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COLLABORATIVE KNOWLEDGE CO-CREATION IN RIVER MANAGEMENT THROUGH CITIZEN SCIENCE AND PROFESSIONAL RESEARCH

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Abstract: Collaborative knowledge co-creation through citizen science and professional research involves bringing together diverse stakeholders, including members of the public (citizen scientists) and trained experts (professional researchers), to collectively generate new insights and knowledge. This approach is particularly important when addressing environmental issues as it fosters community engagement, awareness, a sense of ownership and environmental responsibility within the community. This paper discusses key lessons learned from collaborative knowledge co-creation on the Temenica River, a small karst river in south-eastern Slovenia, particularly vulnerable to environmental change, including climate variability, land use change, water use and pollution. The paper presents a model for a small-scale, community-led environmental initiative, supported by the LEADER/CLLD method of rural development, demonstrating the power of collaboration between citizens and professional researchers – geographers in tackling water-related challenges in river communities. Various knowledge co-creation activities (workshops, focus groups, etc.) are explored, and it is shown how locals and professional stakeholders could be effectively mobilized to actively participate in data collection, information exchange, co-creation of new knowledge, producing various tools, promoting the topic and capacity building.
This increased engagement of local people potentially leads to more informed decision-making in small river basin management, better resource management practices, and greater public support for environmental conservation efforts. The paper offers insights for future efforts to engage communities in responsible, more sustainable, and resilient river management.

Keywords: river protection, environmental empowerment, LEADER/CLLD, Temenica River, Dinaric karst, Slovenia

INTRODUCTION

River management has traditionally been carried out by professional researchers and government agencies to monitor, manage and maintain river ecosystems (Johannes et al., 2002). In the past, the public was often viewed only as recipients of knowledge generated by experts, a perspective known as the "deficit model" (Wynne, 1991; cited in Cross, 2022). In recent decades, however, the value of integrating local communities and citizen science – where members of the public, local people actively contribute to scientific research –has been increasingly recognised, particularly in the field of sustainable river basin management (Eitzel et al., 2023; Cross, 2022; Truchy et al., 2023). Sustainable river basin management relies on multi-stakeholder collaboration that facilitates the interaction, exchange and integration of diverse sources and types of knowledge. This approach involves engaging a broad range of stakeholders from "communities of place" – stakeholders and individuals located close to water bodies, and "communities of interest« - experts, and professional researchers who have relevant information or knowledge (Johannes et al., 2002). According to Conde & Walter (2022), there are three types of collaborative knowledge co-creation among these

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two groups: 1) co-creation of new knowledge, where new information is jointly produced; 2) co-creation of interpretation, through which knowledge is contextualized; 3) co-creation of knowledge mobilization, where different professionals collaborate in the elaboration of strategies based on their (scientific, local, traditional or experiential) knowledge and networks.

In river basin management, locals help - citizen science is commonly used, e.g. monitoring water quality and endangered species (Dickson et al., 2023), assessing stream quality by monitoring of aquatic macro-invertebrates (Krabbenhoft&Kashian, 2020), tracking macroplastic pollution in rivers (Liro et al., 2023), tracking dam removal (Eitzel et al., 2023), etc. Citizen science also appears as a suitable appropriate approach to help locate, map and monitor intermittent rivers and ephemeral streams while raising people's awareness of dry and wet phases in river networks (Truchy et al., 2023). While the Internet, smartphones and geographic information system (GIS) have enabled the collection of location-based data, easy data entry, and centralised databases, significantly expanding the reach and accessibility of citizen science projects (Dickinson et al., 2012), traditional methods such as surveys, data collection kits, storytelling, art, workshops, and community meetings are also common methods of citizen participation. These traditional approaches often provide hands-on experiences and foster direct engagement in river management networks.

Today, most citizen scientists collaborate with or are guided by professional scientists, either in the conception and design or throughout the project. This provides educational benefits to the community more broadly and benefits to science through improved community engagement, cost-effective, large-scale data collection capacity at an unprecedented spatial or temporal scale, and insight through local knowledge in the co-creation of new information and interpretation of co-created knowledge (Dickson et al., 2023; Gurnell et al., 2019).

