake points in areas where well water is not readily available, or where it would not be advisable to use well water for irrigation.

It is crucial to acknowledge that the evaporation of water surfaces closely aligns with the ET0 evaporation, thereby establishing the depth of the reservoirs as a pivotal limiting factor for each investment. Conversely, the evaporation of water from the lake surface increases the vapor pressure of the environment, which slows down the release of water through the stomata. At the same time, this process increases the occurrence of small water cycle precipitation. The investments in question require a larger volume than is currently available, and it is unclear how we can create such a large amount of reservoir and distribution capacity in a timely manner so that we are not behind the curve, but rather at the forefront of the trend.

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