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INTRODUCTION OF THE WATER MANAGEMENT OF THE JÁSZSÁG BASIN, HUNGARY

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Abstract
The Jászság Basin in Northeastern Hungary presents a complex interplay of geological, hydrogeological, and anthropogenic factors that significantly affect water resource sustainability. Surrounded by karstic and volcanic formations, the basin's sedimentary aquifer systems are sensitive to both natural and human-induced stressors. This study provides a comprehensive overview of the region's lithostratigraphy, hydrogeological structure, and historical water management practices, including the impacts of lignite mining and water abstraction. Long-term groundwater monitoring reveals declining trends, particularly in intermediate and deep aquifers, disconnected from surface water systems. Birinyi Edina's drought model identifies the Jászság as one of Hungary's most vulnerable areas for both drought and inland excess water, emphasizing the need for spatially targeted planning. Correlation analyses confirm limited vertical recharge and emphasize the fragmented nature of the monitoring network. The findings underscore the urgent need for high-resolution hydrological data, enhanced legal reporting, and integrated management approaches. The Jászság Basin thus serves as a representative case for addressing lowland groundwater challenges under increasing climate and extraction pressures.

Keywords: *Jászság Basin, groundwater depletion, drought model, hydrogeology, water management*

1. Introduction

The Jászság Basin, a geologically diverse region in Northeastern Hungary, exemplifies the complex challenges faced in integrated water resources management. Bordered by three major geological domains—the porous sedimentary structures of the Pannonian Basin, the karstified Bükk Mountains, and the volcanic formations of the Mátra Range—this region is subject to varying hydrogeological behaviors and water resource dynamics. These conditions are further exacerbated by intense human activity, including lignite mining, agriculture, and public water supply demands.

Effective management of such a basin requires a multidisciplinary approach that combines detailed geological data, hydrological modeling, chemical analysis, and long-term monitoring. This article presents a comprehensive overview of the geological and hydrogeological characteristics of the Jászság Basin, along with the anthropogenic influences, monitoring efforts, and modeling techniques that underpin sustainable water resource management.

2. Geological overview

Jászság Basin located in the northeast part of Hungary, right at the foot of the Mátra and Bükk mountains reaching towards the Tisza River. The Mátra mountain is a middle Miocene aged volcanic range made from andesite and dacite. The Bükk mountain is dominantly Triassic aged dolomite and limestone with metamorphic shale formations formed by tectonic movements.

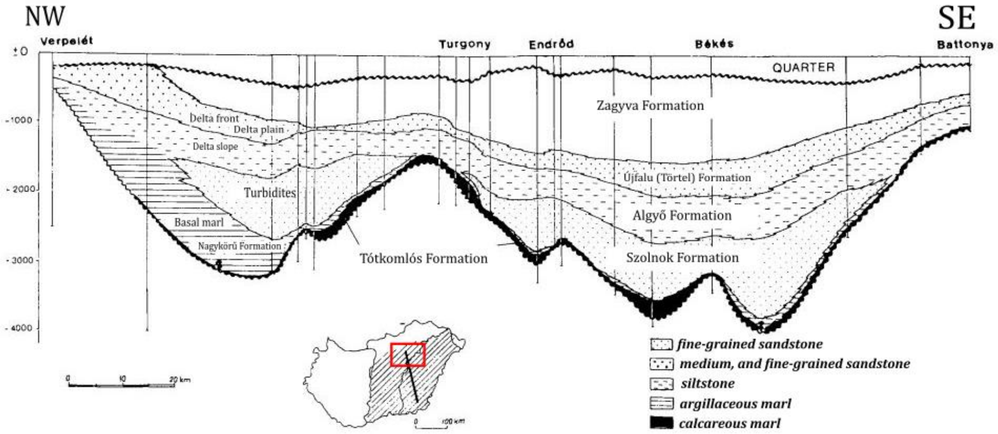

Figure 1. *Stratigraphical and sedimentological profile in the Pannonian sequence across the Great Plain, marked with red the Jászság Basin area (modified after Juhász, 1992).*

The Jászság basin is a tectonic trench which was created during the late Miocene tectonic movements. The Basin was filled with sediments with multiple river delta progradation into the Lake. These several hundred or even thousand-meter-deep sediments represent the different stages of delta progradation. (Figure 1.)