This paper explores how collaborative knowledge co-creation between citizen scientists and professional researchers from the Department of Geography at the University of Ljubljana can improve river management. The aim is to examine the approaches, tools and methods used, analyse the outcomes of such collaborations and discuss the wider implications for environmental science and local communities. This is presented through a case study of the Temenica River, a little-known karst river in south-eastern Slovenia, that is particularly vulnerable to environmental change, including climate variability, land use change, and pollution. Here, community initiatives are the only way to achieve better river management (Mikolič et al., 2024 in press).

METHODS AND APPROACHES

Collaborative knowledge co-creation in river management was explored through the case study of the Temenica River, where the whole process of collaborative knowledge co-creation was steered by the LEADER/CLLD project. The LEADER approach or Community-Led Local Development (CLLD) is a European method to support Member States in pursuing integrated territorial development (Common Provisions Regulation; European Union, 2021). This approach aims to actively involve local communities and stakeholders in the creation and implementation of strategies and projects designed to tackle local development challenges while making collective decisions on the allocation of EU funds. The key features about LEADER/CLLD include (Potočnik Slavič et al., 2022): 1) bottom-up approach, allowing local communities to identify their specific needs and priorities; 2) unique governance, consisting of formal and informal stakeholders in Local Action Groups, which are usually responsible for implementing local development strategies; 3) to address place-based challenges in sub-regions with diverse objectives, including employment, social inclusion, and sustainable environmental practices, 4) to promote an integrated approach to territorial development, where integration implies multiple funds, cross-sectoral policies, multi-level and multi-stakeholder governance, a multi-territorial and community-led strategy; and 5) with the capacity to strengthen community engagement and ownership.

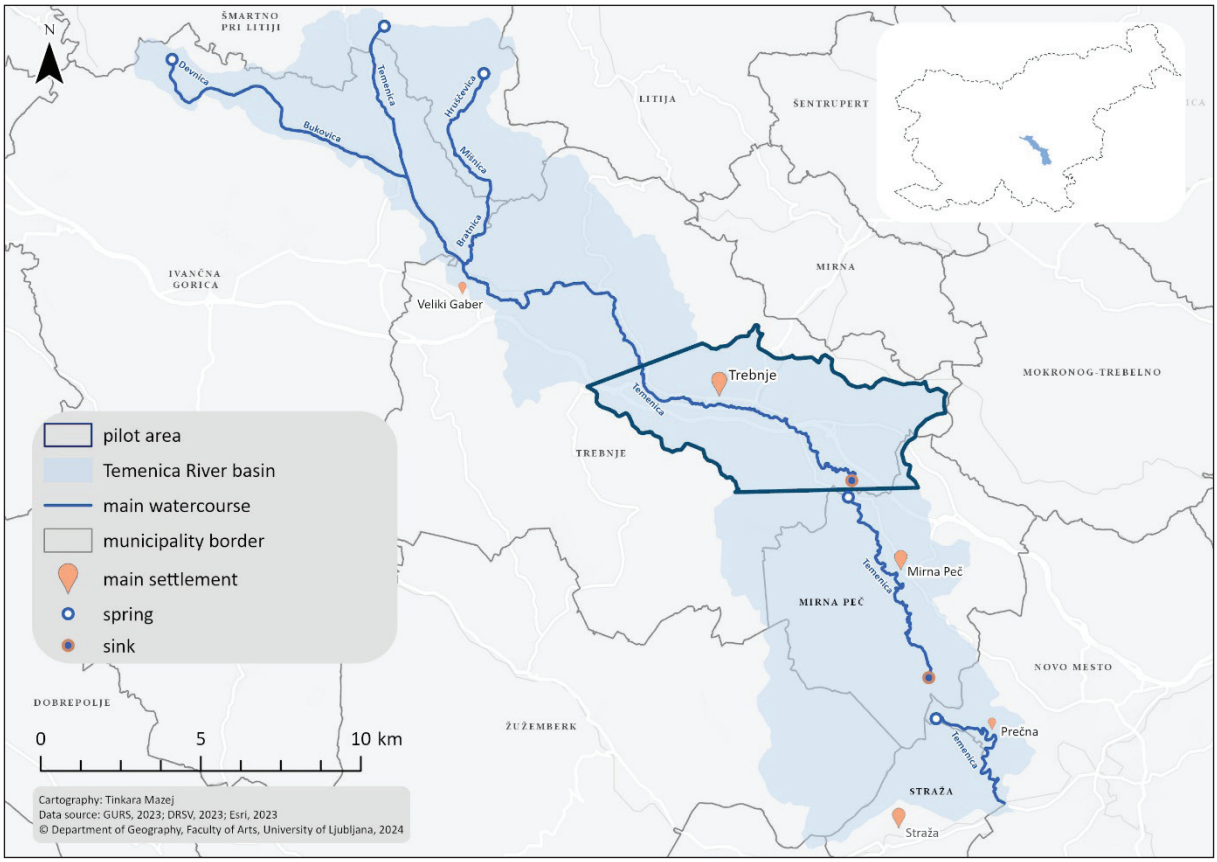
Citizen science is seen as a tool for environmental or ecological research and public engagement (Dickinson et al., 2012). In the LEADER/CLLD project, combined research methods were used to collectively create new information and knowledge about Temenica River: 1) participatory mapping involving students and locals to inventory the natural and cultural heritage associated with the river, environmental elements, ecological issues, and other river-specific features; 2) public competitions in photography, painting and literature were organized to collect data on how locals perceive and interact with the river; 3) collaborative workshops with primary school teachers and students to develop teaching and learning material and techniques for river education; and 4) focus group sessions and public discussions that allowed stakeholders to share their perspectives, local knowledge and propose solutions for more sustainable management of the river basin.

