

# AN INTEGRATED RESTORATION PLAN FOR THE DAMAGED LANDSCAPES OF THE KYSUCA RIVER BASIN



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# 1. Introduction

The drying up of springs, small watercourses, and streams is a 21st-century phenomenon to which the European Union is seeking answers and effective solutions through scientific research projects under HORIZON EUROPE. One such project is **DALIA (Danube Lighthouse Innovation Actions - [www.dalia-danube.eu](http://www.dalia-danube.eu))**, which focuses on strengthening and supporting innovative actions in the Danube River Basin. The project has established nine demonstration sites across six European countries. One of them is **“Rebirth of Springs in Slovakia - Rehydration of the Upper Váh River Basin”** in Kysuce, which aims to restore springs and dried-up streams through ecosystem-based rainwater retention. It is a strategic priority of the European Commission to gain knowledge about the effects of nature-based measures on restoring lost water resources in the headwaters of the Danube River Basin and to apply these findings in a broader context.



Figure 1 : Demonstration sites of the DALIA project

## 2. Analysis of the current state

In the Kysuce River Basin, the average annual precipitation has shown an increasing trend. Over the past 40 years, it has risen by approximately 3-4%. However, dry periods are becoming longer and are increasingly alternating with episodes of intense rainfall, particularly during the summer months (May to September). This pattern is reflected in the alternation between extreme precipitation and deficit anomalies. In the past, short but extremely intense rains were relatively rare, but they are now occurring more frequently, leading to a rise in local flash floods.

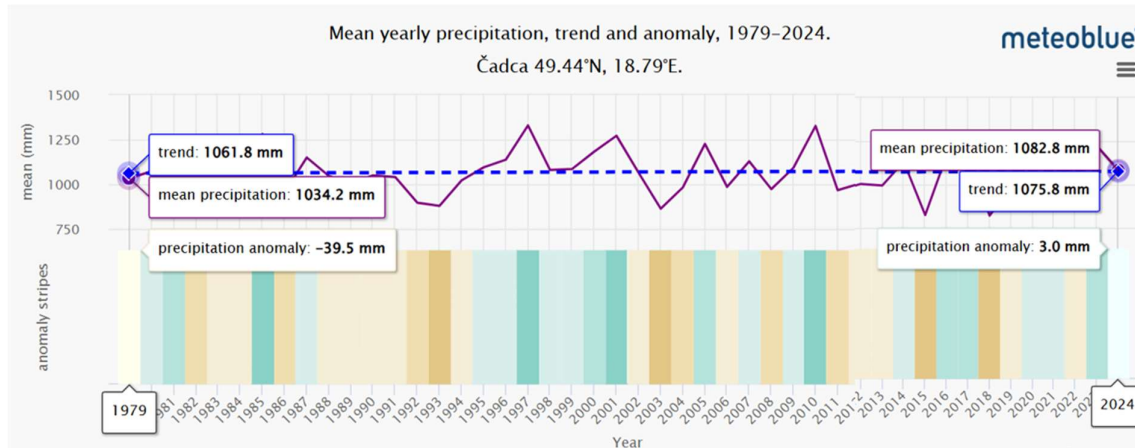


Figure 2 : Average annual precipitation totals, trends and anomalies 1979 - 2024 (source: METEOBLUE)

This trend is linked to longer periods of drought, as confirmed by precipitation anomaly time series dating back to 1980. Temperature anomalies also point to significant ecosystem changes. The most pronounced shifts in the temperature regime have occurred during winter. While the late 20th century saw cold winters with sufficient snowfall and consistent snow cover, the early 21st century has brought temperature anomalies several degrees above the long-term average. For instance, in February 1986, temperatures dropped 7.4°C below the average for the coldest month, whereas such conditions are now almost unimaginable. In February 2024, the temperature was 7.9°C above the long-term average. These changes have serious consequences for water resource formation in the basin, leading to reduced water availability and negatively affecting the local winter sports economy in Kysuce.

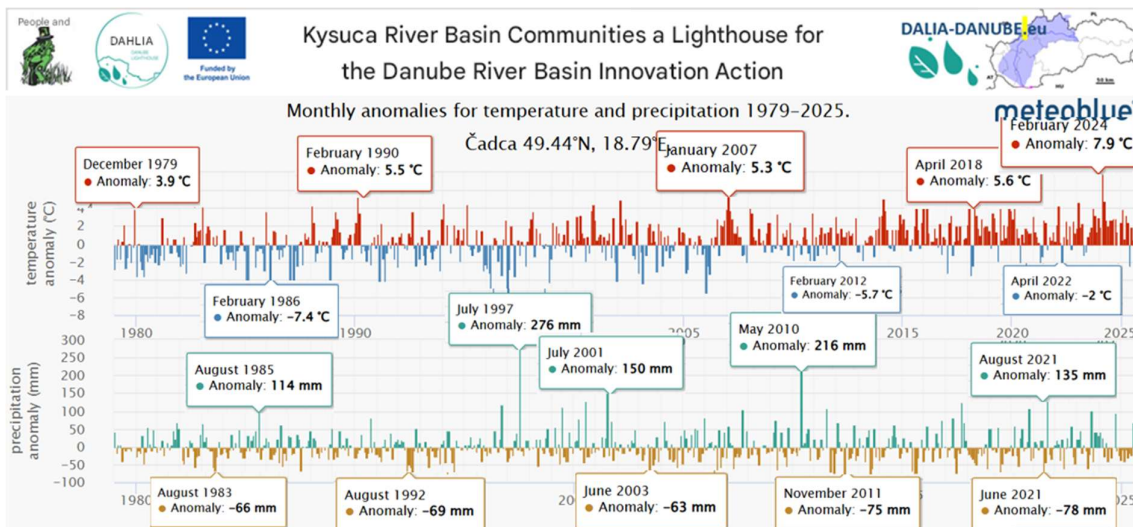


Figure 3 : Monthly temperature and precipitation anomalies 1979-2025 (source: METEOBLUE)<sup>1</sup>

The above-mentioned anomalies in precipitation distribution have a serious impact on increasing risks for the forestry and agricultural sectors. The growing extremes in rainfall intensity are damaging the landscape, leading to greater surface water erosion in both forested and agricultural areas. Heavy rainfall increases the kinetic energy of surface runoff, causing quicker peak flows in the basin's water infrastructure and greater fluctuations in the flow of the Kysuca River. This reduces the infiltration of rainwater into the soil and subsoil, leading to declining groundwater reserves. As a result, groundwater levels are gradually dropping, and springs and small streams are drying up.

The rise in rainfall intensity in the mountainous areas of the Kysuca River is further influenced by temporal and spatial shifts in rainfall distribution across the wider basin. Industrialization of agricultural and urbanized areas has neglected rainwater retention, preventing it from infiltrating into the ground. The depletion of soil and groundwater reserves is also worsened by increased rainfall intensity, which accelerates surface runoff and reduces the time available for infiltration in degraded, sealed, or poorly managed ecosystems.

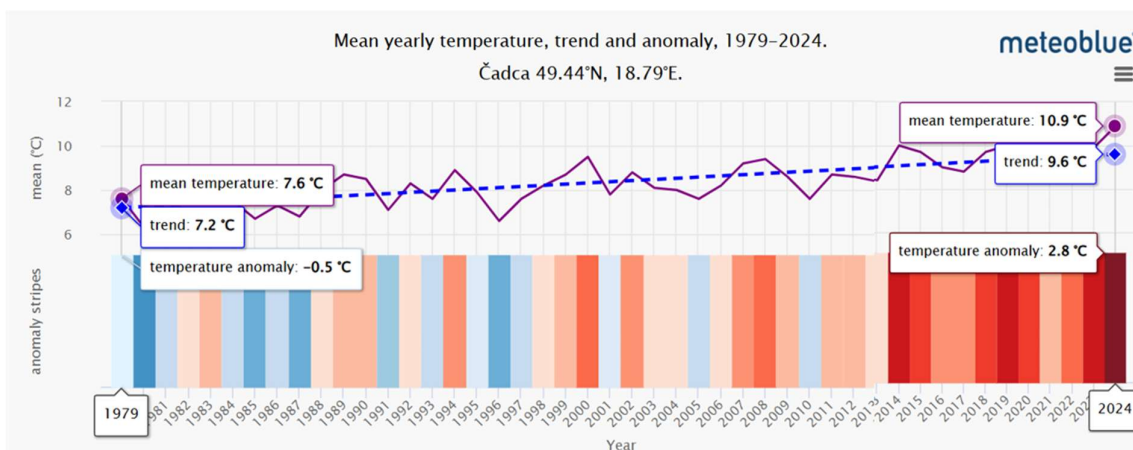


Figure 4 : Average annual temperatures, trends and anomalies 1979 - 2024 (source: METEOBLUE)

The rising temperatures in the Kysuca River Basin are also contributing to drought. Less frequent rainfall leads to faster drying of ecosystems, reduced actual evaporation from

<sup>1</sup> [www.meteoblue.com/sk/pocasioe/týždeň/Čadca\\_slovensko\\_3060835](http://www.meteoblue.com/sk/pocasioe/týždeň/Čadca_slovensko_3060835)

the land, and increased potential evaporation. This imbalance - higher potential but lower actual evaporation - creates a greater water deficit and causes the land surface to “overheat,” which further reduces the soil’s ability to absorb rainwater.

