

Groundwater Dimensions 1

Water Futures on Krk Island Guiding Principles for achieving a Sustainable Water-Tourism-Nexus

Linda Söller, Dženeta Hodžić, Robert Luetkemeier
in collaboration with stakeholders from a co-design process



About this series

Groundwater Dimensions is a publication series of the junior research group regulate – Regulation of groundwater in telecoupled social-ecological systems. The German Federal Ministry of Education and Research (BMBF) is funding regulate within the framework of the strategy “Research for Sustainability” (FONA) www.fona.de/en as part of its social-ecological research funding priority, funding no. 01UU2003A. regulate is part of the funding program “junior research groups in the field of Social-Ecological Research”. The responsibility for the content of this publication lies with the authors.

Groundwater is one of the most important sources of drinking water worldwide and a key resource for food production. As a habitat for endemic species, it is also characterized by a unique biodiversity. Groundwater plays an important role for humans and the ecosystem alike. At the same time, it is threatened by climate change, and is subject to overuse and pollution. Here, influencing factors that lie beyond the boundaries of local social-ecological systems play a significant role. The aim of this series is to collect different perspectives on how groundwater bodies in Europe are (or can be) affected and shaped. These include hydrological, geographic, ethnographic and ecological, as well as inter- and transdisciplinary approaches.

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Water Futures on Krk Island

Guiding Principles for achieving a Sustainable Water-Tourism-Nexus

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Abstract

This case study report presents the outcomes of a co-design process focused on sustainable water management amidst rising demand driven by tourism on the Adriatic Coast, with a specific focus on Krk Island. Under the umbrella term “Water-Tourism-Nexus”, the regulate project team together with engaged stakeholders from water management, tourism, government, and science developed integrated strategies ensuring water security for residents and tourists while preserving the island’s environment and economy. Research activities and a workshop series guided the formulation of site-specific measures that could be implemented on Krk Island. Supply-side measures include water conservation, water reuse and desalinization and seawater pools. Demand-side measures involve spatial planning, mitigating uncontrolled tourism and new water fee structures. Based on our shared experience, we emphasize continuous stakeholder collaboration, supportive policy frameworks, financial incentives and public awareness campaigns as core components of a sustainable water future on Krk Island. The report should ideally serve as a blueprint for sustainable water management beyond Krk Island, highlighting the necessity of stakeholder-driven approaches and integrated solutions in balancing human well-being and economic growth with environmental preservation.

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1 Summary

The Adriatic Coast and especially Krk Island are grappling with rising water demand driven by tourist influx, amidst growing complexity and uncertainty in water resource management due to climate change impacts. This report outlines the outcomes of a co-design process aimed at devising measures for a sustainable (ground)water management, involving stakeholders from water management, tourism entrepreneurs, government officials and scientists. Referred to as the Water-Tourism-Nexus, the objective of the process was to formulate an integrated approach to managing water and tourism in a way that guarantees sufficient water supplies for both local residents and tourists while safeguarding the island's environmental health and economic vitality.

Actions have been developed collaboratively in four workshops and based on research activities as part of the interdisciplinary project regulate that initiated and guided the co-design process. The actions span from supply-side to demand-side management strategies. On the supply side, the actions encompass a diverse mix of resources for water provision, from water conservation to decentralized options such as water reuse, rainwater harvesting, desalination, and the transition from freshwater to seawater pools. Demand-side measures include spatial planning and regulatory interventions, such as limiting the development of accommodation units, reducing construction plots and conducting checks on residency to curtail uncontrolled tourism on the island. Implementing new water fee structures, such as usage-based or seasonal fees, is another vital aspect aimed at equitably distributing the costs of water supply among tourists and the local population. Additionally, demand-side initiatives entail awareness campaigns targeting both tourists and locals to highlight the vulnerability of water resources on the island and promote strategies for water conservation.

Sustaining the successful implementation of the strategies formulated during the co-design initiative necessitates ongoing collaboration among stakeholders, including local communities, the private sector, local policymakers, and scientists. This continued engagement fosters a collective effort towards effective water resource management and ensures that the initiatives remain responsive to evolving challenges and opportunities. Moreover, policy frameworks need to be established that support the adoption and scaling of alternative water sources, ensuring regulatory compliance and environmental sustainability. Financial and technical support mechanisms are also essential to facilitate the development and deployment of these solutions, addressing barriers to adoption and fostering innovation in water management technologies. Furthermore, public engagement and awareness campaigns are critical in building community support and encouraging participation in water conservation efforts.

This report, departing from the collaborative effort of researchers and practitioners alike, might serve as a blueprint for achieving sustainable water management not only on Krk Island. It underscores the importance of integrated, stakeholder-driven approaches to addressing environmental challenges in the context of economic development.

2 Project and Goals

Tourism is the cornerstone for the economy of Krk Island and its surrounding mainland in the Kvarner Bay in Croatia, particularly around the city of Rijeka. In recent years, the tourism industry has increased significantly, bringing not only prosperity but also substantial challenges related to drinking water supply. The heightened demand during peak summer months places immense pressure on the local water resources, groundwater and surface water, affecting both the island and the mainland. This has led to a co-design initiative aimed at addressing the intricate challenges at the intersection of water resources and tourism with the goal of developing a sustainable water management strategy for Krk Island.