The Pannonian sediments are separated into two formation groups, Alföld Formation Group and Dunántúl Formation Group (Figure 2).

Alföld Formation Group contains the formations made in the deeper regions of the basin. The Endrőd Marl Formation represents the anoxic bottom of the lake with dark thick marl. The Szolnok Formation contains various gravitationally moved sediments, in a large range from fine sediments up to large rocks. This formation is one of the thickest in the area, sometimes reaching up to 1000 meters. Algyő Claymarl Formation is the top of the Alföld Formation Group. Algyő Claymarl is a dark gray mica siltstone, considered as a regional aquitard layer.

Dunántúl Formation Group contains the shallow-water, sometimes dryland series, mainly Újfalu and Zagyva formations. The Újfalu Formation consists of alternating layers of clay, silt, fine- to medium-grained sand, huminitic clay to silt, and lignite, showing upward-coarsening and thickening successions in its lower part, while the sandy intervals in the upper part display a more irregular distribution.

Újfalu Formation's series is usually 30–50 m thick coarsening upwards. It was created by the delta lobes: the shelf, the prodelta, the delta slope. The Zagyva Formation was formed on an alluvial plain providing clayey, floodplain-marsh layers, with thin sand bodies interbedded.

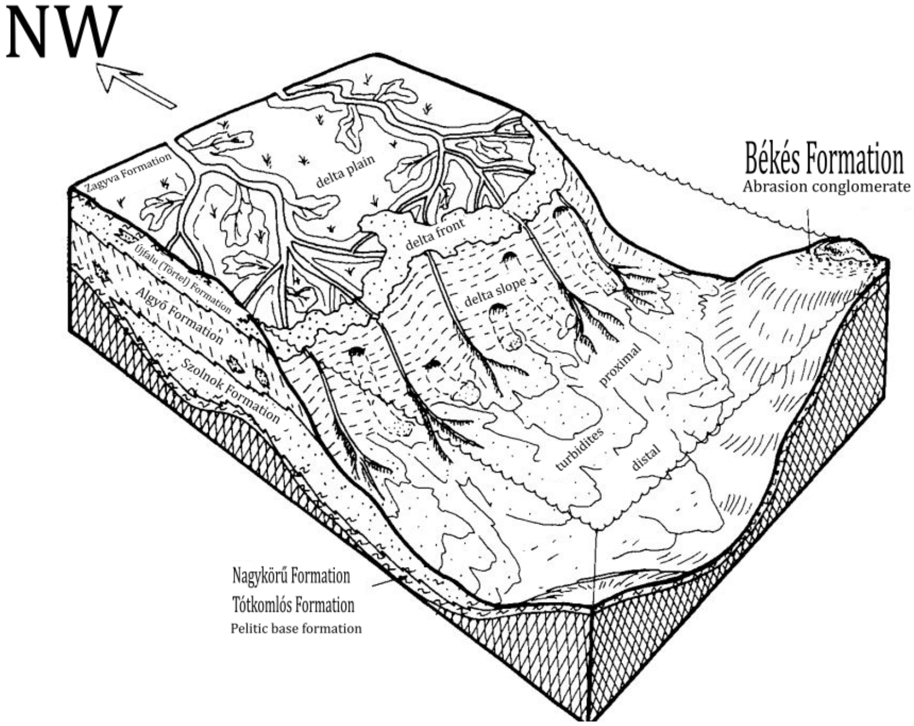

Figure 2. *Three-dimensional depositional model in the western part of the Great Plain (modified after Juhász, 1992).*

3. Water management

In the area lignite presence were known from the 19th century, but the industrial production only started in the 1920-30's.