These changes in the water cycle have created a new reality: rapid runoff after rainfall and longer dry periods. Even healthy forests are now suffering from water shortages, causing shallow-rooted trees to die. Water scarcity weakens forest vegetation, making it more vulnerable to pests. As temperatures rise and water becomes scarcer, photosynthesis in forest ecosystems slows down, leading to reduced wood growth. This poses serious risks for forest management and weakens the forestry economy.

Alterations in the hydrological cycle, combined with rising temperatures, are also degrading vegetation cover, reducing the ability of forests to retain water and replenish groundwater reserves. The Kysuca River Basin is dominated by spruce forests, which have significantly declined over the past 20 years due to these hydrological changes. This situation has been worsened by a lack of clarity and mismanagement in applying environmental protection criteria for forests in Slovakia.



Figure 5 : Examples of dying forests in Kysuce (Čadca, Oščadnica)

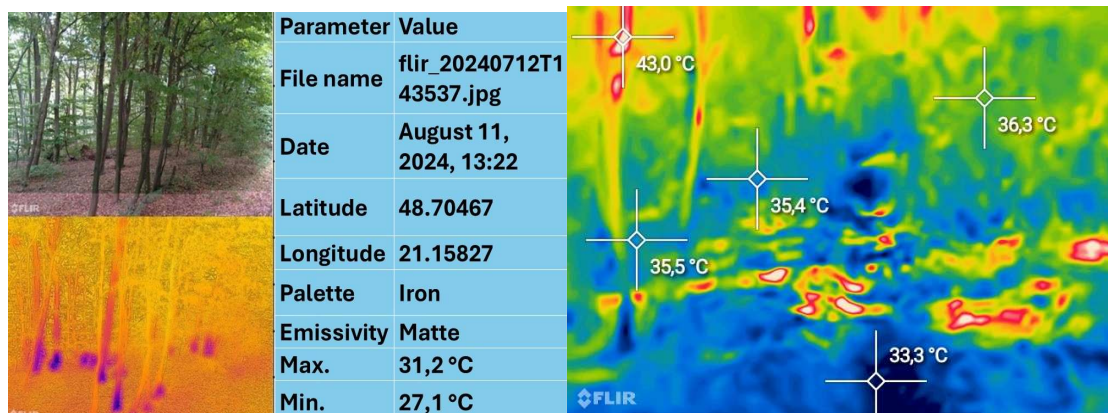


Figure 6 : Thermal imaging confirms that trees are lacking water. During times of drought, water transport through tree trunks is reduced to protect the tree’s survival

A major factor contributing to increased rainwater runoff from the landscape is the way agricultural land has been managed, particularly following the radical changes of the second half of the 20th century. The industrialization of agriculture - through the removal of terraces, meadows, and wetlands - transformed a once fragmented landscape into vast fields spanning several dozen hectares. In the uneven terrain of Kysuce, this type of landscape is highly susceptible to surface and water erosion. This, in turn, contributes to landscape drying and nutrient loss, making the soil dependent on industrial fertilizers to maintain its fertility.



Figure 7 : Agricultural landscape structure in the 1960s in the Stará Bystrica area and agricultural soil erosion after the removal of terraces/boundaries



Figure 8 : Plowing method on agricultural land, surface water erosion on agricultural land and field roads with measures to stop erosion in Stará Bystrica

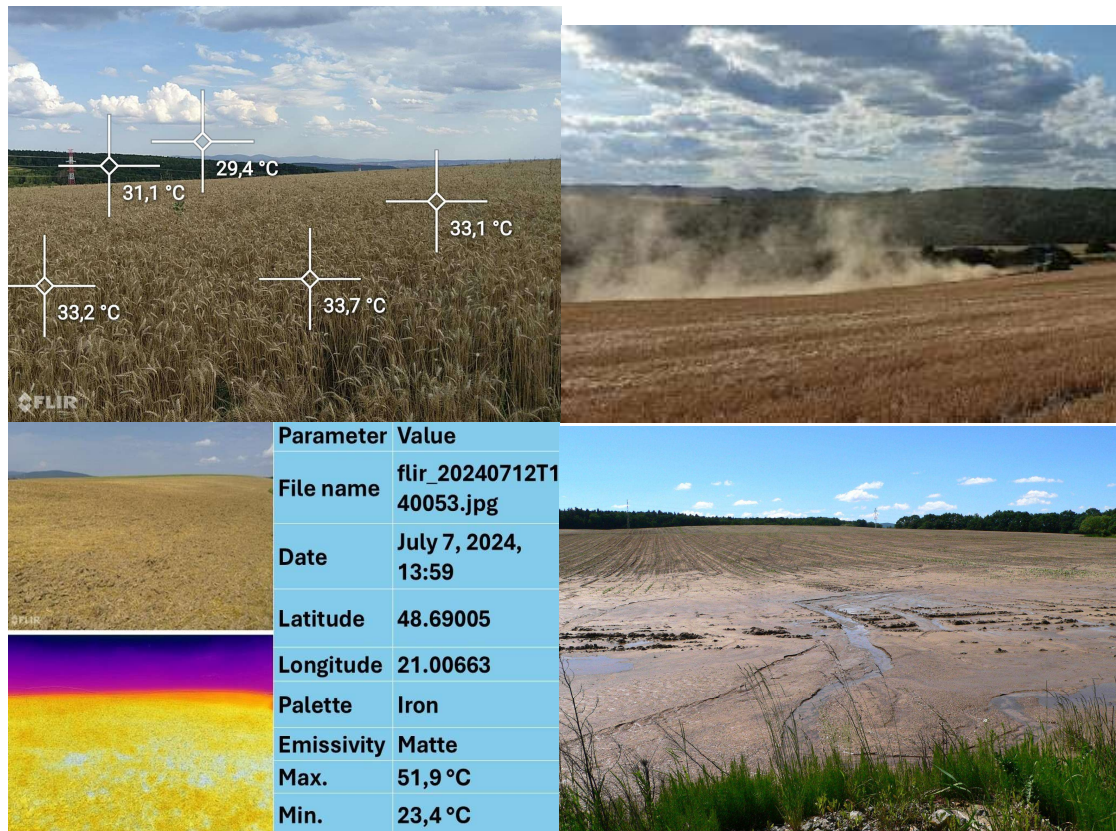


Figure 9 : Thermal imaging can map the temperature of the earth's surface. The surface temperature of both stubble and arable land exceeds 60 °C in the summer. The orientation of agriculture towards large-scale monoculture arable land massively contributes to the overheating of the country. The daily production of sensible heat to the troposphere exceeds 100 MWh. Such fields are susceptible to water erosion, nutrient loss and subsequent overheating.

The drainage of rainwater from roofed, paved, and asphalted surfaces also contributes to the drying of the landscape. Urbanization, along with the development of drainage systems and infrastructure, is often seen as essential for improving quality of life. However, the risk posed by reduced groundwater recharge, caused by the permanent diversion of rainwater that once infiltrated the soil and replenished groundwater reserves, remains largely underestimated.



Figure 10 : Stormwater management in transport infrastructure promotes land drying and the subsequent occurrence of local floods.



Figure 11 : In an urban environment, parking lots and roads are about 20 degrees warmer than the surrounding landscape, provided that rainwater is collected from paved areas in the surrounding landscape. The image on the right shows a location in Košice where water retention measures were implemented in 2005, in which all rainwater remains in green zones.

