Dejan Nemcic, Julijana Petrovska and Goran Apostolovski. 2026.
Karst Intermittent Rivers as Hydrological and Tourism Phenomena: Comparative Perspectives from Croatia and North Macedonia. Jornal of Geography. 2(1): 38-49

Karst Intermittent Rivers as Hydrological and Tourism Phenomena: Comparative Perspectives from Croatia and North Macedonia

Dejan Nemcic[1]
Julijana Petrovska
Goran Apostolovski

Abstract

Karst intermittent rivers represent one of the most complex hydrological systems in Europe due to the interaction between carbonate geology, groundwater circulation, climatic variability, and seasonal precipitation regimes. The Croatian rivers Krčić and Čikola illustrate how karst landscapes may alternate between dry rocky channels during summer and highly energetic turquoise river systems during autumn and winter precipitation periods. This paper analyses the hydrological behaviour and tourism implications of these rivers while comparing them with related karst phenomena in North Macedonia. The analysed case studies indicate that intermittent karst rivers represent hydrologically sensitive landscapes with considerable scientific and tourism relevance. Seasonal hydrological instability contributes to rapid landscape transformation that increasingly attracts geotourism and scientific field observation. At the same time, climate variability increasingly threatens the balance of karst ecosystems through prolonged droughts and intense rainfall episodes. The study argues that sustainable tourism planning and hydrological protection strategies are necessary to preserve these sensitive environments. The empirical basis includes the documented complexity of the Krčić and Krka catchment, the approximately 13 km protected Čikola canyon, and isotope evidence indicating that about 52% of Tushemisht spring discharge derives from Lake Prespa infiltration.

Keywords: karst hydrology, intermittent rivers, Krčić River, Čikola River, Dinaric karst, groundwater circulation, seasonal rivers, geotourism, karst ecosystems, hydrological variability, climate change, sustainable tourism, karst geomorphology, Ohrid Prespa system, North Macedonia

JEL Classification: Q25, Z32, R11, Q54

1. Introduction

The Dinaric karst region represents one of the most hydrologically complex limestone landscapes in Europe. These landscapes develop predominantly in limestone and dolomite terrains where water gradually dissolves carbonate rock and creates underground drainage systems, sinkholes, caves, springs, ponors, and disappearing rivers. The Dinaric Karst region of Southeast Europe represents one of the most developed karst systems globally, extending across Croatia, Bosnia and Herzegovina, Montenegro, Slovenia, Albania, and parts of North Macedonia.

Hydrological behaviour in karst terrains differs substantially from river systems developed in non carbonate environments. Surface water frequently disappears underground through fissures and conduits, while groundwater circulation becomes the dominant hydrological process. Because of this interaction between surface and underground water, many karst rivers display intermittent or seasonal characteristics. During dry summer periods riverbeds may partially or completely dry out, whereas autumn and winter precipitation can transform the same channels into highly energetic watercourses.

The Croatian rivers Krčić and Čikola represent remarkable examples of such hydrological behaviour. Both rivers are situated within the Dinaric karst region and

[1] **Dejan Nemcic, MSc.,** Teacher in Zagreb, Croatia, **Julijana Petrovska, MSc.,** Academic Associate, and **Goran Apostolovski, MSc**., Academic Associate, University Skopje, Skopje, Republic of North Macedonia.

exhibit dramatic seasonal transformations. Marked seasonal variability, canyon morphology, and intermittent waterfall activity have transformed these rivers into recognizable karst tourism landscapes. The scientific significance of these rivers extends beyond regional geography because they provide insight into climate sensitivity, groundwater recharge, flood dynamics, and sustainable management of fragile karst ecosystems.

The study compares seasonal karst river dynamics and their growing tourism significance in Croatia and North Macedonia. Particular attention is devoted to the Croatian examples of Krčić and Čikola and to comparable karst phenomena in North Macedonia, especially within the Ohrid Prespa karst system.

The study is based on comparative hydrological analysis, literature review methodology, and interpretation of regional karst phenomena through hydrogeological and tourism related indicators.