STUDY AREA: TEMENICA RIVER

The Temenica River, a karstic sinking stream in Slovenia, rises from two springs in the southern foothills of the Posavje Hills. It flows mainly through the low Dinaric karst of the Lower Carniolan Basin before joining the Krka River near Novo mesto. Although the exact length of the river is unknown due to extensive underground sections, its surface course measures approximately 42 km. After flowing for around 27 km, it sinks for the first time near Trebnje, reappearing on the surface at the Zijalo karst spring in the Mirna Peč karst valley, only to sink again at Goriška vas and reappear as the Prečna stream in the Zaloško Polje valley and continue its course until its confluence with the Krka River. The Temenica River flows through seven municipalities: Šmartno pri Litiji, Ivančna Gorica, Trebnje, Mirna Peč, Žužemberk, Straža and Novo mesto. The biggest town along the river is Trebnje (GURS, 2023).

While some aspects of the research focused on the entire Temenica River basin, a pilot area of about 6 km near Trebnje, from Štefan to Ponikve, where the Temenica sinks for the first time, was selected for detailed analysis and research. This particular section was chosen because Trebnje, the largest town along the Temenica, is located here, making it an important point of interest. Additionally, this area faces the greatest challenges: Climate change, land use change, water use and pollution, and the abandonment of traditional river management practice to assure water for the operation of water mills - all critical issues affecting the river and its surroundings. Therefore, detailed participatory mapping and other important activities have been carried out here to effectively address these challenges.

Figure 1: Map of Temenica River.