For decades, parking lots have been drained into city sewer systems, placing an unnecessary burden on them, even though this water could serve as a valuable resource for watering green spaces. Rainwater from paved areas can be collected in parks to keep vegetation healthy while helping to cool the city. The example of Košice demonstrates this: rainwater that is normally diverted through the sewer system can instead be retained within cities, helping to regulate the urban climate.



Figure 12 : The temperature of public green space is almost as high as the temperature of the road. The temperature is lower only in the depression, where rainwater is collected, seeps into the soil and evaporates. It is also illogical to channel rainwater and plant new plantings with bambi bags. This increases the costs of channeling rainwater, planting and also the operation of maintaining the green space.

For the past ten years, parking lots have been drained into city sewer systems, burdening them with rainwater. Both the city and property owners pay for this drainage, even though the water could serve as a valuable resource for irrigating green spaces.

It has also become common to cover playgrounds and sports fields with artificial turf. However, these surfaces heat up excessively, contributing to the overheating of urban areas and making them uncomfortable to use during summer heatwaves. A particularly poor example is the installation of artificial turf between tram tracks, where surface temperatures can exceed 50°C.

Parameter	Value		Parameter	Value
File name	flir_20240711T153823.jpg		File name	flir_20240711T145610.jpg
Date	June 19, 2024, 15:38		Date	June 8, 2024, 14:55
Latitude	48.58860		Latitude	48.71625
Longitude	19.36967		Longitude	21.23473
Palette	Iron		Palette	Iron
Emissivity	Matte		Emissivity	Matte
Max.	44,1 °C		Max.	51,5 °C
Min.	15,0 °C		Min.	16,2 °C

Figure 13 : Artificial turf contributes significantly to the increase in surface temperature in the places where it is installed

Similarly, investments in roadside drainage ditches are counterproductive, as they dry out the soil and subsoil, leading to a decline in groundwater levels. Green areas planted in parking lots also suffer from a lack of water. If these areas were irrigated with collected rainwater, they could help humidify and cool the urban environment through evaporation. Instead, rainwater is directed into sewers, overloading wastewater treatment plants or mixing with wastewater before flowing into Kysuca River tributaries, which further degrades water quality in local streams.



Figure 14 : Rainwater management needs to be reassessed and rainwater harvesting for public green spaces needs to be technologically developed



Figure 15 : Large parking lots in cities become hot spots in summer, where the surface temperature exceeds 60 degrees Celsius. More than 6,000 m<sup>3</sup> of rainwater is drained from each hectare of parking lot in Kysucie . This water is missing from the roots of the planted greenery, which is why they do not thrive and thrive. The green operation in parking lots built in this way cannot permanently water these trees. Therefore, these trees die, or grow poorly and their crown is small and does not shade the parking lots that are exposed to sunlight.

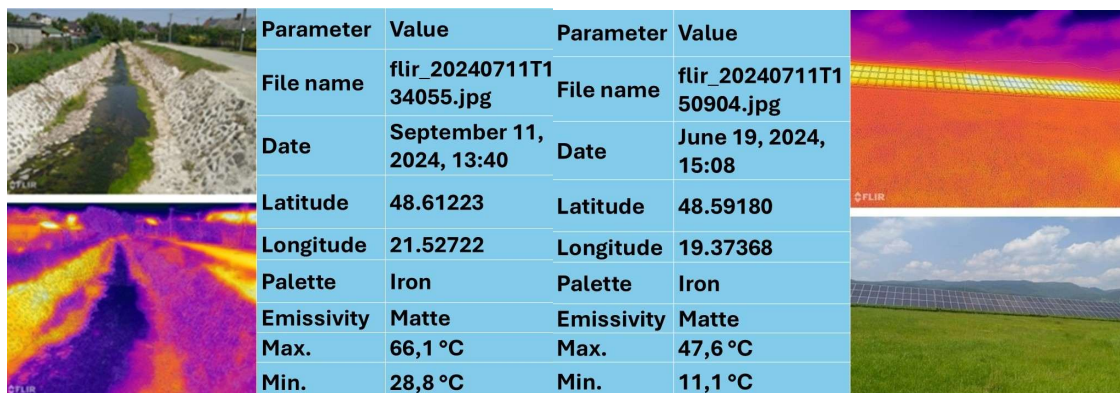


Figure 16 : Regulation of water flows in urban areas of cities and municipalities not only exacerbates very low water levels in streams, but also increases the temperature regime in the regulated channel, which causes the flowing water in the channel to overheat. Solar collectors are also significant contributors to environmental warming. Their temperature exceeds the ambient temperature by more than 30 degrees

### 3. DALIA - REBORN OF THE SPRINGS OF SLOVAKIA - REHYDRATION OF THE UPPER VÁH RIVER BASIN IN KYSUCIE

The Kysuca River Basin is part of the Váh River Basin, which joins the Danube at river kilometer 1,765.8. Changes in the Kysuca’s headwater areas are reflected downstream in the Kysuca, Váh, and Danube Rivers. When these source areas dry up, for example because intense rainfall quickly runs off damaged ecosystems instead of soaking into the soil, there is little opportunity for groundwater replenishment or for water to later emerge as springs. This process significantly contributes to the drying of the Kysuca, Váh, and Danube Rivers. Rapid runoff from headwater areas also increases flood risks further downstream.

For these reasons, research was launched to study the effects of ecosystem-based rainwater retention through nature-friendly measures. The goal is to understand how such measures influence water resource formation, improve spring yields, and prevent small streams from drying up. The expectation is that these interventions will help stabilize flow patterns across streams and their wider hydrological network.

One of these innovative actions is being carried out in the Kysuca River Basin, where the effects of ecosystem-based rainwater retention are being monitored in nine micro-basins. The impact of these water retention measures on the hydrological regime of small watercourses is being tested, and the results will be summarized, evaluated, and shared with stakeholders.

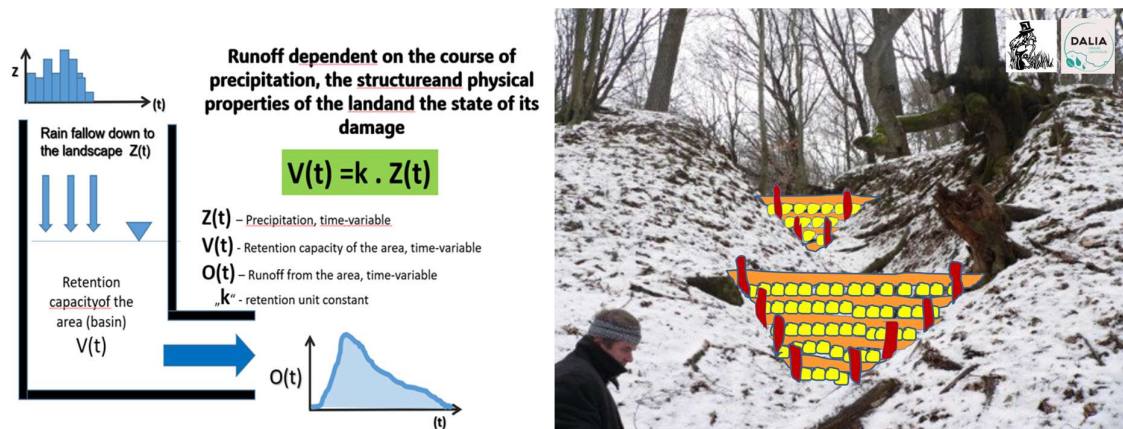


Figure 17 : Principle of a unit diagram for slowing down rainwater runoff through water retention measures in damaged landscape

In the Kysuce Basin, nine micro-basins were selected as part of the pilot demonstration site. Water retention measures, such as small dams, indentations with infiltration pits, and contour infiltration strips, were implemented in five of them, while four micro-basins without interventions serve as a control group.

Through the implemented nature-based solutions (NBS), hydrological processes are being continuously monitored to test how ecosystem-based rainwater retention can help prevent both floods and droughts. The goal of monitoring the impact of NBS on

hydrological changes is to quantify how these measures support rainwater infiltration into the soil and subsoil, thereby slowing surface runoff. In addition, such solutions enhance ecosystem services.



*Figure 18 : Some types of water retention measures at the Kysucký Lieskovec pilot site*



*Figure 19 : Monitoring object for monitoring flow and precipitation and water retention objects filled with collected rainwater during intense precipitation*

This knowledge will be reflected in recommendations for the water management plan and flood risk plan for the Kysuca River Basin, with an emphasis on the possibilities of replicating these solutions downstream, at least in the Váh River Basin and other areas of the Danube River Basin.