Karst Hydrology and Geological Background

Karst hydrology is fundamentally controlled by the permeability of carbonate rocks. Limestone and dolomite are highly susceptible to dissolution through slightly acidic rainwater containing dissolved carbon dioxide. Over geological time this process creates enlarged fractures, conduits, underground channels, and cave systems capable of transporting enormous quantities of groundwater.

According to Ford and Williams (2007), karst aquifers differ from conventional porous aquifers because water flow is concentrated within discrete conduits rather than distributed evenly throughout sediment layers. This creates extremely rapid groundwater circulation and highly variable discharge rates. Bonacci (2015) emphasizes that Dinaric karst systems are among the most complex hydrogeological environments in Europe due to the strong interaction between surface water and underground drainage networks.

Intermittent karst rivers develop where seasonal precipitation strongly influences groundwater recharge. During dry months infiltration exceeds surface runoff, causing rivers to lose water into underground conduits. When precipitation intensifies, underground reservoirs become saturated and water resurges through springs and river channels. This hydrological mechanism explains why rivers such as Krčić may remain dry for weeks or months before suddenly reappearing with intense discharge after rainfall.

The hydrological regime of karst rivers is also closely associated with climate variability. Mediterranean climatic conditions produce prolonged summer droughts followed by concentrated autumn rainfall. Hartmann et al. (2014) argue that climate change is expected to intensify these hydrological extremes by increasing the frequency of drought periods and intense rainfall events in karst regions."

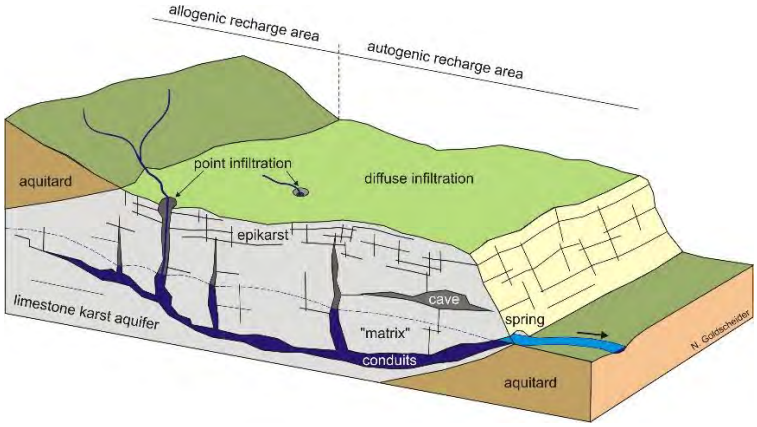

Figure 1. *Karst Hydrology and Geological Background*
Source: Adapted from Ford and Williams (2007).

The Krčić River: Seasonal Transformation and Hydrological Dynamics
The Krčić River originates near the Dinara mountain massif in Croatia and flows toward the Krka River system. The river is widely recognized for its seasonal intermittence and spectacular waterfall formations. During summer the riverbed may become almost entirely dry due to reduced precipitation and strong evaporation combined with infiltration into karst conduits.

Figure 2. *The Krčić River*
Source: Adapted from Krka National Park Official Website

The Krčić catchment functions as a highly permeable karst basin where underground conduit circulation strongly controls recharge and discharge variability.
In contrast to conventional fluvial systems defined primarily through visible topographic boundaries, karst catchments frequently exhibit subsurface hydrological connections that extend beyond surface watershed limits. Bonacci, Jukić and Ljubenkov (2006) demonstrated that groundwater flow within the Krčić karst system may cross apparent drainage divides through underground carbonate conduits and fissure networks. This complexity contributes to unpredictable river discharge behaviour and confirms that seasonal disappearance and reactivation of the Krčić River are measurable hydrogeological processes associated with groundwater storage capacity, conduit flow activation, and rapid recharge following intense precipitation events.