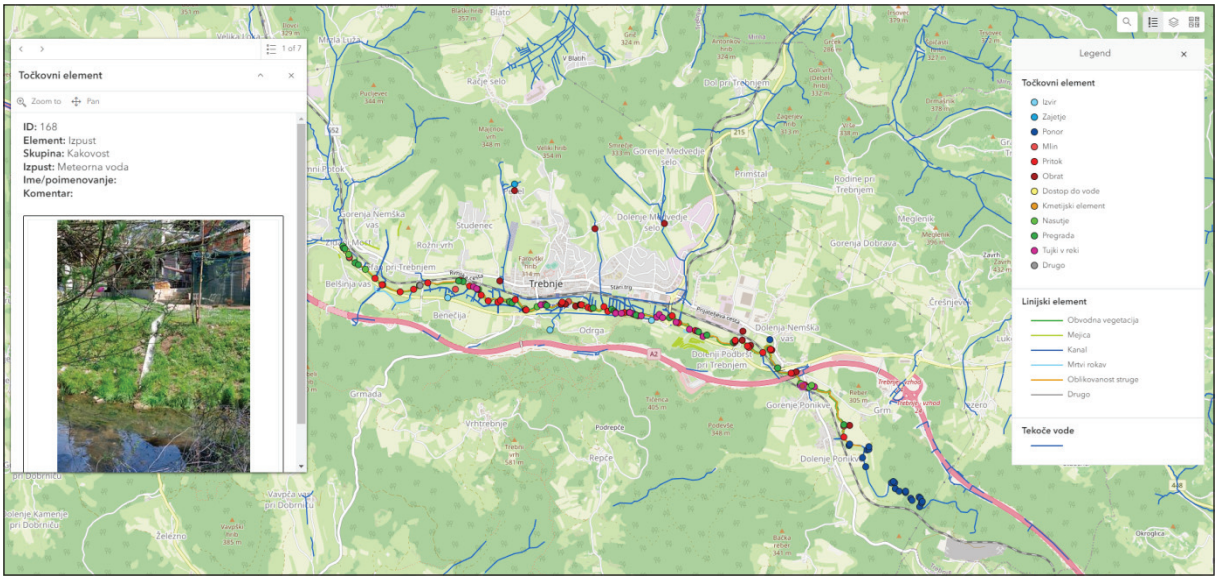
RESULTS AND DISCUSSION

The first step in the co-creation of knowledge was **participative mapping** of the Temenica River in the selected pilot area. It was conducted in two ways: 1) organized or centralized; and 2) spontaneous, with the help of individuals in the local community.

The first method was carried out by geography students in spring 2022. During a few days of fieldwork, they identified point elements (e.g. springs, sinks, water mills, tributaries, water intakes,

waterworks, dams, foreign objects in the river), linear elements (e.g. riparian vegetation, hedgerows, channels, oxbow lakes, riverbed formations), and area elements (e.g., floodplains, wetlands). Using the ArcGIS Collector application on smartphones, they identified over 150 different elements. For example, only a limited number of sinkholes (9) were listed in the official records, but participatory mapping revealed more than 15 additional sinkholes. This method facilitated precise location tracking via GPS, image capture and uploading it, and brief descriptions of each element, enriching the dataset with detailed spatial information.

Figure 2: Participative mapping of the different elements along the Temenica River in Trebnje.



In addition to the students, individual community members also engaged in observation and participatory mapping along the Temenica River. Although they did not use a mobile application and their data collection was not centralized, they made significant contribution. For example, one resident wrote a 25-pages report documenting various elements of the Temenica River's aquatic and riparian environment. He described in detail some sources of pollution, dams, water mills, changes in the river's course in the past, land use changes, etc. and provided interpretations based on local knowledge. He sent report to us and expalined that he was inspired by the students' work. In addition, the individual mapping approach also include direct information sharing by the local population via email (e.g. reports of fish and crayfish deaths), and social media (e.g. photos of low water levels when the Temenica River dried up in certain parts during the summer drought in 2022). Combining professional tools for citizen science with community input results in a richer dataset that includes both technical, semi-professional fieldwork and local insights. It expands our ability to collect data at an unprecedented spatial or temporal scale. Importantly, this approach enables the documentation of processes, events, and changes even when professionals are not physically present.

Another tool for fostering knowledge co-creation in river management through citizen science involves **cultural competitions**. Three such contests were organized, one focused on photography, another on painting, and the third on literature. These creative contests serve as valuable tools for collecting data on local perceptions and interactions with the river. They were tailored to different age groups.