Two research were published in 1941 regarding the dewatering system of the lignite mines of Mátra mountains. One is by István Vitális, a (that time) retired mining geologist regarding…. The other publication is by Sándor Vitális the leading geologist of the Salgótarján Coal Mining Company researched…

Articles were published in 1941 by I. Vitális (Vitális I., 1941) regarding an artesian well near Petőfibánya mine, where active lignite production and dewatering system worked. In the same year, S. Vitális researched the geology, hydrogeology, and surface waters around Rózsaszentmárton, where the lignite mine operated in that time (Vitális S., 1941). Later, in 1955 Szebényi examined the recharge of artesian waters at the foot of the Mátra Mountains, the relationship between deeper aquitards and the phreatic water layers and attempted to estimate the quantity of water flowing through clay layers. In his 1956 publication, he focused on the geology, history, and hydrogeological conditions of the Mátra foreland. In this article, he continued I. Vitális's line of thought on the influence of artesian water levels and potential aquitards on mining operations.

The connection of hydrogeological systems in the area was a subject of debate for many years. In his 1955 article titled *On the Vertical Movement of Our Artesian Waters*, Szebényi proposed the existence of connections between these systems. In contrast, Schmieder, in his 1965 publications *Quantitative Analysis of Groundwater Recharge in the Mátra and Bükk Forelands*, examined the communication between the “Upper Pannonian formations” (present-day Transdanubian Formation Group) and Quaternary layers from geological, pressure (Figure 3.), and chemical perspectives, concluding that any such connection was negligible.

Research conducted in the area played a key role in understanding the basin-wide groundwater flow systems. In his 1955 article, Szebényi recognized the significance of interlayer water flow within a continuous flow system, which he later extended to larger areas of the Great Plain in 1958 and 1965, where he also performed flow rate calculations. His 1965 article prompted József Tóth to publish his first Hungarian-language article in response.

In his 1962 and 1963 publications, József Tóth described his theory on basin-scale groundwater flow, which laid the foundation for modern hydrogeology. His gravitational flow model provided a simple explanation for the unusual pressure conditions and chemical variations observed in basin aquifers.

From the 1970s onward, nationwide research into both the qualitative and quantitative aspects of basin-scale groundwater flow began, in which the water geochemical surveys and evaluations conducted by the Hungarian Geological Institute (MÁFI) played a significant role. In 1975, building on earlier work, Mihály Erdélyi studied the groundwater flow conditions in the Great Plain in a paper published in *Hidrológiai Közlöny*, where he outlined hydrogeological cross-sections of the basin.