The co-design initiative is part of the inter- and transdisciplinary research project regulate – Regulation of Groundwater in Telecoupled Social-Ecological Systems. Since 2021, the project conducted a co-design process that facilitates collaboration among a diverse array of stakeholders involved directly and indirectly in (ground)water management. This collaborative initiative aimed at bringing together insights and expertise of local and regional water managers, tourism entrepreneurs, government officials and local researchers. The objective was to identify and articulate the specific (ground)water related challenges facing Krk Island and the adjacent mainland areas, fostering a shared problem understanding among the participants. Throughout a series of workshops organized by the research project (Figure 1), stakeholders engaged in and worked towards a cohesive understanding of the present challenges based on their diverse perspectives. This paved the way for collaborative development of sustainable water management, ensuring Krk Island's prosperous tourism sector.

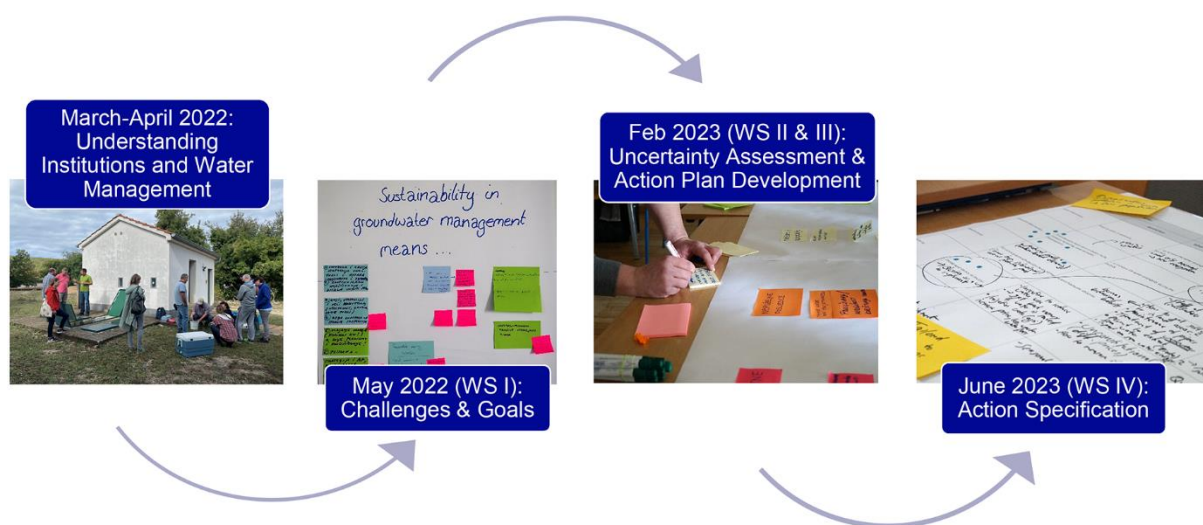


Figure 1: Chronology of co-design initiative for developing guiding principles for sustainable water-tourism-nexus.

Source: Own design by regulate project.

The outcome of the co-design initiative encompasses actions addressing the supply and demand aspects of water management. The application-oriented measures aim to ensure the long-term sustainability of groundwater and surface water resources, thereby simultaneously securing the economic benefits derived from tourism. The co-design process was complemented by individual research activities to ensure the adequate grounding in local social-ecological, economic and political contexts. This final report aims at providing valuable insights into possible measures that can be taken to ensure sustainable groundwater management and that can guide similar initiatives elsewhere.

3 Challenges

Croatia's coastal regions have emerged as premier destinations within the European tourism landscape. This prominence, however, brings to the fore the critical challenge of sustainable water management, particularly against the backdrop of the burgeoning tourism sector. The record-breaking year 2019, with more than 4.7 million tourist arrivals in Croatia¹, highlighting the acute pressure on the country's water resources. Following a decline during the Covid-19 pandemic, tourist arrivals began to rise again in 2021 and returned to the 2019 level by 2023². Given the pronounced fluctuations in water usage tied to tourism activities along the Adriatic coast, an in-depth exploration of the water-tourism nexus becomes necessary. In this context, the case of Krk Island, Croatia's most visited island by tourists, offers a poignant illustration of the complex challenges involved. During the peak tourist month of August, tourist arrivals on Krk Island outnumber the local population by a factor of 12 (Figure 2), highlighting the multifaceted nature of the issues at hand³.