After autumn rainfall begins, groundwater reservoirs recharge rapidly and water reappears along the river channel. Field observations after autumn precipitation reveal rapid hydrological reactivation of previously dry channel sections. Dry rocky surfaces become active waterfalls and fast flowing turquoise streams within short periods. The intense blue green colour derives from the optical properties of mineral rich karst water combined with low sediment concentration and high transparency.

From a geomorphological perspective, Krčić illustrates how intermittent flow contributes to canyon erosion and travertine development. Seasonal hydrological energy influences sediment transport, carbonate deposition, and ecological distribution within the river corridor. The hydrological behaviour of the Krčić River therefore represents an important empirical example of how hydrogeomorphological processes within Dinaric karst terrains influence seasonal runoff regimes, surface flow intermittence, and spatial variability of river discharge.

The Čikola River and Canyon Environment

The Čikola River flows through a deep canyon near the town of Drniš in Croatia and forms part of the broader Krka National Park hydrological system. Similar to Krčić, Čikola demonstrates strong seasonal discharge fluctuations characteristic of Mediterranean karst rivers.

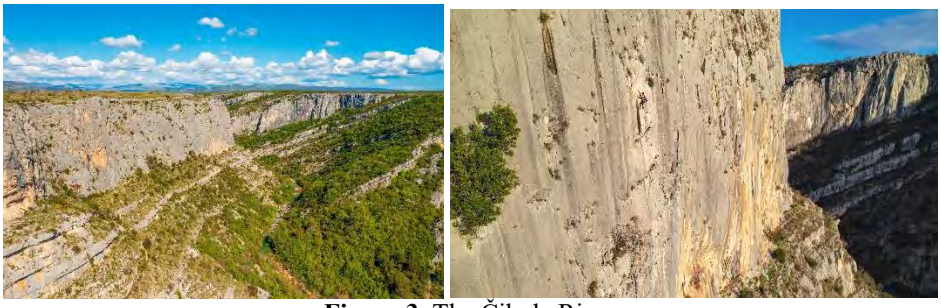

Figure 3. The Čikola River

Source: Author's comparative synthesis based on Croatian Waters

The canyon morphology intensifies the visual and ecological significance of the river. Steep limestone cliffs, narrow passages, and seasonal waterfalls create a highly attractive landscape for tourism and scientific observation. During wet periods discharge increases rapidly, generating strong erosive forces and turbulent flow conditions. During dry seasons water levels decrease substantially.

Research on Dinaric karst rivers has shown that canyon systems often function as biodiversity refuges because the microclimatic conditions differ from surrounding dry Mediterranean landscapes. Moist canyon habitats support endemic vegetation, cave fauna, and aquatic species adapted to unstable hydrological conditions.

The Čikola canyon has become increasingly associated with adventure tourism, including hiking, canyoning, climbing, and nature photography. Seasonal increases in visitor numbers have intensified environmental pressure on sensitive karst habitats within the Čikola canyon area, particularly during peak tourism periods. The Čikola canyon provides a measurable example of the link between hydrology, geomorphology

and protected landscape management. Approximately 13 km of the Čikola River Canyon, from Petrovo Field to the boundary of Krka National Park, has been protected as an important natural landscape since 1967. This protection status confirms that the canyon has recognized scientific, ecological and tourism value, especially because seasonal discharge variability shapes both its physical appearance and visitor experience.

Tourism Importance of Intermittent Karst Rivers

Seasonal transformation of river channels significantly increases tourism attractiveness. Nature based tourism within karst regions has expanded considerably during recent decades, particularly in areas characterized by visually distinctive hydrological phenomena (Dowling, 2011; Bonacci, 2015). Rivers such as Krčić and Čikola provide opportunities for field education in hydrology, geomorphology, climate science, and environmental management (Ford & Williams, 2007).

Tourism activities associated with karst rivers include hiking, kayaking, canyon exploration, eco tourism, wildlife observation, photography, and educational excursions. However, tourism growth may negatively affect karst systems through pollution, uncontrolled infrastructure development, habitat degradation, and hydrological disturbance. Karst aquifers are highly vulnerable because contaminants can rapidly spread through underground conduits without natural filtration. Effective tourism planning must therefore integrate hydrological protection measures, visitor regulation, and ecological monitoring.