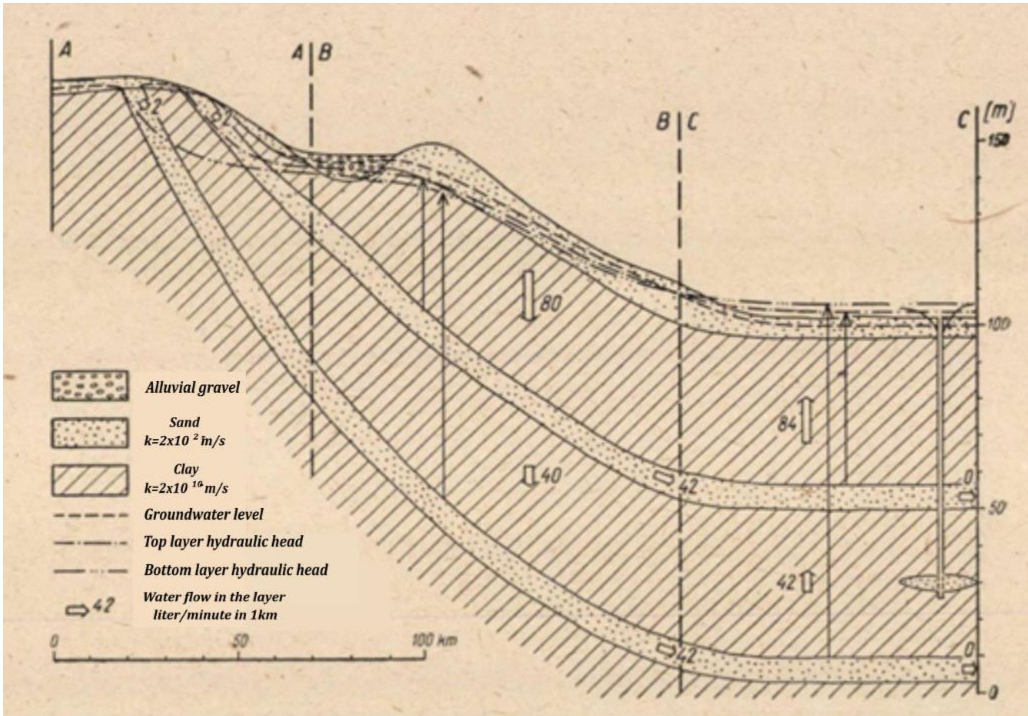

Figure 3. *Schematic section of artesian water movement (modified after Szebényi, 1955)*

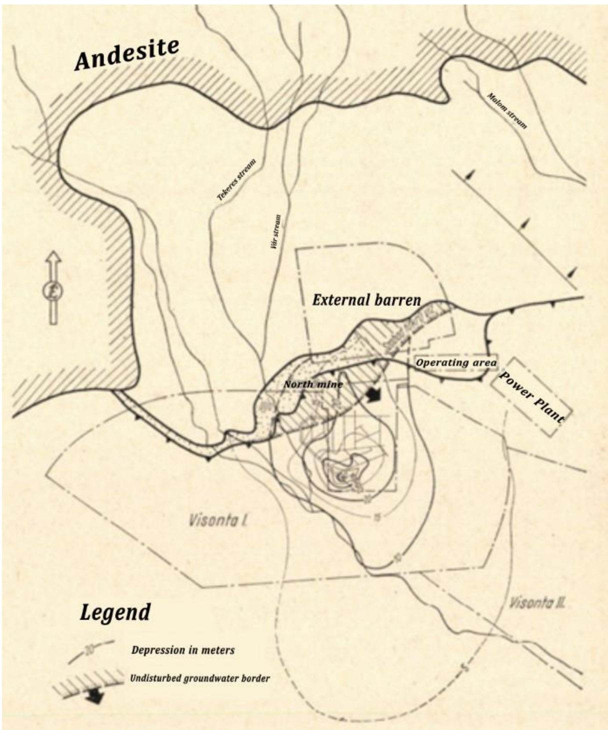

Figure 4. *Water level drop in reservoir layer III/0 in the Visonta area, July 1964 (modified after Schmieder, 1965 II)*

In 1975, during their hydrogeological investigation of the southern foreland of the Bükk Mountains, Böcker et al. hypothesized a connection between the “Upper Pannonian”, after Quaternary, and Bükk karst systems based on geothermal anomalies, water chemistry, and pressure conditions. Research into the region's hydrogeological conditions continues to this day, although investigations of local streams have been underway since the 1960s (Figure 4). In 1967, Almássy and Scheuer studied the Kács and Sály springs from a hydrogeological perspective. Two years later, in 1969, Karácsonyi and Scheuer published a study on the subsurface waters and hydrogeological conditions, problems, and potential of the Gyöngyös area, drawing on experiences from the municipal waterworks.

Articles on the environmental impact of groundwater abstraction for mining have been published for over half a century. In 1973, Szilágyi studied water extraction in mining in an article published in *Bányászati és Kohászati Lapok*, in which he analyzed and calculated the volume of extracted water, its origin, and the quantity of rechargeable water. His results indicated that nearly half of the extracted water was stored water, one-third was released from consolidation, and the remaining portion originated from recharge. The 2020 article by Szepesi and Harka explored the history and potential future of the Bene Stream, discussing post-mining closure issues and their impact on surrounding aquatic ecosystems, as well as possible solutions.

Not only human impact causing water management problems, but the climate change as well. The Hungarian General Directorate of Water Management (OVF) constantly measuring the drought level in the country providing data for the crops. Even after a few dry days the level of drought elevates to the maximum level. This shows the vulnerability of the areas of the Plain area as well as the Jászság area (Figure 5.).