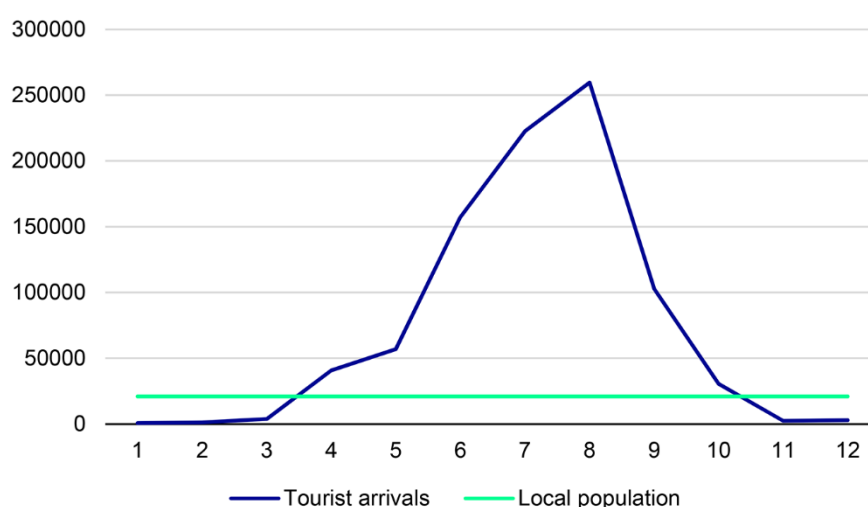


Figure 2: Tourist arrivals on Krk Island in 2019.

Source: Croatian Bureau of Statistics: Table 1.6. Accommodation capacities, tourist arrivals and nights, Republic of Croatia, NUTS 2013 – 2nd level, counties, towns, municipalities, by months (2019).

The periodic spikes in water use, attributed to the seasonal tourism surge, underscore the precarious balance between promoting tourism – a key economic driver – and ensuring the sustainability of water resources. Particularly on islands like Krk, the sustainability of local water supplies is jeopardized. Krk's attempt to address this imbalance – by connecting its northern half to the mainland's water supply in 2008 – highlights the complexities of managing water resources in a tourism-dominated context. Despite these efforts, projections indicate critical changes in groundwater recharge due to climate change impacts as well as escalating water demand, straining both the island's water and the mainland's supply capacity.

¹ Croatian Bureau of Statistics: Number of tourist arrivals 2014-2023. [<https://web.dzs.hr/dashboard/en/>, last accessed 17.03.2024].

² Republic of Croatia – Ministry of Tourism and Sport (2024). [<https://mint.gov.hr/news-11455/croatia-registers-20-6m-tourist-arrivals-and-108m-overnight-stays-in-2023/23697>, last accessed 17.03.2024].

³ Croatian Bureau of Statistics: Table 1.6. Accommodation capacities, tourist arrivals and nights, Republic of Croatia, NUTS 2013 – 2nd level, counties, towns, municipalities, by months (2019). [https://web.dzs.hr/PXWeb/Selection.aspx?px_path=Turizam__Do-lasci%20i%20no%20c4%87enja%20turista%20u%20komercijalnim%20smje%20c5%a1tajnim%20objektima&px_tableid=BS_TU16.px&px_language=en&px_db=Turizam&rxid=0365ccf3-beb7-4876-b6b2-dc7c589fa039, last accessed 17.03.2024].

3.1 Climate Change and Water Quality Concerns

The relationship between the surge in tourism-driven water demand and climate variability presents a complex challenge for Krk Island. On one side, the rising concerns over groundwater quality, worsened by sea level rise and the risk of seawater intrusion, underline the immediate necessity for effective water management strategies. On the other side, climate change is expected to alter water availability due to changing precipitation patterns, heightened evapotranspiration rates, and increased frequency of droughts, adding layers of complexity to water supply issues on the island.

The scientific examination of how groundwater recharge might shift under various climate change scenarios offers crucial insights for future water management strategies on Krk. The regulate team analysed a wide range of climate and hydrological models to assess the impacts of climate change on groundwater recharge. However, projecting the impacts of climate change on groundwater resources is challenging and connected to a wide range of uncertainty. Despite these uncertainties, projections clearly point to a potential reduction in groundwater recharge by the century's end, especially under extreme climate scenario (Figure 3). This emphasizes the imperative for adaptable water management approaches, which must be equipped to address the pressures both from climate change and tourism expansion.

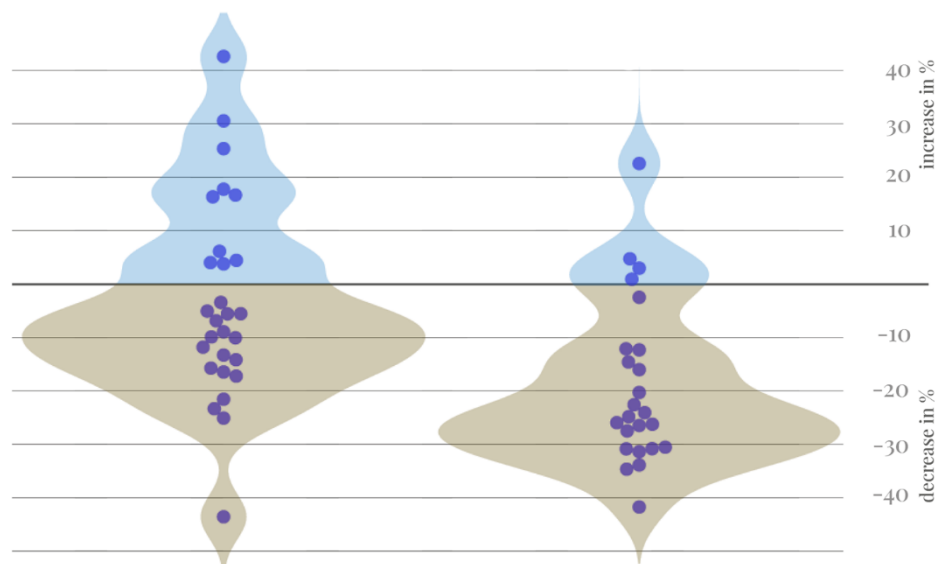


Figure 3: Groundwater recharge projections computed by several hydrological and climate models under a weak climate change scenario (left) and a strong climate change scenario (right) until the end of the 21st century compared to the end of the 20th century on Krk Island.