Figure 4. Tourism Importance of Intermittent Karst Rivers
Source*:* Author's comparative synthesis

Karst Phenomena in North Macedonia

North Macedonia contains several important karst regions characterized by underground drainage systems, springs, sinkholes, and seasonal hydrological variability. The most scientifically significant example involves the hydrological relationship between Lake Prespa and Lake Ohrid. Research conducted by Anovski, Andonovski, and Mineva (1991) demonstrated that water from Lake Prespa infiltrates through the Galicica mountain massif and resurges through springs feeding Lake Ohrid.

This underground hydrological connection represents one of the most important karst systems in Southeast Europe. The phenomenon illustrates how surface water in karst environments may travel through underground conduits across considerable distances before reappearing at lower elevations.

Several regions in western North Macedonia, including Mavrovo and Mariovo, also

contain intermittent streams and seasonal springs influenced by precipitation variability and carbonate geology. Although less internationally recognized, these rivers possess considerable scientific and tourism value.

Additional karst related hydrological characteristics are present within the Treska River basin, particularly in the Matka Canyon area near Skopje. The canyon is developed within carbonate formations characterized by underground fissures, karst springs, and pronounced geomorphological erosion. Seasonal discharge variability, combined with steep limestone morphology and cave systems such as Vrelo Cave, has transformed the area into an important location for scientific observation, adventure tourism, and karst landscape interpretation.

Karst landscapes around Lake Ohrid already attract international tourism because of their natural and cultural significance. Nevertheless, many karst phenomena remain under researched and under promoted. Developing geotourism strategies focused on karst hydrology could strengthen sustainable regional tourism while encouraging environmental conservation.

The Ohrid Prespa system offers a scientifically verified karst comparison because isotope studies indicate that part of the water from Lake Prespa infiltrates through the Galicica and Mali Thate carbonate massif and resurges through springs feeding Lake Ohrid. Eftimi et al. report that 52% of the mean discharge of Tushemisht springs is recharged from Lake Prespa, while 48% originates from precipitation infiltration in the Mali Thate Galicica mountain area. This numerical evidence strengthens the comparison between Croatian intermittent rivers and Macedonian karst systems by showing that underground hydrological connectivity is measurable, not only descriptive.

Table 1. Empirical indicators for selected karst phenomena

Case study	Hydrological characteristic	Empirical indicator	Scientific relevance	Tourism relevance
Krčić	Intermittent karst river with seasonal disappearance and rapid reactivation	Underground groundwater circulation crosses visible surface watershed boundaries; hydrological variability documented in karst catchment analysis (Bonacci, Jukić, & Ljubenkov, 2006)	Demonstrates complexity of karst aquifer recharge and instability of surface flow in carbonate terrain	Strong seasonal landscape transformation attracts geotourism, photography, hiking, and hydrological field observation
Čikola	Canyon river with strong seasonal discharge fluctuations	Approximately 13 km of canyon protected as significant	Illustrates interaction between canyon geomorphology, erosion, and	Important destination for canyoning, hiking, eco tourism, and

Case study	Hydrological characteristic	Empirical indicator	Scientific relevance	Tourism relevance
		landscape since 1967	Mediterranean karst hydrology	landscape interpretation
Lake Prespa – Lake Ohrid karst system	Underground hydrological connection through carbonate massif	Isotope studies indicate that approximately 52% of Tushemisht spring discharge derives from Prespa Lake infiltration	Confirms measurable underground hydrological transfer within Balkan karst systems	Enhances scientific tourism and educational interpretation of karst hydrogeology
Dinaric karst aquifers	Climate sensitive groundwater systems	Rapid infiltration and limited natural storage increase vulnerability to drought and extreme rainfall	Important for understanding climate change impacts on karst hydrology and groundwater stability	Seasonal hydrological variability influences tourism attractiveness and environmental management strategies

Source: Author's synthesis based on Bonacci et al. (2006), Anovski et al. (1991), Hartmann et al. (2014), and Green et al. (2011).