Figure 20 : Cascade of water retention measures on periodically drying up small watercourses

The connection between this project and the rest of the Danube Basin lies in the fact that processes occurring in the monitored headwater areas influence the hydrological dynamics of downstream watercourses. When any part of the headwaters in the Danube Basin becomes degraded and rainwater rapidly runs off during rainfall, it affects both water levels and flow patterns in the Danube's tributaries and the river itself. The same principle applies to periods of low flow. This effect is cumulative, the further downstream one goes, the stronger the overall impact, whether positive or negative.



Figure 21 : Water flow measurement stations with online data transmission

Leaving the damaged landscape in its current condition will only prolong and intensify droughts and flow irregularities. If springs and small watercourses in the headwater areas of the Danube Basin dry up, hydrological anomalies will increase along the Danube itself. The insights gained from this project will therefore be highly valuable for shaping agroforestry policies and spatial planning across all countries and communities within the Kysuca River Basin. These communities can act as innovators, contributing meaningful solutions to their own challenges while serving as examples of solidarity and inspiration for others across the Danube Basin.

For each monitored area, surface runoff from an extreme rainfall event of 60 mm was calculated using the CN curve method. This rainfall intensity was carefully chosen, as such events occur roughly once a year in the Kysuca River Basin. From a water management perspective, designing measures to handle this level of rainfall allows ecosystems to cyclically capture and infiltrate up to 60 mm of rainwater, converting surface runoff into subsurface flow. It is estimated that implementing water retention measures designed for this level of rainfall could enable ecosystems to retain more than 90% of the rainwater that currently runs off from degraded land each year.

Based on this analysis, the required volume of water retention measures was proposed for each monitored site. The project also studies how these measures influence the water regime of streams and the formation of springs. To better understand their effects on the hydrological balance of the landscape, measures of different scales were proposed according to the calculated runoff volume, as follows:



Figure 22 : Map of monitored micro-catchment locations

- Micro-basin 2 – Suchá:** NBS volume equals 70% of the total runoff volume.
- Micro-basin 3 – Agro Družstvo:** NBS volume equals 30% of the total runoff volume.
- Micro-basin 4 – Kováčové:** NBS volume equals 100% of the total runoff volume.
- Micro-basin 6 – Svrčinovec:** NBS volume equals 100% of the total runoff volume.
- Micro-basin 8 – Makov Prameň:** NBS volume equals 80% of the total runoff volume.

Flow rates, precipitation, and temperatures are continuously monitored across all nine sites, along with the condition of the implemented measures. The landscape structure of the basin has been analyzed, and ongoing changes are being tracked for future evaluation. The goal is to identify a correlation between the volume of retained water and the flow regime at the gauging profiles.

Preliminary results clearly show that water retention measures slow the rate of water level rise at monitoring stations and extend the duration of elevated flows during dry periods. The specific output from the Svrčinovec monitoring site illustrates this: the red and green ellipses mark precipitation and flow events recorded by the rain gauge station and the level sensor in the measuring device.

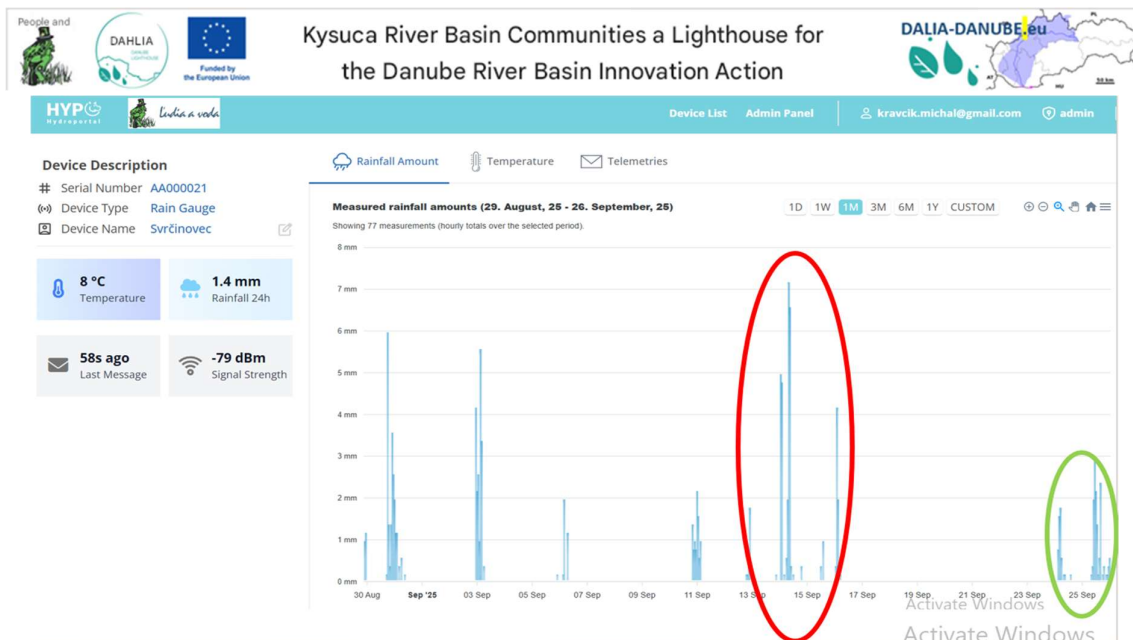


Figure 23 : Precipitation total 29. August 25- 26. September 25

The precipitation in the graph is in millimeters and the movement of the levels is monitored by a sensor that continuously records the rise or fall of the levels. In the diagram, a drop in the line means a rise in the water level in the basin . The hydrometer profile is calibrated dBm and from the movement of the levels we can define the flow rate over time .



Figure 24 : Water level 8. September 25 - 26. September 25

All the collected data will be evaluated in the next phase to analyze the impact of nature-based solutions on the hydrology of the catchment area. The goal is to transform this knowledge into recommendations for restoring degraded landscapes and to determine what volume of water retention measures is most effective in preventing floods and droughts. The ambition is to design NBS volumes that retain as much rainwater as possible within the basin's ecosystems during intense rainfall, restore ecosystem services, and remain economically efficient.

The initial findings are promising and confirm real effects, though they are not yet conclusive. Nonetheless, it is already possible to confidently present a draft action plan that incorporates the preliminary results. This plan can later be refined once the research is complete to ensure effective protection of water resources and flood control, in line with the expectations of all stakeholders and relevant authorities.

Based on observations of extreme torrential rainfall, the plan proposes implementing water retention measures capable of handling runoff from a one-hour rainfall of up to 60 mm. If realized, such measures could capture more than 90% of the rainwater that currently runs off from catchment areas without benefit. This applies to various land types: forests, meadows, arable land, gardens, built-up zones, and transport infrastructure within municipal boundaries.

This recommendation is supported by the example of the water retention system in Košice, implemented in 2005. Over the past 20 years, this previously desiccated ecosystem has fully regenerated thanks to rainwater retention. It is important to consider that multiple rainfall events can occur before the system has fully drained, which may temporarily increase flood risk through wave transformation. However, as mentioned earlier, the prevailing trend is longer dry periods alternating with intense rainfall.

Current evidence shows that revitalized landscapes host healthier, denser vegetation with deeper root systems, making ecosystems more resilient to climate risks. Such areas are less prone to both floods and droughts, and they warm and cool more gradually. Restoring dried-out ecosystems to lush, thriving ones is achievable. Following the implementation of rainwater retention measures, even relatively modest rainfall quickly replenished the system. For instance, shortly after installation, 47 mm of rainfall was enough to fill the retention structures. In May 2010, total rainfall reached 153 mm, yet the systems did not overflow, showing their ability to effectively regulate water.





Figure 25 : Example of water retention measures in an urban environment in Košice. Area 3 ha, costs €8 thousand. Restoration of a damaged ecosystem by collecting rainwater. In addition to the restoration of vegetation and a significant drop in temperature, species that are in decline are appearing. Even holm oak has appeared on the site.

We expect that, alongside local government initiatives, there will be genuine partnership and cooperation among public institutions, such as local authorities, agencies responsible for forest, nature, and water protection, agricultural landscape management, and civic initiatives, so that all stakeholders can contribute to improving water resources throughout the Kysuca River Basin for a sustainable future.