Source: Analysis within regulate project based on ISIMIP data⁴, visualization by Elise Reuschel, 2023 (LUCA School of Arts Brussels; modified by regulate project).

3.2 Tourism's Impact on Water Resources

The tourism industry on Krk Island, with its roughly 5 million overnight stays annually and a seasonal population that far exceeds the number of permanent residents, places significant stress on local water resources. This heightened demand for water during peak tourist seasons presents considerable challenges, not only in supplying fresh water but also in managing wastewater – a concern shared by many tourist-centric locations across Croatia.

⁴ ISIMIP (The Inter-Sectoral Impact Model Intercomparison Project). Data from the ISIMIP2b Protocol was analyzed [<https://www.isimip.org/protocol/2b/>, last accessed 17.03.2024], data availability via the ISIMIP data repository [https://data.isimip.org/search/tree/ISIMIP2b/Output-Data/water_global/%2C/, last accessed 17.03.2024].

The direct impact of tourism on water demand is observable through the expansion of water supply networks and an increase in freshwater extraction to meet the growing needs. This manifests in supply-side measures like the construction of a desalination plant and the inter-basin water transfer to the mainland. It again highlights the urgency for adopting sustainable water management practices capable of adapting to the fluctuating demands associated with tourism.

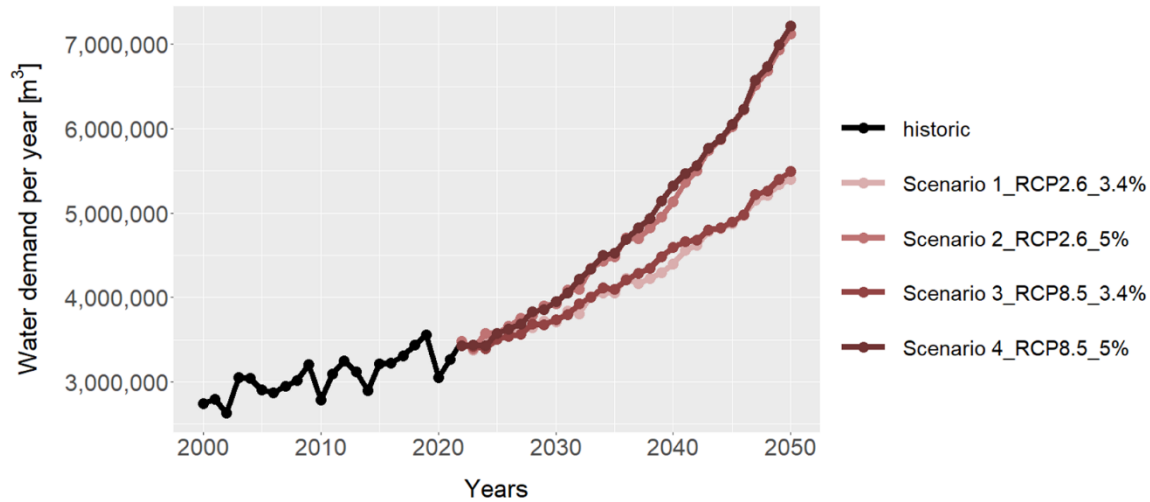


Figure 4: Projections of annual water demand on Krk Island based on extrapolation of tourist numbers under strong and weak climate change scenarios. Both climate change projections were coupled to two tourism growth scenarios with annual growth rates of 3.4% and 5%, extrapolating previous growth rate observations.

Source: regulate project based on delivered water volume from Ponikve Voda d.o.o., Krk (2023).

The regulate team analysed existing data on water demand for Krk Island and constructed a computer model to analyse and project water demand patterns into the future. Figure 4 shows that assuming a steady growth in tourist numbers that correspond to the previous years, water demand on the island is expected to roughly double until the end of the century, only with little changes broad about by either a strong or weak climate change.

4 The Water-Tourism-Nexus

The co-design process was preceded and complemented by individual research activities by the regulate team, such as a study of future groundwater recharge dynamics in the region, projections of future water demand scenarios for Krk Island, and ethnographic research and interviews providing insights into local knowledge and management practices. The interviews with stakeholders and the first stakeholder workshop confirmed that there is a high dependency between water, tourism and overall well-being of citizens on the island. Against the background of climate change and a simultaneous increase of tourism especially in the summer months, we identified the need to discuss new approaches to ensure a prosperous yet more sustainable tourism.