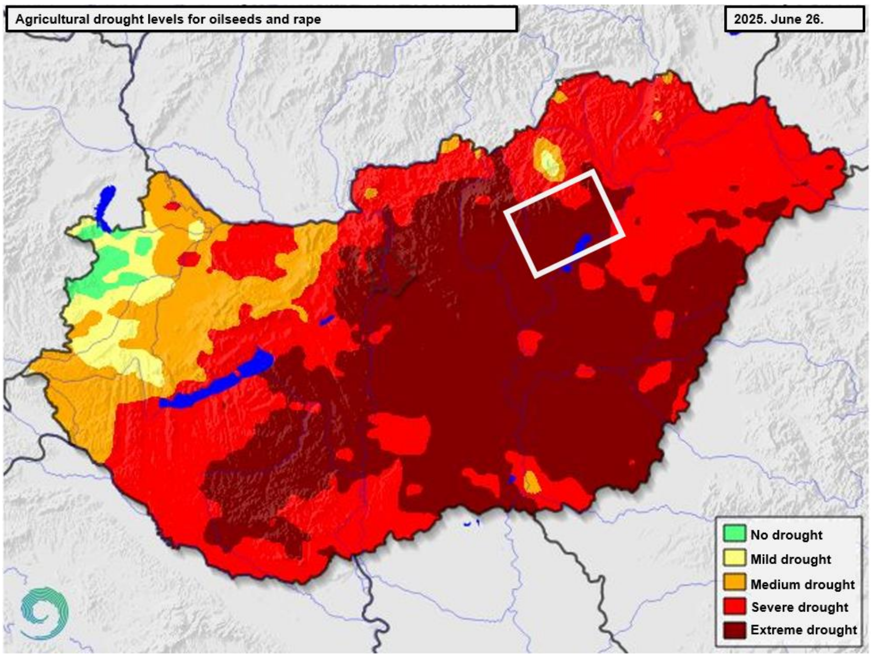

Figure 5. *Drought map of Hungary at 26. June 2025. marked with white the Jászság Basin area (modified after HungaroMet)*

Current research of Birinyi states that the most vulnerable part of the country is the Jászság, where not only the drought, but the inland water risk is the highest. Edina Birinyi's drought model (Figure 6.**Figure 5.**) represents a significant advancement in the assessment of agricultural drought risk in Hungary, particularly in sensitive regions such as the Jászság.

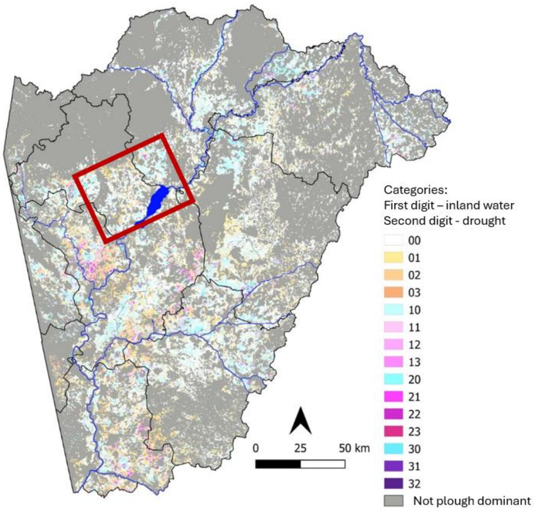

Figure 6. *Drought and inland water risk map with the Jászság Basin area marked with red (Birinyi, 2025)*

This area is especially vulnerable to summer water shortages, making the model's localized spatial risk analysis crucial for planning sustainable land use and agricultural strategies. By integrating meteorological, soil, and land cover data, the model identifies the severity and frequency of dry periods during the vegetation season. It places special emphasis on the combined analysis of soil moisture and potential evapotranspiration, offering reliable forecasting, especially for the semi-arid landscapes of the Jászság. Birinyi's methodology also contributes to more accurate estimations of climate change impacts and can effectively support the design of regional water retention and adaptation strategies.