To achieve this, it was first essential to understand the true state of the landscape, the extent of its degradation, and how these conditions affect runoff in specific areas. Knowing how much rainwater currently runs off unused is key to determining how this untapped resource can be harnessed to restore water supplies, strengthen ecosystem services, guide necessary investments, and assess the benefits for all stakeholders.

Therefore, the foundation of effective water planning, water resource protection, and flood and drought prevention lies in a three-step approach:

1. **Capture rainwater** where it falls.
2. **Retain, accumulate, or infiltrate** it into the soil.
3. **Drain only the remaining portion** that the basin or territory cannot absorb.

This approach defines the core priorities for comprehensive solutions: retaining rainwater in the landscape, slowing its runoff, enabling infiltration, and revitalizing and restoring degraded land across entire cadastral areas. We propose preventive measures that complement existing technical flood protection structures to better safeguard people, health, property, both public and private, as well as cultural and environmental values from the damage caused by flash floods and destructive flooding.

A key step toward effective flood prevention will be the restoration of the ecosystem functions of cadastral territories. By using their natural properties to retain rainwater, enable infiltration into the subsoil, and improve soil quality, these areas can be spatially optimized to balance human use with ecological stability and biodiversity support.



## 4. Ecosystem retention of rainwater in the landscape

The goal is to retain rainwater that currently flows away unused from the Kysuca River Basin, covering an area of 917 km<sup>2</sup> and including all cadastral areas of the Čadca and Kysucké Nové Mesto districts, in an ecosystem-based manner across forested and urbanized landscapes. This water, which now runs off rapidly and increases flood risks, should instead contribute to regenerating natural resources and stabilizing the climate. Under current conditions, rainwater runoff from cadastral areas is artificially accelerated.

The objective is to keep rainwater within the cadastral territory so it can perform its natural ecosystem functions. This will significantly improve the water balance, help stop landscape drying, and gradually enhance the soil's retention capacity. In turn, this will further reduce the risk of destructive floods and other climate-related hazards.

Specifically, the aim is to create and construct, across forest, agricultural, and urbanized landscapes within the cadastral territories of the Kysuca River Basin, a network of water retention landscape features, formations, systems, and technical installations. Together, these will have a total cyclic retention capacity sufficient to absorb all rainfall up to 60 mm. These retention systems and devices must then be operated responsibly, kept functional, and regularly maintained. This will be a continuous, cyclic process.

The planned cyclic water retention capacity is based on analyses of precipitation-runoff ratios within the catchment areas, ensuring the measures are both economically efficient and designed for rainfall events expected to occur once per year.

### 4.1 Revitalization and restoration of damaged landscapes

The revitalization of the entire Kysuca River Basin cadastral area is a comprehensive goal within the region's strategic plan for sustainable economic growth, including the pursuit of food self-sufficiency under ongoing climate change. The plan focuses on implementing ecosystem-based measures that retain rainwater currently lost from the landscape, initiating ecosystem restoration to rebuild natural resources and strengthen the local economy, while also protecting communities from floods and other climate-related risks.

Revitalizing the landscape through appropriate interventions, structural adjustments, and a new approach to managing forest-agricultural areas will minimize the formation of flood surges in the Kysuca River Basin's headwaters and help reduce heat island effects over intensively farmed and urbanized areas. By retaining rainwater across a broad area and slowing surface runoff, conditions will improve for infiltration into the soil. This will enable rainwater within ecosystems to fulfill its essential functions, which are crucial for the long-term economic growth, environmental stability, and climate security of the Kysuce region.

To achieve slower rainwater runoff, the plan supports the introduction, development, and continuous improvement of rainwater retention techniques in:

- Forested landscapes
- Agricultural landscapes
- Urban areas

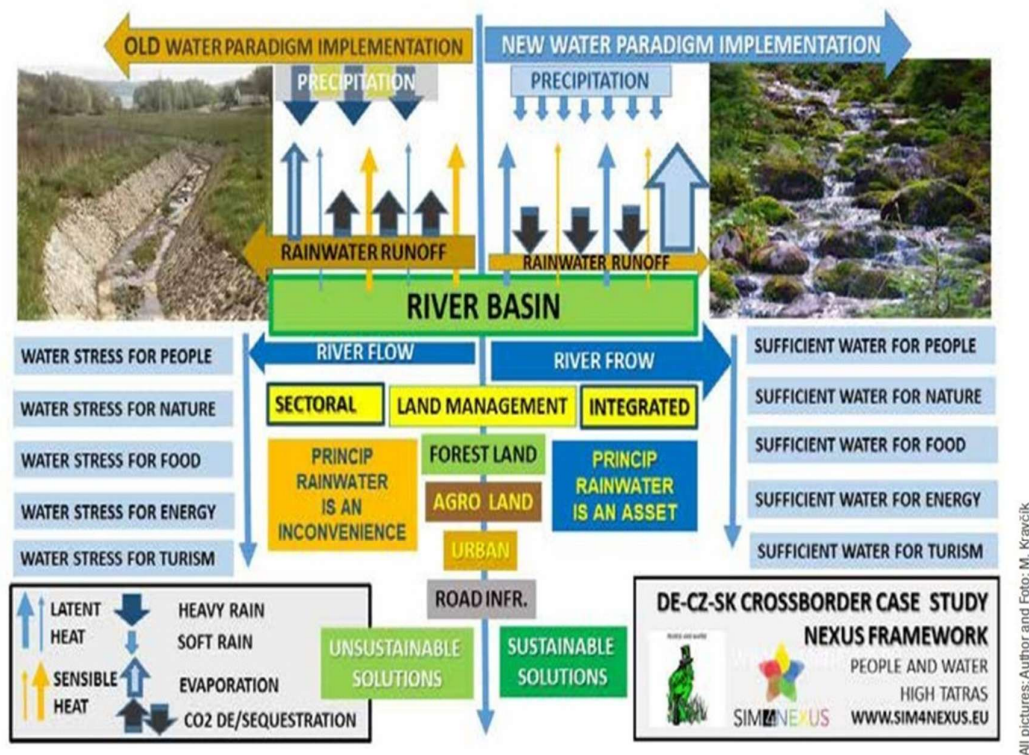
These measures will also help align rainwater retention efforts with the broader revitalization of watercourses. Implementing the plan through a combination of methods from ecological restoration of cadastral areas and infiltration technologies to small-scale

technical interventions will ensure that sufficient rainwater is retained for meaningful and lasting landscape revitalization. At the same time, it will strengthen flood and drought protection and reduce the risks of other sudden natural disasters.

## 4.2 Changing the approach to community development

The philosophy of the plan centers on transforming how rainwater and the landscape are perceived, recognizing their mutual interaction and complex interdependence. The plan serves as a tool to understand the multiplier effect of rainwater within the landscape and to harness its potential as a strategic resource for both economic growth and environmental sustainability. From this philosophical standpoint, the goal of the plan is to reduce the runoff of rainwater that currently causes harm during periods of heavy or torrential rainfall, leading to floods and inundation, instead of serving as a beneficial resource that supports economic growth within the cadastral area. Implementing the plan will promote optimal spatial water management across the landscape, particularly in agricultural, forested, and urban areas, in line with spatial planning principles. It supports the restoration, revitalization, and creation of renewable natural resources such as water, soil, vegetation, and forests, and aligns with the sustainability objectives outlined in [Agenda 21](#)<sup>2</sup>.

Rainwater retention is a driving force of climate-resilient landscapes



Example of regeneration of damaged soil by rainwater retention in the urban environment of Košice. Project implemented by the approval of the Košice Water Protocol in 2005

Figure 26 : Promoting rainwater retention in the landscape comprehensively addresses the principle (NEXUS) that rain is wealth, which is multiplied by the abundance of water for all stakeholders.

<sup>2</sup> [Agenda 21](#)

This represents a methodological approach to developing a concept for ecosystem-based water restoration in degraded landscapes, aimed at regenerating environments that are more resilient to weather extremes. To understand these relationships, the plan employs a **landscape regeneration model** that enhances ecosystem services through the adoption of a new **water paradigm**<sup>3</sup> - one capable of addressing the comprehensive water needs of people, nature, food production, energy, tourism, and the urgent challenge of climate recovery. This model was developed by the **SIM4NEXUS scientific research consortium**<sup>4</sup>, as illustrated in the below diagram.