The participants of the co-design initiative developed and proposed to work with the concept of “Water-Tourism-Nexus” with the goal that such an integrative concept might help to conceptually and practically ensure thriving tourism on Krk Island based on integrated long-term (ground)water management strategies. The concept aims at offering the opportunity to address simultaneously the interconnection and dependency between water and tourism, acknowledging the broader context of surface and groundwater linkages and human, environmental and economic factors. Therefore, the concept allowed us to think of different fields of action and discuss possible measures that could be implemented.

The participants in the co-design initiative developed actions in three major fields. Figure 5 gives an overview of the fields of action, which are presented in detail in the following section.

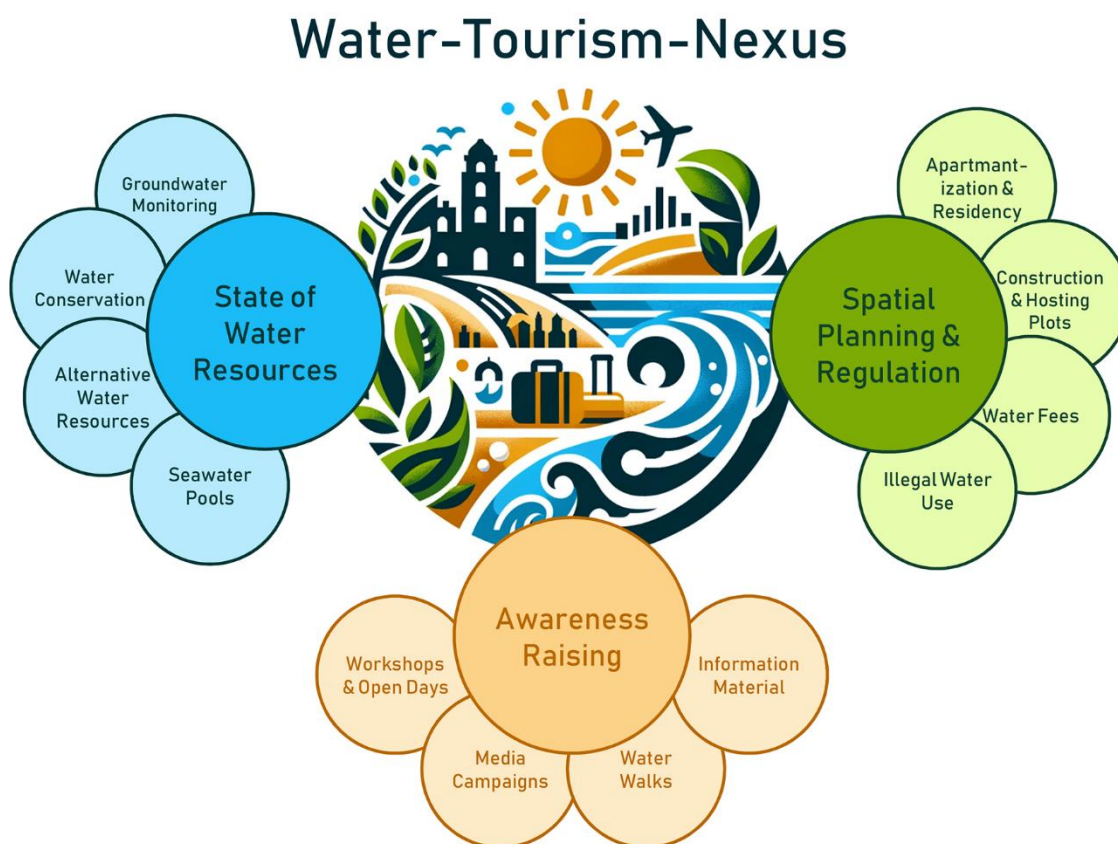


Figure 5: The Water-Tourism-Nexus: Recommendations for action as developed during the co-design initiative.
Source: OpenAI DALL-E prompted by Robert Luetkemeier 2024.

5 Recommendations for Actions

In the following, we summarize and elaborate the measures developed collaboratively across the different stakeholder workshops. Generally, we categorized the measures into supply-side actions and demand-side actions. The formulated recommendations and actions are non-exhaustive and represent the outcomes of the discussions and working groups during the stakeholder workshop series.

Table 1: Overview of key aspects of the co-developed actions.