4. Water level changes

Another great indicator of the water management problems in the area is the water level in monitoring wells. There are several monitoring wells operated by either the Hungarian General Directorate of Water Management (OVF) or the Supervisory Authority for Regulatory Affairs (SARA) (Figure 7.).

The groundwater level time series can be categorized by well depth into shallow (0–100 m), intermediate (100–300 m), and deep (>300 m) wells. Using both visual and statistical analysis of long-term data confirmed seasonal correlation between shallow aquifers and precipitation patterns, indicating a direct, although increasingly strained, recharge mechanism (Figure 8**Figure 7.**). However, intermediate and deeper aquifers show a persistent groundwater level decline, in some cases exceeding 20 meters over recent decades. The deeper wells show minimal or no correlation to surface water fluctuations, including the Tisza River or the Tisza-lake. This shows an imbalance between abstraction and natural replenishment in the aquifer.

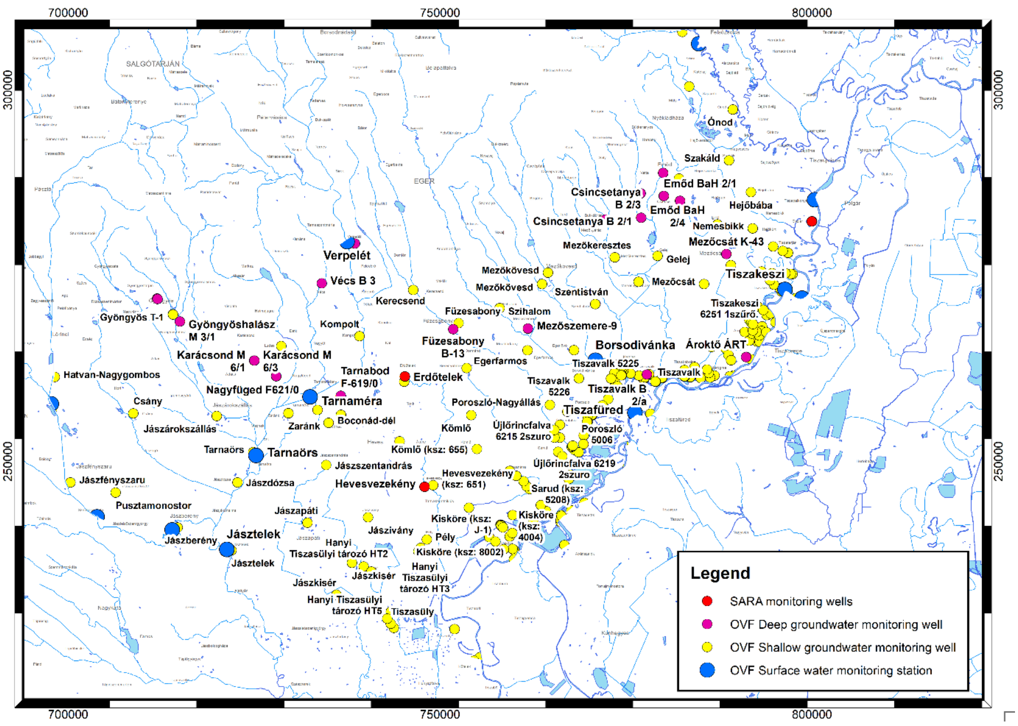

Figure 7. *Groundwater monitoring wells and surface water monitoring stations in the Jászság area*