### 4.3 Calculation of the volume of rainwater runoff from extreme precipitation

The following steps were taken to analyze rainwater runoff from the target area to determine how it can be economically utilized for regenerating degraded landscapes and enhancing resilience to climate change:

1. For the cadastral landscape structure (Table 1), we defined vegetation, soil, and geological characteristics. Since the area is extensive, average values were used for the entire basin.
2. Based on the climatic characteristics of the Kysuca River Basin, we identified the intensity of extreme torrential rainfall. The analysis showed that simulating runoff for a 60 mm rainfall event, occurring roughly once a year, is most appropriate.
3. To calculate runoff from precipitation, we applied the CN curve methodology<sup>5</sup>, which reliably estimates rainwater runoff for small catchment areas.
4. We developed proposals for rainwater use within each cadastral area as an analytical foundation for forestry, land management, and municipal spatial planning to prevent local flooding, drought, and mitigate climate change. These include:
  - Protection and restoration of water resources
  - Improved soil fertility in agricultural areas through increased carbon storage in biomass and soil
  - Biodiversity conservation
  - Reducing temperature fluctuations across the landscape
  - Estimating investment needs and their return through carbon credit financing for ecosystem-based water retention measures
  - Adoption of a binding municipal regulation to integrate these measures into local spatial planning and establish a framework for cooperative partnerships

Based on these criteria, we calculated the volume of rainwater runoff for various land-use types in each cadastre. For each, the total area, land-use category, and calculated runoff volume during a 60 mm extreme rainfall event were defined. At this rainfall intensity, approximately **5.8 million m<sup>3</sup>** of water flows out of the entire area (see Table 1). Implementing water retention measures across the basin to capture this volume would generate numerous positive outcomes through enhanced ecosystem services, offering not only protection against floods and droughts but also new water sources, increased

<sup>3</sup> [www.vodnaparadigma.sk](http://www.vodnaparadigma.sk)

<sup>4</sup> [www.sim4nexus.eu](http://www.sim4nexus.eu)

<sup>5</sup> CHOW, VT: Handbook of Applied Hydrology, New York: Mc. Graw-Hill Book Company 1964

biomass production, lower local temperatures, stabilized crop yields, and potentially even the return of Kysuce's traditionally snowy winters.

<b>Kysuca River Basin</b>	<b>Arable Land</b>	<b>Garden</b>	<b>Permanent Grassland</b>	<b>Forest</b>	<b>Urban Areas</b>	<b>Other Areas</b>	<b>Total</b>
Čadca	11 918	15 847	62 368	118 551	189 497	65 311	463 491
Čierne	5 994	5 962	25 980	40 658	65 421	9 109	153 123
Dlhá Nad Kysucov	361	1 380	9 016	32 185	17 600	46 876	107 419
Dunajov	905	1 808	3 350	15 281	15 385	20 125	56 853
Klokočov	7 021	4 878	32 709	169 812	48 472	12 571	275 463
Klubina	1 889	753	8 970	52 573	9 035	12 287	85 507
Korňa	4 423	3 889	26 563	66 322	29 125	17 114	147 458
Krásno N. Kysucou	6 638	6 119	35 139	54 463	81 890	15 076	199 325
Makov	1 030	3 013	37 630	147 981	54 132	8 254	252 060
Nová Bystrica	1 273	6 902	86 370	404 324	74 272	71 881	645 022
Olešná	6 759	2 370	17 462	52 800	20 310	12 776	112 476
Oščadnica	8 598	8 797	60 645	156 034	96 474	22 966	353 512
Podvysoká	1 523	1 526	7 317	10 148	13 954	6 971	41 439
Radôstka	2 374	2 344	10 862	38 453	14 190	6 909	75 132
Raková	13 723	6 971	44 099	99 353	73 841	12 458	250 445
Skalité	7 122	10 640	56 515	51 637	55 168	3 310	184 392
Stará Bystrica	7 432	4 382	27 741	110 235	44 027	14 039	207 857
Staškov	3 796	1 268	15 232	42 762	31 029	22 557	116 644
Svrčinovec	4 058	4 706	19 594	28 943	54 359	17 021	128 682
Turzovka	7 097	8 948	34 827	86 541	71 853	23 050	232 316
Vysoká nad Kysucov	10 498	7 454	34 627	128 484	57 424	10 989	249 477
Zákopčie	5 180	7 101	41 310	63 987	32 559	21 278	171 416
Zborov nad Bystricou	1 782	2 339	15 308	57 567	20 468	5 702	103 166
Dolný Vadičov	856	589	7 193	14 379	12 359	1 107	36 483
Horný Vadičov	6 147	2 872	30 504	40 221	34 711	2 727	117 181
Kysucké N.Mesto	8 461	6 552	16 132	65 142	121 577	19 977	237 841
Kysucký Lieskovec	3 163	7 685	11 621	29 070	27 384	10 124	89 047
Lodno	3 532	3 837	6 566	24 783	9 706	1 066	49 488
Lopušné Považie	362	1 491	2 957	11 810	5 621	10 576	32 818
Nesluša	4 516	6 151	27 222	66 974	32 500	8 244	145 607
Ochodnica	5 029	4 731	15 185	50 850	21 239	4 661	101 695
Povina	1 101	2 913	8 616	64 541	14 722	30 407	122 301
Radofa	1 335	1 806	8 430	13 441	18 065	5 945	49 022
Rudina	1 250	2 099	5 900	14 605	9 451	12 296	45 601
Rudínka	1 805	1 572	2 937	5 826	10 872	2 453	25 466
Rudinská	2 329	2 801	751	33 590	11 341	1 688	52 499
Snežnica	250	1 869	8 588	10 841	11 942	2 519	36 009
<b>Povodie rieky Kysuca</b>	<b>161 530</b>	<b>166 365</b>	<b>866 236</b>	<b>2 475 167</b>	<b>1 511 975</b>	<b>572 420</b>	<b>5 753 733</b>

Table 1 : Volume of rainwater runoff in cubic meters from individual landscape types in the cadastres of municipalities in the Kysuca River basin during intense rainfall with a yield of 60 mm and a short duration



## 5 Design of water retention measures and their reflection in spatial planning documentation

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Given the characteristics of the area and the occurrence of local flooding, it is necessary to establish water retention measures across forested, agricultural, urbanized, and transport landscapes, as summarized in the runoff volume table.

The results of this analysis should be integrated into land-use planning, forest management plans (FMPs), municipal spatial plans, and transport infrastructure strategies. These should include the development of a comprehensive plan for implementing green and blue infrastructure capable of cyclically retaining all rainwater from events of up to 60 mm. This goal can be achieved by enhancing the water retention capacity of degraded ecosystems, thereby contributing directly to flood and drought prevention within cadastral areas, increasing landscape greenness, and improving resilience to climate change.

It is the responsibility of land-use planners, forestry experts, and municipal spatial planners to incorporate this knowledge into official spatial planning documentation. While the choice of specific solutions may vary based on local examples and conditions, the decisive factor will be how public policies are designed and adopted at the municipal level.

The most effective approach is to formally approve this document as binding for all stakeholders, forest and agricultural land managers, property owners, and local authorities. The annex includes detailed proposals for the necessary water retention volumes in each local government cadastre, offering tailored recommendations for forests, agricultural land of various types, and urbanized areas.

### 5.1 Benefits of water retention measures

Flood prevention measures can be implemented within the cadastral area of each municipality for the benefit of all. Unfortunately, over the past decade, most concepts have focused primarily on the fastest possible drainage of rainwater from micro-catchments and runoff areas. From a long-term perspective, these technical approaches have proven largely ineffective and, in many cases, counterproductive. Under conditions of high rainfall intensity and heavy downpours, they actually worsen flood situations.