In the 34 collected literary works, children between the ages of 8 and 14 wrote prose or poems on varoius topics. They captured their parents and grandparents' memories of the Temenica River and described activities such as swimming in the river or grinding flour in the water mills in the past. Pupils also penned experiential essays about fishing and spending leisure time by the river, wrote imaginative stories about mythical creatures living in Temenica River, and imagined what the river might say if it could speak. These works often reflect elements of environmental advocacy. The literary pieces also describe the fauna (fish, crayfish, ducks, frogs, storks, etc.) and flora (e.g. willows), the low water level of the river in summer, and the high water level on flood days (example below). They emphasise the karst features of the river, such as sinkholes, re-emerging springs, and meandering river courses. In most of the works, the Temenica is negatively perceived as a polluted river emerges, along with expressed a sincere wish for the river to be cleaner and full of life. However, a few works emphasise very positive perception of the river as very beautiful natural spectacle.

Table 1: Example of a poem written by Val Smolič, 12 years old (in Slovenian and English).

V Temenici ni več rib in rakov, saj vode je vsak dan manj. Ko poleti suša pride, je Temenica le spomin. Po nalivu pa naraste, travnikov ob njej več ni, takrat življenje se prikaže vsaj za nekaj mokrih dni.	In Temenica, no fish or crabs reside, for every day, there's less water inside. When summer droughts arrive and the sun is high, Temenica's but a memory, passing by. After the rain, it swells and flows, but the meadows near it, no longer grow. Then life appears, though briefly so, for a few wet days, its presence does show.

Nine local took part in the photography competition, 9 locals participated, submitting a total of 28 photos. The motifs of the photos can be divided into four groups: 1) river habitats, including images of wetlands, springs, river flora and fauna, emphasizing the preservation of the natural environment and biodiversity along the river; 2) the impact of human activities, such as river dams, water mills, bridges, monitoring station, agricultural landscape along the river, artificial swallow holes, depicting elements and consequences of human impact on the river and surrounding nature; 3) the beauty and experiences along the river, such as aerial photos and experiences such as dawns by the Temenica, showcasing the aesthetic appeal of the river and the emotional connection of the local community with it; and 4) environmental problems indicated by photographs of eutrophication of the river and dead crayfish, which symbolize awareness of the environmental challenges and call to action for preservation and protection of the Temenica River.

As part of the art competition, we received 32 paintings in various techniques. The participants were mainly adults. The motifs can be divided into the following groups: 1) natural habitats and landscapes, including depictions of the river channel, springs, and vegetation such as willows and oaks, as well as the famous Zijalo spring in Mirna Peč; 2) life by the river, with birds, crayfish, ducks, swans, etc.; 3) the beauty and experiences by the river, illustrated by sunsets, summer scenes, walks along the Temenica, a wooden boat and reflections in the water; 4) environmental problems and advocacy, highlighting the flooded Temenica, the river crying due to fish kills, and SOS birds calling for help; 5) and human influence and historical elements, represented by a watermill on the Temenica. These themes reflect the diverse perspectives and concerns of the participants regarding the Temenica River.

Figure 3: Painting and photography content about Temenica River.