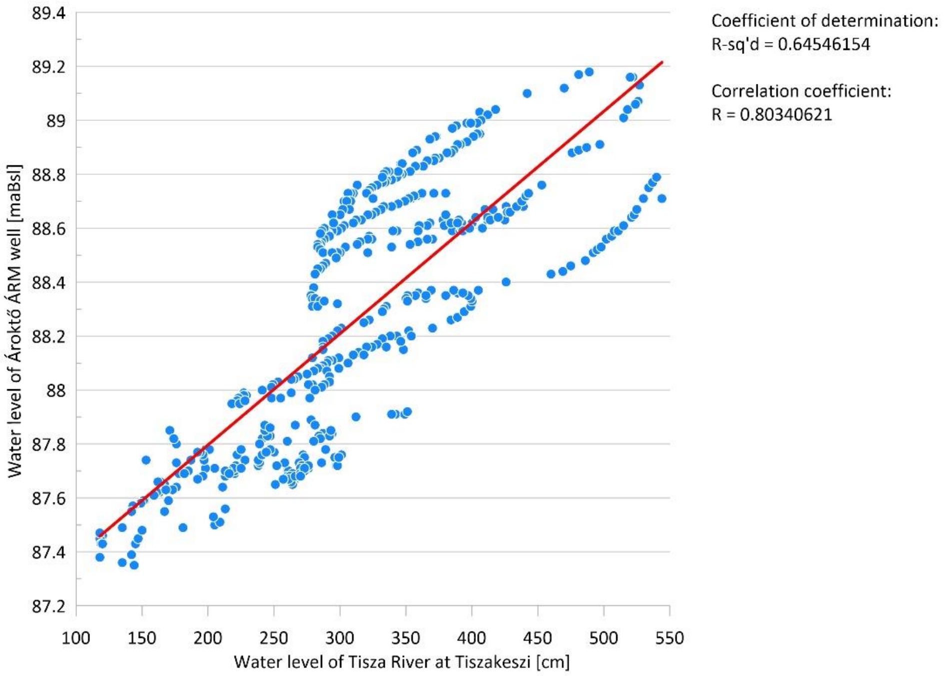

Figure 8. *Deeper water well and surface water (Tisza) correlation*

The correlation analysis using Pearson's coefficient revealed strong positive relationships among wells screened at similar depths and located in proximity, suggesting hydrodynamic communication with these aquifers (Figure 9.). However, broader regional analysis found no statistically significant correlation between surface water and groundwater levels, highlighting limited vertical connectivity and recharge from surface sources, especially for deeper formations.

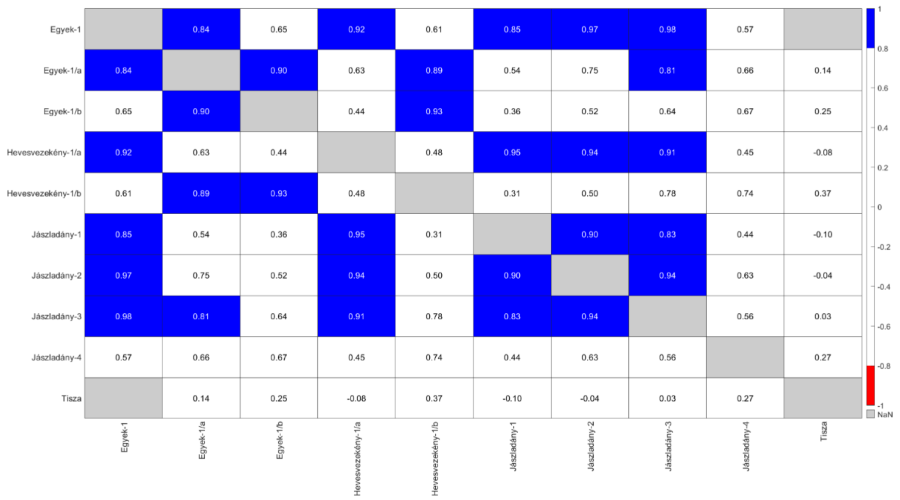

Figure 9. *Correlation matrix. Blue shows the good correlation and its correlation value.*

Reporting is required for annual summaries of extractions in each well, which are insufficient for correlation analysis in such a sensitive hydrological environment. The lack of high-resolution (daily or sub-daily) water production data—particularly from agricultural and industrial users—required for understanding their impact on groundwater level. Unregistered production wells with unknown depth and extraction rates elevate the depletion trends (*Figure* 10.). During the analysis the lack of data quality and continuity proves the need for modernized, high-frequency monitoring systems, improved data integration, and robust regulation of groundwater use.