Current flood protection measures often fail to account for the natural dynamics and processes occurring within cadastral areas, particularly in agricultural and urbanized landscapes, as well as in the development of transport and industrial infrastructure and built-up zones. Over the past ten years, such developments have accelerated rainwater runoff from cadastral territories, increasingly straining the capacity of existing technical flood protection systems in municipalities. At the same time, they contribute to landscape drying, soil damage, and degradation. It is important to recognize that although built-up areas in the basin cover less than **5% of the total territory, during an intense 60 mm rainfall event, they account for more than 25% of total runoff.**

		Kysuca River Basin Communities a Lighthouse for the Danube River Basin Innovation Action						
Kysuca River Basin	Arable Land	Garden	Permanent Grassland	Forest	Urban Areas	Other Areas	Total	
Area [ha]	4078.9	1168.8	24942	55100.8	4225.9	2231	91747.4	
Created Water Retention Volume [m <sup>3</sup> ]	161527	166365	866235	2475167	1511975	572419	5753690	
Estimated Retained Rainwater Volume [m <sup>3</sup> /year]	371512	232912	1299353	3217717	13607777	4006936	22736207	
Estimated Costs [€]	1938326	1996385	10394826	29702005	60479010	17172581	121683132	
Acquired Water Source [l/s]	3.927	2.462	13.734	34.011	143.833	42.353	240.32	
Increased Evaporation Due to Retained Rainwater [m <sup>3</sup> ]	247675	155274	866235	2145145	9071851	2671290	15157471	
Enhanced Dew Formation [m <sup>3</sup> ]	2039439	584399	12471003	27550377	1112954	1115515	45873687	
Increased Water Balance in Ecosystems [m <sup>3</sup> ]	2287114	739673	13337238	29695522	11184805	3786805	61031158	
Estimated Increased Biomass Production [t]	4574.23	1479.35	26674.48	59391.04	22369.61	7573.61	122062.32	
Reduction of Sensible Heat [GWh]	1600.98	517.771	3066.207	20786.866	7829.364	2620.764	42421.811	
Reduction of Actual Summer Temperature [°C]	-0.99	-1.12	-0.94	-0.95	-4.67	-2.29	-1.17	
Carbon Sequestration [t]	6404	2071	34347	83147	31317	10603	167888	
Carbon Credit [€ at price 77.53 €/t]	496496	160571	2895301	6446423	2428042	822055	13248888	
Payback Period of Investment on Carbon Credit [years]	4	12	4	5	25	21	9	

Table 2 : Estimated quantification of benefits after implementation of the plan

In addition to creating new water sources, enriching the soil, increasing forest biomass yield, and lowering the landscape's temperature regime, this knowledge also brings significant benefits for biodiversity restoration. For instance, alongside the increase in plant diversity at project sites, species have been discovered that had not previously been recorded there. One such plant, the white-flowered **Rezavka Aloes (Stratiotes aloides)**, was found in an artificially created rainwater retention ecosystem. This critically endangered species typically grows in the floodplains of lowland rivers with stagnant water, yet it was unexpectedly discovered in the rugged terrain of northern Košice.

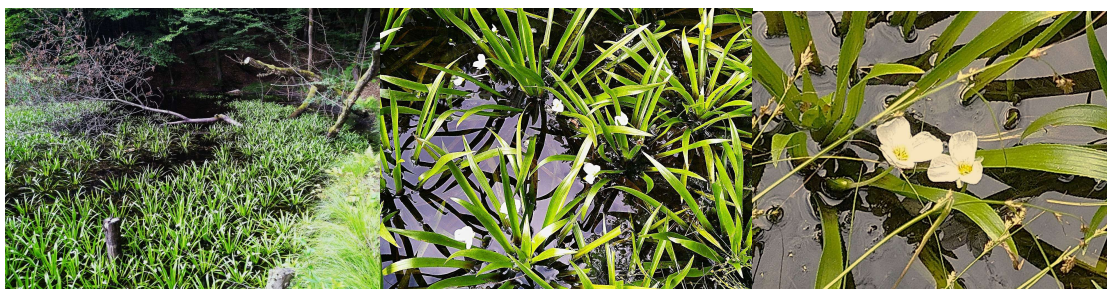


Figure 27 : Red-bellied toad Aloes ( *Stratiotes aloides* )

In one of the water retention sites created in the rugged forest terrain above the village of Ťahanovce, a unique plant species appeared about two years ago and bloomed for the first time this summer. The estimated social value of a single plant is €200, and there are believed to be over 500 individuals in the area. A detailed systematic survey would likely uncover additional important findings, further demonstrating that biodiversity restoration in ecosystems can be achieved by increasing rainwater retention.

The solution is not to expand or build new large-scale rapid rainwater drainage systems. Given the current landscape dynamics and changing hydrological conditions, such systems, based on the *old water paradigm*, quickly lose effectiveness. The real solution lies in comprehensive, integrated management of contiguous landscape areas.

The plan is designed to be implemented at various levels. It can be carried out by any landowner or manager of forest-agricultural areas or parts of urban environments. It can also be initiated by public officials seeking to strengthen or activate ecosystem services, whether by improving flood and drought prevention, creating water resources, restoring soil fertility, protecting forests, restoring biodiversity, or improving the local climate. It also supports decision-making in forestry, agriculture, water management, regional development, nature conservation, biodiversity, and climate policy, all aimed at sustainable development in the Kysuce region.

The proposed plan offers a high return on investment. Implementing it through carbon credit financing would require an estimated €120 million. However, its benefits extend far beyond financial returns. In addition to reducing damage from natural disasters, it would stabilize the hydrological regime and create new water resources with an output of 240 liters per second, equivalent to over 7 million cubic meters of water annually.

The plan also contributes to forest ecosystem rehabilitation. Its implementation would increase annual biomass production in ecosystems by approximately 120,000 tons, resulting in an additional 40,000 cubic meters of wood each year. This would strengthen the economic viability of forest communities while ensuring sufficient food and water for wildlife. Moreover, the plan is expected to deliver significant climate benefits, estimates suggest that average summer temperatures could drop by more than 1°C.

The return on investment alone may not seem remarkable, even though carbon credit-based investments are expected to pay back within 10 years. However, when additional benefits are considered, such as the creation of new local water resources and increased yields in both forestry and agriculture, the estimated annual benefits exceed €5 million. This would reduce the payback period to around seven years.

For this reason, we recommend coordinating the work as a joint strategic investment plan among stakeholders, with strong public interest. At a minimum, the public benefit lies in climate protection. This program helps lower local temperatures and ensures integrated water, food, environmental, climate, and social security for the region, thereby promoting long-term well-being and sustainable prosperity.

**Annex 1** presents the projected impacts of revitalization by cadastral area and by land-use type, showing effects on water resources, biomass growth, temperature regulation, and carbon sequestration. We recommend implementing the Plan in stages and in close cooperation with local governments, foresters, farmers, water managers, fishermen, and conservationists.

The accompanying tables also quantify the annual CO<sub>2</sub> capture resulting from increased photosynthesis through landscape revitalization. Municipalities can take the initiative to invite emission allowance holders to invest their credits locally, giving communities in the Kysuca River Basin a clear competitive advantage.



## 6 Proposed measures

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This chapter presents the types of solutions recommended for implementation in forested landscapes. In line with the principles of sustainable development, integrated water resource management, and climate protection, it is essential to quantify the reduction of surface rainwater runoff and increase landscape retention capacity; key elements of effective flood protection.

Captured rainwater in forest areas can be stored in suitable locations to replenish soil and groundwater reserves, support vegetation through evaporation, improve the microclimate, and simultaneously reduce surface runoff as part of a systemic approach to flood prevention.

Rainwater harvesting measures aim to promote infiltration into the soil, thereby enhancing soil moisture and groundwater reserves. Higher groundwater levels improve spring yields, while soil water supports vegetation transpiration and helps regulate the local microclimate.

After 1989, new innovative, ecosystem-based water management solutions began to emerge. However, from a historical perspective, these methods are not entirely new, they have been used for centuries, with varying levels of application over time.

The objective is to collect rainwater in small, concentrated terrain micro-reservoirs, supplied by runoff from surrounding drainage areas, strategically placed in suitable locations with adequate capacity and appropriate slope.

### 6.1 Measures on forest land

In the Kysuca River Basin, forest ecosystems dominate, covering up to 60% of the area. They account for around 43% of total floodwater formation. During a 60 mm rainfall event, nearly 2.5 million m<sup>3</sup> of water runs off from forested areas. If this rainwater were retained within the forest instead of flowing out, it would provide substantial benefits enhancing forest health, supporting better forest management, and offering greater flood protection for nearby municipalities.

Stormwater management in forests has long been underestimated. There is an urgent need to strengthen the water retention capacity of forests, particularly in economically managed areas, and to find a balance between economic forestry use and the broader public benefits of nature protection, environmental stability, and climate resilience. This requires a shift in how stormwater is managed in forest transport infrastructure to prevent forest drying, increase spring yields, enhance fire protection, ensure adequate water for wildlife, and support the development of local tourism.