Brane Praznik, Vrbe ob Temenici

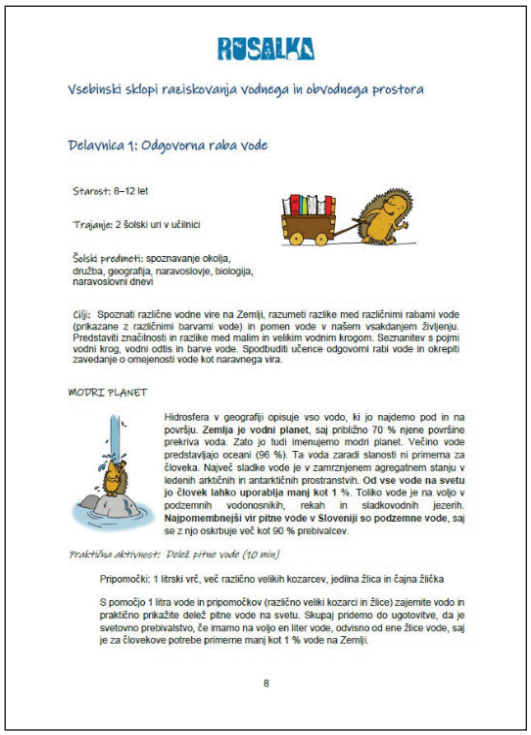
Anastazija Dežman Žagar, V strugi

Darko Jakovec, Meander

Jani Vimpolšek, Jutro ob Temenici

The third approach for knowledge co-creation are collaborative **workshops with primary school teachers and children** to develop teaching and learning materials and techniques. The workshop with teachers identified existing school activities related to the Temenica River. Currently, the Temenica is covered in the 6th-grade natural science curriculum through a two-hour field work focused on the identifying aquatic organisms. However, a dedicated science day on the Temenica has been discontinued, and students rarely come into contact with their local river. Teachers and professional researchers identified gaps in the content and developed four educational workshops for students aged 10 to 14. These workshops cover responsible water use, water reuse, the functioning of water bodies and riparian zones, and river pollution. The workshops were tested in eight sessions at different schools and led to the creation of a didactic manual entitled "Exploring Aquatic and Riparian Spaces" (Mikolič et al., 2023). The materials contain didactic tools and illustrations that encourage exploration of rivers in the classroom and in the field. Together with teachers, we also determined the main characters of the Temenica story for children, namely the frog and the hedgehog. Our aim was to encourage interdisciplinary connections in exploration the local watercourse. Although the workshops are specific to the Temenica, they can also be transferred to other water bodies. To ensure ongoing environmental education, we also familiarized primary school teachers with the necessary tools and methods in a specialized workshop.

Figure 4: Didactic manual for primary school teachers.


RUSALKA

Vsebinski sklopi raziskovanja vodnega in obvodnega prostora

Delavnica 1: Odgovorna raba vode

Starost: 8–12 let

Trajanje: 2 šolski uri v učilnici

Šolski predmeti: spoznavanje okolja, družba, geografija, naravoslovje, biologija, naravoslovni dnevi

Cilji: Spoznati različne vodne vire na Zemlji, razumeti razlike med različnimi rabami vode (prikazane z različnimi barvami vode) in pomen vode v našem vsakdanjem življenju. Predstaviti značilnosti in razlike med malim in velikim vodnim krogom. Seznanitev s pojmi vodni krog, vodni odtis in barve vode. Spodbuditi učence odgovorni rabi vode in okrepiti zavedanje o omejenosti vode kot naravnega vira.

MODRI PLANET

Hidrosfera v geografiji opisuje vso vodo, ki jo najdemo pod in na površju. **Zemlja je vodni planet**, saj približno 70 % njene površine prekriva voda. Zato jo tudi imenujemo modri planet. Večino vode predstavljajo oceani (96 %). Ta voda zaradi slanosti ni primerna za človeka. Največ sladke vode je v zamrznjenem agregatnem stanju v ledenih arktičnih in antarktičnih prostranstvih. **Od vse vode na svetu jo človek lahko uporablja manj kot 1 %.** Toliko vode je na voljo v podzemnih vodonosnikih, rekah in sladkovodnih jezerih. **Najpomembnejši vir pitne vode v Sloveniji so podzemne vode**, saj se z njo oskrbuje več kot 90 % prebivalcev.

Praktična aktivnost: Delež pitne vode (10 min)

Pripomočki: 1 litrski vrč, več različno velikih kozarcev, jedilna žlica in čajna žlička

S pomočjo 1 litra vode in pripomočkov (različno veliki kozarci in žlice) zajemite vodo in praktično prikažite delež pitne vode na svetu. Skupaj pridemo do ugotovitve, da je svetovno prebivalstvo, če imamo na voljo en liter vode, odvisno od ene žlice vode, saj je za človekove potrebe primerne manj kot 1 % vode na Zemlji.