Figure 5. Karst Phenomena in North Macedonia
Source: Adapted from Anovski et al. (1991).

Climate Change and Environmental Vulnerability

Recent hydroclimatic variability across the Mediterranean basin increasingly affects the stability of intermittent karst rivers (Hartmann et al., 2014). Increasing temperatures intensify evaporation, while altered precipitation regimes create longer droughts and more concentrated rainfall events. Such climatic instability directly affects intermittent rivers because their discharge depends heavily on groundwater recharge.

Green et al. (2011) argue that groundwater systems worldwide are highly vulnerable to climate variability, especially in regions characterized by seasonal precipitation. In karst terrains these impacts become amplified due to rapid infiltration and limited natural storage capacity.

Extreme rainfall events may produce flash floods in normally dry riverbeds, creating hazards for tourism infrastructure and local communities. Conversely, prolonged droughts reduce water availability, threaten aquatic ecosystems, and alter the visual identity of tourism landscapes.

Hydropower development, water diversion, urbanization, and uncontrolled tourism further increase environmental pressure on karst systems.

Bonacci and Roje Bonacci (2015) demonstrated that hydrotechnical interventions may drastically alter the hydrological regime of karst rivers and damage ecological balance.

Future management requires stronger groundwater protection and sustainable tourism regulation.

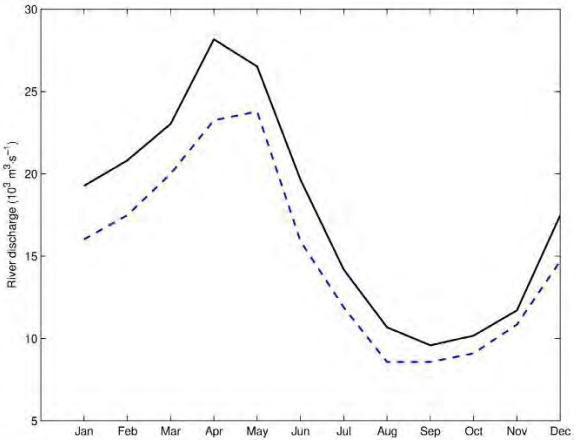

Figure 6. Conceptual representation of the influence of droughts and intense rainfall events on karst groundwater recharge and intermittent river discharge.
Source: Author's visualization based on Hartmann et al. (2014) and Green et al. (2011).

Karst aquifers are particularly sensitive to climate variability because rapid infiltration reduces the buffering capacity typical of many porous aquifers. Hartmann et al. (2014) emphasize that karst modelling faces major limitations related to data availability and process representation, while the global review by Green et al. (2011) links groundwater vulnerability with altered precipitation regimes and rising temperatures. In intermittent karst rivers this means that prolonged drought may extend dry channel periods, whereas intense rainfall may generate sudden flood pulses.

The broader Dinaric karst region is characterized by Mediterranean precipitation regimes with pronounced seasonal contrasts, where autumn and winter rainfall maxima strongly influence groundwater recharge and intermittent river activation (Bonacci, 2015).