The "Jászság–Nagykunság" groundwater bodies are already classified as being in poor quantitative and chemical status. Without significant improvements in both groundwater monitoring and governance frameworks, the long-term sustainability of the region's groundwater-dependent ecosystems, agricultural productivity, and drinking water supply may be at risk.

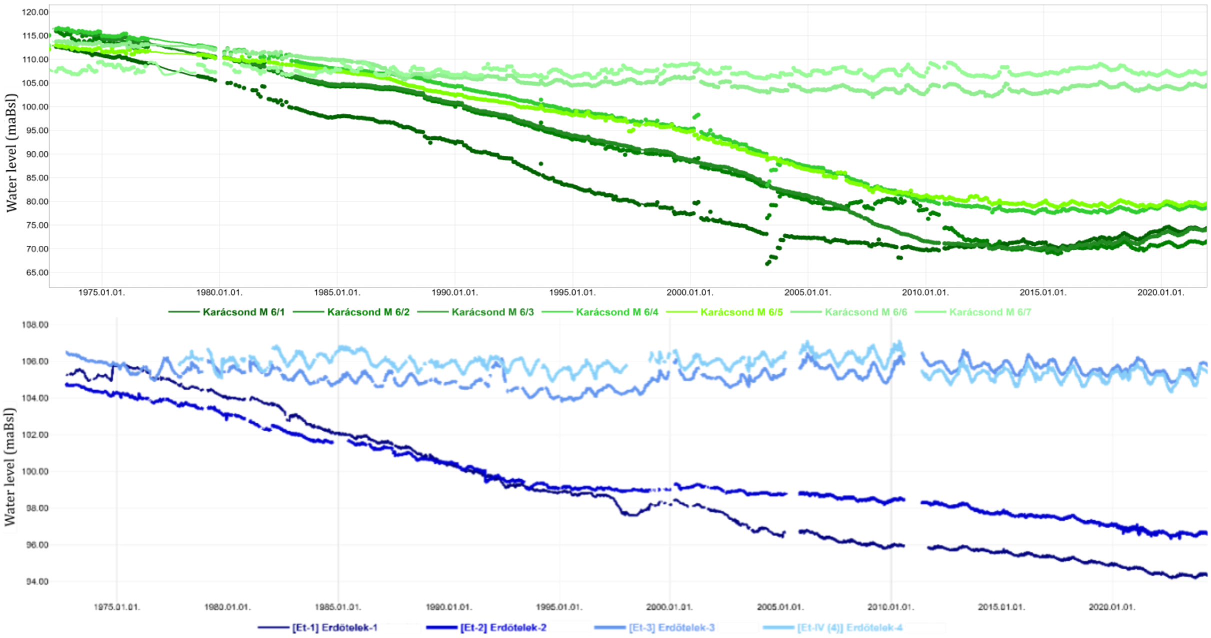

***Figure* 10.** *Water level changes are recorded as a function of time in groundwater wells. Darker colour refers to deeper wells.*

5. Summary

The water management problems of the Jászság Basin are due to complex geological and hydrogeological conditions and significant anthropogenic influences. Long-term monitoring of the stratified water resources of the region has shown the limited connectivity between shallow, medium and deep-water bodies and has recorded severe water level declines, especially in the deeper strata. The drought model developed by Edina Birinyi showed that Jászság is not only one of the driest areas in the country, but also one of the areas with the highest risk of inland water. The meteorological, soil and land cover data integrated in the modelling allow for the creation of targeted land development and adaptation strategies. Correlation analyses have highlighted the intrinsic interconnectedness of the aquifers, while confirming the weakness of the link between the subsurface and surface systems. The research highlights the need for a high temporal resolution monitoring network and transparent, detailed water abstraction data. At present, several water bodies in the region are of poor quantitative and chemical status. The study concludes that the problems in the Central Tisza Valley are a general feature of the water management challenges in the Central European lowlands, which require integrated and proactive responses.

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