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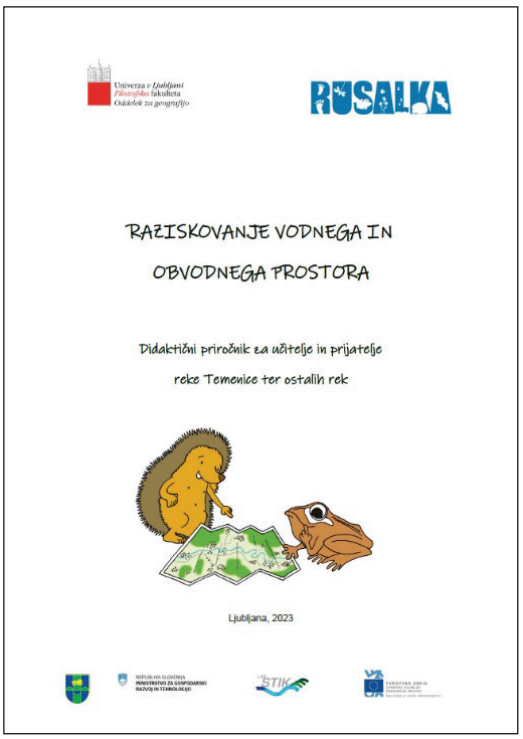

Univerza v Ljubljani Filozofska fakulteta Oddelek za geografijo

RUSALKA

RAZISKOVANJE VODNEGA IN OBVODNEGA PROSTORA

Didaktični priročnik za učitelje in prijatelje reke Temenice ter ostalih rek

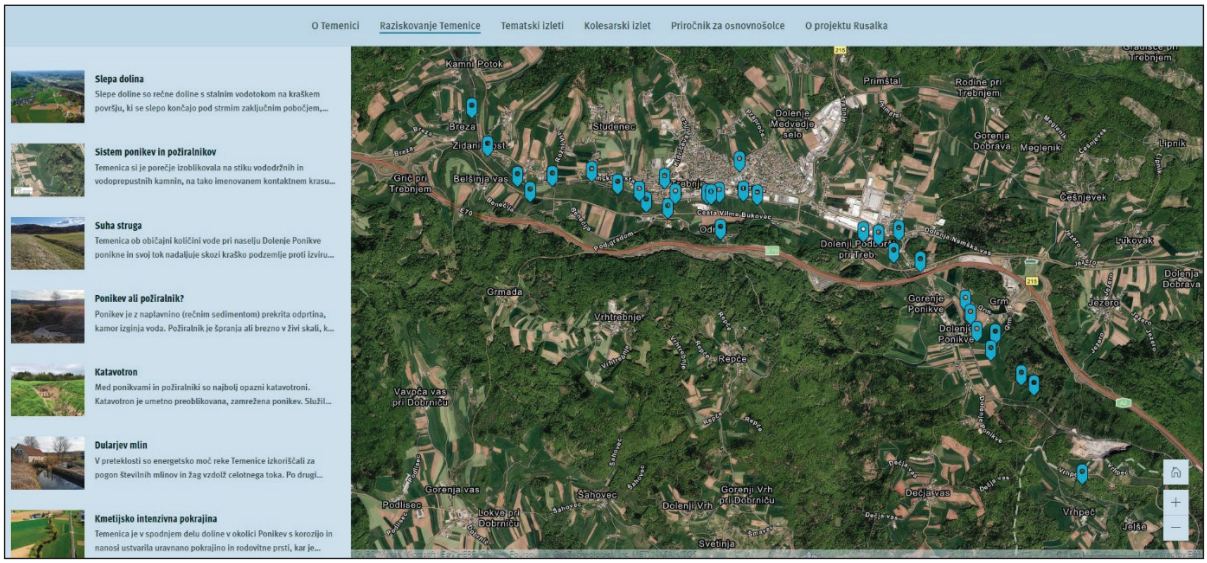
Ljubljana, 2023

The fourth collaborative knowledge co-creation activity involves the **organisation of workshops by the local community**. The firstirst workshop focused on the exchange of local knowledge about the tangible and intangible heritage of the Temenica River. Another workshop was dedicated to co-creating a bike tour along the Temenica River. The workshop on tangible and intangible cultural heritage enables community members to share and document their unique local knowledge, which is essential for the preservation of the region's culture, history and traditions. The bike tour co-creation workshop, on the other hand, promotes sustainable tourism and environmental awareness. By involving locals in the planning process, the bike tour is likely to be more authentic and meaningful, reflecting the true spirit and heritage of the Temenica River Basin. These activities not only foster e a sense of community and ownership, but also promote the sustainable use and appreciation of local resources.