	Action	Description	Effect
Supply-Side Actions			
State of Water Resources & Multi-Resources-Mix	Groundwater Monitoring	More efficient groundwater monitoring and faster data processing	Control of water quality and quantity
	Water Conservation	Conserve (rain)water in reservoirs	Increase the water availability during dry periods and support new ecosystems to evolve
	Alternative Water Resources	Identify alternative water resources, such as water reuse, rainwater harvesting and desalinization	
	Seawater/Natural Pools	Replace common pools with seawater/natural pools	Conserve freshwater resources
Demand-Side Actions			
Spatial Planning & Regulation	Apartmentization & Residency	Inspection control of private accommodation and residency	Protect and preserve space on the island from uncontrolled tourism development
	Construction Plots & Hosting Units	Increase minimum construction plot and reduce number of hosting units	Decrease number of apartments and reduce tourist arrivals on the island
	Public Transport	Improvement of public transport	Reduction of cars on the island
	Water Fee Depending on Usage	Creating a tiered water fee structure based on different usages	Reduction of water use and encouraging the use of alternative water sources
	Seasonal Water Fees	Developing seasonal water prices: Higher in summer, lower in winter	Fair distribution of water fees among tourists and local population
	Illegal Water Use	Control of illegal water use	Efficient planning and forecasting of water use
Awareness Raising	Workshops	Conducting workshops for children/locals on water conservation and traditional methods of water provision and conservation	Engaging the community with water resources and supply, which increases the awareness of limited water availability on the island
	Media Campaigns	Presenting Krk's own water supply	Promoting water resource vulnerability awareness and encouraging sustainable tourist water consumption
	Water Walks: Touristic Tours to Water Supply Facilities/Infrastructure	Educating tourists about the island's water supply system	
	Information Material for Hotels and Apartments	Informing tourists about water usage and conservation practices	

5.1 State of Water Resources & Multi-Resources-Mix for Water Supply

In addressing the multifaceted challenges of a sustainable Water-Tourism-Nexus, particularly in regions where the demand for water is influenced significantly by seasonal tourism, alternative water resources can complement supply-side management strategies. This approach of a Multi-Resources-Mix for water supply not only aims to alleviate the pressure on centralized water supply systems but also ensures a protection of the fragile karst groundwater resources and associated ecosystems by promoting decentralized solutions. This section delves into several solution strategies, including (i) the enhancement of groundwater monitoring and expertise in water intelligence, (ii) the expansion of water conservation measures, (iii) the reactivation and promotion of rainwater harvesting techniques as well as (iv) the introduction of seawater pools in the tourism industry.

5.1.1 Groundwater Monitoring

Data on the current and prospective future status of water resources is an integral part in sustainable water management. Only if good quality information is available, water managers and other stakeholders can take profound decisions. In this regard, we identified a need to expand the current groundwater monitoring station network to obtain more data on a regular basis. This is particularly relevant in karst aquifer systems due to its rapid flow patterns and high variability in water quality indicators. Thus, an enhanced monitoring network with associated automated reporting and analysis infrastructures is required.

Alongside this necessity, the lack of qualified, professional staff is a key obstacle. Laboratories are understaffed, which might jeopardize effective and high quality work required for groundwater monitoring in the future. Thus, funds have to be directed to enhance the staff base and their qualification. Furthermore, the promotion of respective jobs is required for raising awareness and educating trainees and students about career paths and job opportunities in the water sector to attract more talent. Water management institutions could also contribute to sharing information about career paths and the importance of this work through social media platforms, using visuals and short videos to convey the significance of groundwater monitoring. Enhancing the coverage of monitoring stations and building more expertise in handling groundwater-monitoring data is key to an effective water intelligence system on the Krk Island.

5.1.2 Water Conservation

Water buffers are an essential component for sustainable water management. Often, groundwater aquifers serve the purpose of storing water over seasons, years or even decades. However, in karst aquifer systems flow velocity is high and thus, aquifers usually cannot store significant volumes of water for longer periods. In these cases, artificial water buffers can provide a promising solution to seasonal water scarcity or peak water demands. On Krk Island, Ponikve dam and reservoir act as the major backbone of the island's water supply system.

Since water demand has been increasing on the island in the last decades, primarily due to increasing tourist numbers⁵, plans are evolving to more than double the total capacity of the reservoir⁶. Despite the technical and financial challenges in accomplishing this project and the initial disturbance of the ecosystems surrounding the reservoir lake, this project can contribute to water security on Krk Island. However,

⁵ Delivered water volume data from Ponikve Voda d.o.o. Krk (2023).

⁶ Personal communication with Ponikve Voda d.o.o. Krk (2023).

this traditional supply-side action should always be accompanied by decentralized measures, following a Multi-Resources-Mix approach.

5.1.3 Alternative Water Resources

Traditional freshwater sources such as groundwater or surface water are usually the backbone of a water supply system. Alternative water resources can, however, play a crucial role in complementing these systems and thus increase water security. In coastal regions, desalination of seawater provides a reliable water source. On Krk Island, one desalination plant is currently operating, providing drinking water to the population and tourists in the southern part of the Island in Stara Baška. In regions of highly seasonal demand patterns in particular, steady operation of desalination plants is challenging with over-capacities during the winter months and thus high operating costs.

An alternative water source is recycled or reused water. Freshwater that was used for showering for instance, can be used for toilet flushing or garden irrigation. This so-called greywater can substantially reduce the freshwater demand and thus save the island's groundwater resources. Again, this water source often comes with additional costs due to infrastructure upgrades in buildings and small-scale treatment on the household or district level as well as legal restrictions. Therefore, one of the most promising alternative water resources is rainwater. Since the Adriatic coast receives a substantial amount of precipitation (about 1.200 mm per year), rainwater harvesting can complement freshwater withdrawals to a significant amount. In particular, against the background of the island's tradition in using rainwater on the household level or even in towns, the participants of the co-design process consider the potential for accepting and implementing rainwater-harvesting facilities as high.