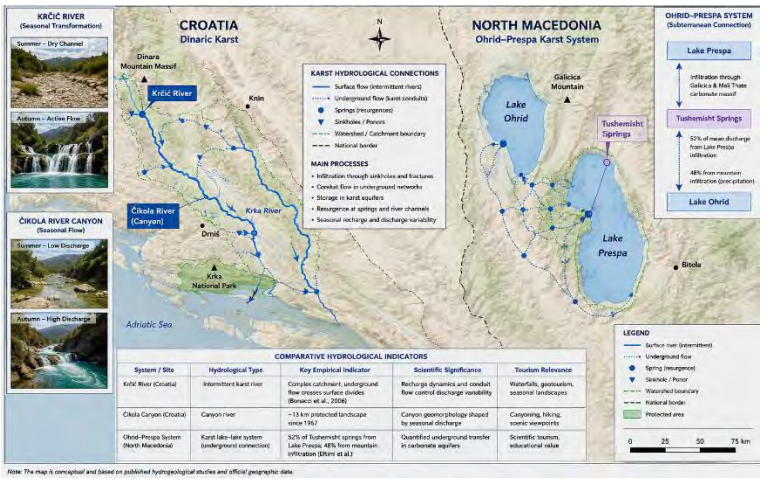

Figure 7. Comparative Hydrogeological Framework of Selected Karst Systems in Croatia and North Macedonia

Source: Author's comparative synthesis based on Bonacci et al. (2006), Anovski et al. (1991), Hartmann et al. (2014), and Green et al. (2011).

Conclusion

The analysed river systems demonstrate how carbonate geology, groundwater circulation, and seasonal climatic variability jointly control intermittent karst hydrology. The Croatian rivers Krčić and Čikola illustrate how seasonal hydrological variability shapes recognizable karst landscapes with considerable scientific and tourism relevance. Their transformation from dry rocky channels into energetic turquoise rivers illustrates the dynamic character of Dinaric karst hydrology. The analysed rivers demonstrate that underground conduit circulation strongly influences seasonal discharge behaviour.

Comparable karst processes are also present within North Macedonia, particularly in the Ohrid Prespa hydrological system and western mountain regions. Although less internationally promoted, these landscapes possess strong potential for scientific tourism and sustainable regional development.

Future environmental management should prioritize groundwater protection, climate adaptation strategies, ecological conservation, and responsible tourism planning. Preserving karst rivers requires interdisciplinary cooperation among hydrologists, geologists, ecologists, tourism experts, and policy institutions.

Future research should focus on quantitative discharge monitoring, isotope hydrology, climate sensitivity modelling, and sustainable tourism carrying capacity within Dinaric karst environments.

References

Anovski, T., Andonovski, B., & Mineva, B. (1991). *Study of the hydrologic relationship between Ohrid and Prespa Lakes*. Proceedings of the Symposium on Isotope Techniques in Water Resources Development, 62, 71–79.

Bonacci, O. (2015). *Karst hydrogeology/hydrology of Dinaric chain and isles.* Environmental Earth Sciences, 74(1), 37–55. https://doi.org/10.1007/s12665-014-3677-8

Bonacci, O., & Roje Bonacci, T. (2015). *Drastic hydrological changes caused by hydroelectrical development in karst: A case of the karst river Zrmanja (Croatia*). Environmental Earth Sciences, 74(9), 6767–6777. https://doi.org/10.1007/s12665-015-4700-5

Bonacci, O., Jukić, D., & Ljubenkov, I. (2006). *Definition of catchment area in karst: Case of the rivers Krčić and Krka, Croatia.* Hydrological Sciences Journal, 51(4), 682–699. https://www.tandfonline.com/doi/abs/10.1623/hysj.51.4.682

Ford, D., & Williams, P. (2007). *Karst Hydrogeology and Geomorphology.* Chichester: Wiley.

Dowling, R. (2011). *Geotourism's global growth.* Geoheritage, 3(1), 1–13. https://link.springer.com/article/10.1007/s12371-010-0024-7

Green, T. R., Taniguchi, M., Kooi, H., Gurdak, J. J., Allen, D. M., Hiscock, K. M., Treidel, H., & Aureli, A. (2011). *Beneath the surface of global change: Impacts of climate change on groundwater.* Journal of Hydrology, 405(3–4), 532–560. https://doi.org/10.1016/j.jhydrol.2011.05.022

Hartmann, A., Goldscheider, N., Wagener, T., Lange, J., & Weiler, M. (2014). *Karst water resources in a changing world.* Reviews of Geophysics, 52(3), 218–242. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2013RG000443

White, W. B. (1988). *Geomorphology and Hydrology of Karst Terrains.* Oxford University Press.