Following the citizen science efforts, **professional researchers from the Department of Geography at the University of Ljubljana took on the task of reviewing** all the deployments, locations and information gathered through citizen science. This included conducting field investigations to validate the information collected through participative mapping, reviewing existing research and documentation related on the Temenica River and similar ecosystems, analysing official hydrological data to understand the flow rate and volume of the river, and conducting on-site water quality tests and GIS analysis over the Temenica River basin to combine the citizen scientists' data with official records and other geographic data layers to detect discrepancies and validate the results.

From the data collected, we selected the 30 most important elements and created a detailed description for each. The interpretation was based on local knowledge passed on through citizen science and professional research. We utilized advanced GIS tools and platforms such us ArcGIS StoryMaps to develop an interactive and educational application titled "Temenica – The Little River of Big Secrets" to promote the topic. The application is open to the public and is aimed at locals and visitors. It is also accessible via a QR code on the information board installed in Trebnje and a leaflet inviting visitors to three thematic excursions along the Temenica with the slogans "Discover Temenica," "Act responsibly," and "Admire Temenica". Additionally, the application includes a bike tour along Temenica River co-designed by the local community, as well as a didactic manual for teachers.

Figure 5: ArcGIS StoryMap application about the Temenica River.



Researchers from the Department of Geography at the University of Ljubljana also organised two **public discussions** where stakeholders could share their perspectives and local knowledge and propose solutions for more sustainable river management practices. Presenting research results to the public enables for two-way communication between researchers and the community. It provides an opportunity for researchers to receive feedback, address concerns and incorporate local perspectives into their work, enhancing the relevance and applicability of the research. Access to research results empowers the local community by providing them with valuable information about their environment. It promotes a sense of ownership of the research outcomes.

CONCLUSION

According to the European Commission, engaging citizens - locals helps to better define problems, generate new policy ideas and increase trust and ownership of policy outcomes. This approach shifts the process from mere information dissemination to active deliberation (Nascimento et al., 2016). The collaborative knowledge co-creation model demonstrated in the Temenica River project, led by the Department of Geography at the University of Ljubljana and local stakeholders (municipality, local association, local school, local enterprise), illustrates the transformative potential of integrating citizen science and professional research. By engaging local communities in participatory activities such as mapping and co-creating interpretations of different elements along the river, cultural competitions to collect data on local perceptions and interactions with the river, co-designing educational workshops for school children with teachers, and public discussions organised by professionals and locals, the project successfully harnessed different sources of knowledge.

Although citizen science is often viewed with scepticism by decision makers, who may exclude it from decision-making due to perceptions of poor quality and lack of scientific credibility (Cross, 2022), the LEADER/CLLD development method supports exactly that - collaboration between different stakeholders (public and private, professional and non-professional actors, etc). The "Temenica River project" demonstrates enriched knowledge about Temenica River, promoting the river and water issues in primary education and tourism, raised local awareness and commitment to environmental protection and built trust between researchers, policy makers, and the community. The use of both traditional methods and modern technologies, such as GIS tools and online StoryMap platforms,

ensured comprehensive documentation and dissemination of results. These efforts not only contributed to more informed and sustainable river management practises but also empowered the community by instilling a sense of ownership, responsibility and stewardship of their local environment.

The success of this project suggests that similar approaches can be effectively applied to other environmental management challenges. Future initiatives and development projects should continue to emphasize community involvement. By encouraging collaborative efforts, we can achieve more resilient and sustainable management of natural resources and ensure that environmental conservation efforts are both science-based and community-driven.

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