The *regulate* research team analysed the rainwater harvesting potential on Krk Island with a particular focus on the tourism sector. This sector is predestined to utilize collected rainwater for toilet flushing and garden irrigation due to high per capita density in hotels and large park areas. The team simulated rainwater volumes that could be harvested under realistic conditions by considering the actual rainfall patterns on the island and the roof sizes available for hotels. The modelling procedure also captured the hotel size in terms of available beds and was thus able to indicate how much water could be saved potentially in a hotel when rainwater harvesting was implemented. The results show that for a 300-beds hotel, a storage tank of 140 m³ is enough to cover the entire water volume for toilet flushing⁷.

5.1.4 Seawater Pools

Swimming pools are an attractive investment for both households and hotels. However, they are water intensive, as they require large volumes of freshwater with regular renewal procedures. Therefore, finding alternative sources apart from freshwater would be a significant contribution to protecting water resources on Krk Island. The utilization of seawater pools represents an innovative approach to supplementing freshwater resources, particularly in coastal regions where seawater is closely available. Seawater pools in hotels save freshwater by using filtered seawater collected from the sea. Balancing chemicals and regular circulation maintain water quality, while evaporation losses are replenished with seawater. Maintenance tasks like filter cleaning and equipment inspection are crucial for efficient operation.

Seawater pools offer a sustainable alternative, reducing reliance on freshwater while providing guests with a unique swimming experience and potential health benefits from natural minerals. However, the

⁷ Magdalena Hau (2023): Rainwater Harvesting as Potable Water Substitution in Tourism. Analysis of Potential for the Krk Island, Croatia. Master Thesis, Technical University Berlin, Germany.

implementation of seawater pools requires careful consideration of environmental impacts and the selection of appropriate locations to minimize disruptions to marine ecosystems and coastal landscapes.

5.2 Spatial Planning and Regulation

Overall, the implications of spatial planning in the region are highly consequential to the current state of groundwater systems, and are tied intricately to various factors, ranging from the rampant ‘apartmentization’ and the influence of transnational investors, fuelling uncontrolled tourism development. The importance of adapting planning to existing infrastructure, understanding the capacity of specific locations, and forming regional alliances to influence state-level laws needs to be highlighted continuously. Moreover, a need was identified for stronger networking among regional water utility companies to gain strength in representing current needs and challenges in the water sector.

5.2.1 Apartmentization and Residency

The term ‘apartmentization’ emerged in the co-design initiative to describe the current state and trend regarding tourism development. The increasing amount of illegal building developments of apartment houses and villas on the island correlates with an increase in informal renting practices in which (re-)visiting tourists engage. This further contributes to uncontrolled tourism development with large shadow numbers of actual tourist arrivals on the island. Therefore, conducting regular inspections of residences is essential for protecting Krk Island from further uncontrolled tourism development, as hosts often do not register tourists staying in their accommodations. In turn, this leads to an evasion of taxes (e.g. tourist tax, income taxes on rent) and further obscures the tourist statistics used for planning for and prognoses of future developments in tourism, water supply and waste (water) treatment capacities. By enforcing regulations, zoning laws, and thorough evaluations before construction (e.g. through stricter Environmental Impact Assessments), authorities could prevent the proliferation of large-scale developments that may detract from the natural beauty and character of the island. However, this requires monitoring and enforcement measures to deter unauthorized construction and land use. At the same time, planning for island development should take into account the limitations and capacities of existing infrastructure. Adapting planning initiatives to complement existing infrastructure helps ensure sustainable growth and minimizes the strain on island resources.

This not only includes water, waste and housing infrastructure but also transportation. Through an improvement of public transport on the island, the number of cars on the island could be reduced, contributing to mitigating environmental pollution, overcrowded streets where movement for pedestrians is obstructed, and a consequent devaluation of the island landscape. Overall, it is essential to ensure the general quality of life on the island across the divide of locals and tourists.

5.2.2 Construction Plots and Hosting Units

The current regulations regarding construction plots for housing units are spatially very generous and should be revised so that the minimum construction plot promotes smaller houses, fewer apartments, and larger gardens with Mediterranean plants/landscaping. In addition, increased taxation on weekend houses might further deter big players. Moreover, there is a need to reduce the number of hosting units to curb tourist arrivals and control residence to make the area less appealing for investors. Ideally, these measures will lead to a decrease in water demand as housing capacities are smaller, there is a larger retention surface and local plants require less water to survive even during drier periods.

5.2.3 Water Fees

The adaptation of the existing water fee system serves as both a regulatory and economic mechanism to encourage the judicious use of water resources. By pricing water to reflect more accurately its true cost and scarcity, a water fee system can incentivize conservation and the adoption of water-efficient practices among users. The revenues generated from water fees can be reinvested in the maintenance and upgrade of water infrastructure, the development of alternative water sources, and the support of water conservation programs. It is crucial, however, to structure water fees in a way that ensures equitable access to water, with considerations for varying economic capacities among users and the provision of subsidies or tiered pricing models depending on the type of water use. One option is the introduction of dynamic water price models that change along the seasons, meaning all water consumers pay the same water price while deviating between summer and wintertime to avoid putting additional pressure on local residents.

5.2.4 Preventing Illegal Water Use

By cracking down on illegal water use, registered water use will increase, allowing for a more realistic picture of actual water use, ultimately enabling more efficient planning and forecasting. The focus here should be on addressing illegal buildings and activities that contribute to unauthorized water use, thereby enhancing overall water resource management and conservation efforts.

5.3 Awareness Raising

5.3.1 Workshops and Open Days

The implementation of workshops (e.g. in schools and kindergartens) serves as an educational tool to inform children, teachers and the local population about the constraints surrounding water resources. These workshops and open days should be designed to be interactive and captivating, tailored to the comprehension levels of their respective audiences. Additionally, integrating teachings about traditional methods of water provision and conservation into school curricula offers an additional dimension to students' understanding. By capitalizing on existing structures like Ponikve's waste management workshops, efforts can be consolidated to encompass water awareness initiatives. This approach covers the scientific facets of water conservation and instills an appreciation for its cultural and historical importance.

5.3.2 Media Campaigns

To promote water consumption education among the local population and tourists, leveraging media campaigns can highlight the unique characteristic of Krk's own water supply, which sets it apart from many other islands. In general, it is crucial to ensure that information about water quantity and quality is featured prominently during summer and winter through social media, local newspapers, or on the website of the water supplier. Moreover, adding details about water losses on the website can raise awareness about conservation efforts and the importance of minimizing wastage. Additionally, billboards strategically placed in high-traffic tourist areas can effectively convey messages about water conservation and the significance of Krk's independent water supply. Storytelling elements in media campaigns can be impactful to evoke emotions among tourists towards water conservation and appreciation for nature.

5.3.3 Touristic Tours to Water Supply Facilities: Water Walks

To enhance awareness of water resource vulnerability on the Krk Island and promote sustainable habits among tourists, the introduction of “Water Walks” presents an innovative educational opportunity. Unlike traditional food or wine walks, Water Walks focus on understanding hydrological systems, ecosystems, and the importance of water conservation. A water walk can consist of a guided tour of water supply facilities and infrastructures, such as water treatment plants, reservoirs, and pumping stations and incorporating visits to natural areas, such as wetlands, rivers, and coastal habitats, to display the interconnectedness between water resources and local ecosystems.

5.3.4 Information Material for Hotels and Apartments

To raise awareness of the vulnerability of water resources on the island and promote sustainable water usage practices among tourists, informative materials such as sheets or pamphlets can be distributed. These materials should contain basic information on water usage and offer practical advice on changing habits to reduce water consumption. By distributing the informative materials to guests upon check-in or including them in welcome packages, accommodations can play a pivotal role in educating tourists about water conservation and fostering a culture of responsible water usage during their stay on the island.

An approach to conveying the effects of climate change to tourists is by so-called *data soaps*. These soaps illustrate climate change impacts, such as those on groundwater resources, and provide further information in simple language or via a QR code on the packaging, aiding in raising awareness about this vital resource and motivating to reduce water use. Figure 6 depicts examples of such data soaps created as part of Elise Reuschel’s master’s thesis in 2023 in collaboration with the *regulate* project. A collaboration between scientists capable of analysing data of interest and local soap producers capable of manufacturing these data soaps could further advance this initiative.



Figure 6: Data Soaps showing the simulated change of groundwater recharge on Krk Island until the end of the century (based on Figure 3) created as part of Elise Reuschel’s master’s thesis (LUCA School of Arts, Brussels) in 2023 in collaboration with the *regulate* project.

Source: regulate project team 2023.

6 Outlook

Sustaining the successful implementation of the strategies formulated during the co-design initiative necessitates ongoing collaboration among stakeholders, including local communities, the private sector, local policymakers, and scientists. For instance, students at the University of Rijeka could contribute by conducting exploratory studies on topics such as water fees or developing awareness campaigns in collaboration with water suppliers or tourism stakeholders. This continued engagement fosters a collective effort towards effective water resource management and ensures that the initiatives remain responsive to evolving challenges and opportunities. Moreover, policy frameworks need to be established that support the adoption and scaling of alternative water sources, ensuring regulatory compliance and environmental sustainability. Financial and technical support mechanisms are also essential to facilitate the development and deployment of these solutions, addressing barriers to adoption and fostering innovation in water management technologies.

Ultimately, the integration of these measures into existing water management plans has to be addressed with an understanding of local contexts and needs, ensuring that solutions are tailored to address specific challenges and opportunities. Issues such as corruption, a lack of ultimate responsibility due to obscure administrative layers, and the conflict between political authority on higher levels and local administrations further challenge the implementation of the presented measures. Therefore, public engagement and awareness campaigns are critical in building community support and encouraging participation in water conservation efforts.

This report, departing from the collaborative effort of researchers and practitioners alike, might serve as a blueprint for achieving sustainable water management not only on Krk Island. It underscores the importance of integrated, stakeholder-driven approaches to addressing environmental challenges in the context of economic development.

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