Therefore, it is crucial to develop targeted strategies for managing water in commercially exploited forests. Several successful projects in Slovakia already serve as good examples of best practice, such as the **Renovation of the Tatra Forests after the Windstorm**, the **Hričovská Waterway**, and the **Blue Alternative** and other revitalization initiatives. These can provide valuable inspiration for achieving integrated restoration of degraded ecosystems.

The first regenerative forest restoration projects in Slovakia began after the Tatra windstorm of November 2004. One of the pioneering initiatives demonstrating how to retain rainwater and restore ecosystems was launched in Horný Smokovec in 2005. The following photos illustrate the process of forest recovery after the windstorm: the first

step was to ensure that all rainwater remained within the damaged forest area, followed by replanting a new, more diverse forest with a mixed composition of tree species.



Figure 28 : Slovenská sporiteľňa Water Forest Project, restoration of the Tatra forests after the windstorm in November 2004 through water retention measures and diversified planting

### Interlaced wooden dams in ravines

Given the nature of the area and the need to rehabilitate erosion gullies, ravines, and depressions, it is essential to revitalize these damaged sections. In the upper parts of the terrain, we recommend using locally available materials to implement the measures. The most suitable solution for these areas consists of **interlaced dams** made from branches and small timber, which are abundant in ravines and nearby forests. Waste wood from pruning can also be effectively used.

The main advantage of this approach is that the dams quickly fill with sediment, preserving the embedded wood for several decades. These structures then act as **artificial floodplains**, retaining rainwater during each rainfall event, raising groundwater levels, and helping to restore dried-up springs. By creating a cascade of interlaced dams, erosion gullies and ravines become stabilized. The raised bottoms of these ravines also help prevent landslides and further deepening of erosion channels.

Over time, sediments will accumulate behind the dams, gradually becoming saturated with rainwater. New vegetation will establish itself on these sediments, significantly contributing to the recovery of plant cover and allowing the vegetation itself to take over part of the flood protection function.



Figure 29 : Impact of interlaced dams on the water regime of periodically drying up small watercourses (Snežnica, Povina, Skalité, Oščadnica, Čadca).

### Wooden dams

In areas where interlaced dams are not suitable, we recommend building **wooden dams** of various types, adapted to local conditions and available materials. These are particularly appropriate for the upper sections of erosion gullies. The design and construction method should be determined based on site-specific factors. Such dams can be made from waste wood and arranged in cascades in damaged areas where the depth does not exceed two meters.



Figure 30 : On the stream, new wooden weirs in Hertnik ended stream narrowing in 2011. In 2018, the same weirs with alluvium moderated the water speed and stabilized the riverbed.



Figure 31 : The result of volunteer-built dams on the Tichy Potok (1996) in an erosion ravine, and after 20 years (2019), they are still functioning and small streams emerge from the originally dry erosion groove even in the driest season.



Figure 32 : Hričov Waterway Project (2008) in damaged forest ecosystems in the forests of Horný Hričov

### Log dams

**Log dams** can be built in dry ravines, positioned sequentially above stone dams. These structures can also be made from waste wood. For increased durability, it is recommended to peel the bark from the logs. Wherever possible, use locally sourced wood directly from the site where the dams are being built.



Figure 33 : Log stone-wood dams (Matysová, 2012)

### Stone dams

In areas with an abundance of local stone, we recommend building **stone dams** up to 1 meter high. Where higher dams are required, **quarry stones** with a diameter of 30-80 cm should be used. These measures are best implemented in the valley sections of ravines, with a maximum dam height of up to 2 meters. Smaller dams, up to 1.5 meters high, should be placed at the end of the valley, just before the confluence with the main stream of the micro-basin. When only smaller stones (5-30 cm in diameter) are available, the dam should be reinforced with **wooden beams**, interlacing the wood and stones to increase stability and durability.





Figure 34 : Stone dams (Snežnica, Krivany, Dunajov, Orlov)

### Trench ( gabion ) baskets

**Gabions** are suitable as the final dam structure on small streams. They are particularly effective in periodically drying ravines and minor watercourses. **Trench baskets** are also appropriate for small watercourses but should be installed only along straight sections of the stream, not on bends or immediately after a curve. The height of trench baskets should not exceed 1 meter.



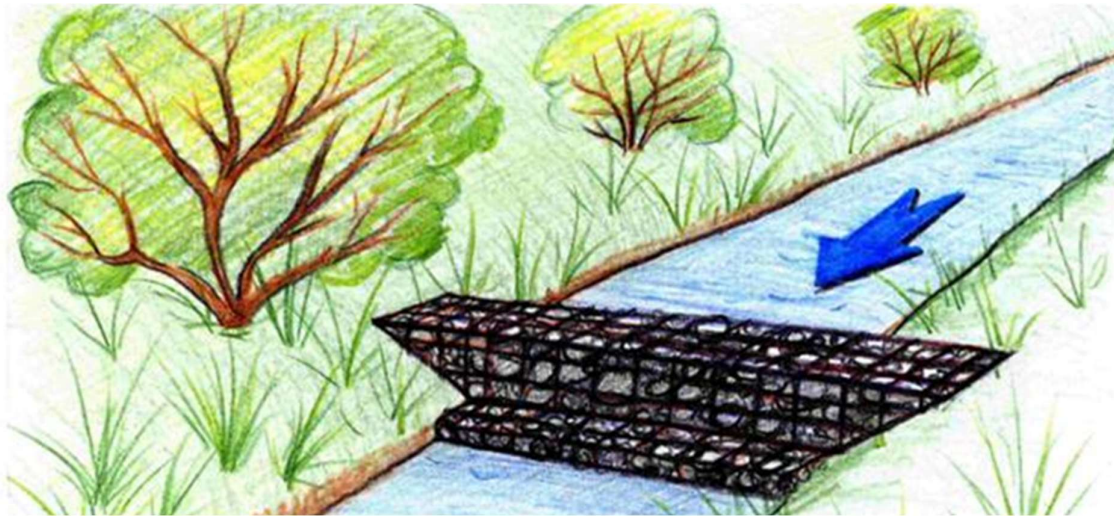


Figure 35 : The impact of gabions on the sedimentation of water retention areas (Košice, Čermel'ské údolie, Svrčinovec, Nižný Slavkov)

### How the NBS measures work in practice



Figure 36 : Dams during the flood (Prenčov, Čadca, Zázrivá, Oščadnica, Lipovce)

## Bullets on unpaved roads with potholes

Road ditches should be standardized so that each one includes a **water retention pit**. The recommended types of ditches are listed below, but the key principle is that rainwater collected in the ditch must flow into **seepage pits**, where it can infiltrate into the surrounding vegetation. The exact shape of the seepage pit is not important only its volume. We recommend constructing seepage pits with a **capacity of 10 m<sup>3</sup>** for each ditch. In practice, this means installing ditches approximately every **40 meters** along forest roads or access routes. We also recommend revitalizing these access lines immediately after timber extraction.

The spacing of ditches does not depend on the road slope, since the total water volume running off compacted forest or field roads remains roughly the same regardless of gradient. The focus should therefore be on total **water volume retention**, not runoff speed.

We recommend constructing **gullies** using a combination of materials, but primarily wood, depending on financial feasibility. These gullies direct rainwater into seepage pits, where it collects and gradually infiltrates into the subsoil, helping to reduce soil erosion. Lining the area beneath gully outlets with stone further prevents erosion. The gullies should be built with a **slight slope** in the direction of water flow to make them largely **self-cleaning**. Regular **maintenance and cleaning** of the gully network are essential for ensuring long-term functionality.



Figure 37 : Experiment of the functionality of a bullet on a forest road and a bullet with sinkholes in real time with rain (Lodno, Kysucký Lieskovec)



Figure 38 : Bullet holes from Kysucký Lieskovec

## 6.2 Land management measures in agricultural landscapes

In agricultural landscapes, rainwater can be retained in suitable areas to replenish soil and groundwater reserves, support vegetation and crop transpiration, improve the microclimate, and simultaneously reduce surface runoff serving as part of broader, systemic flood prevention measures. Collected and slowed rainwater, when directed into appropriate terrain features such as micro-reservoirs, wetlands, or contour infiltration belts, can be used beneficially as a water source during dry periods.

Over the past 20 years, various techniques and technologies have been developed globally to manage rainwater in agricultural land, aiming to reduce flood and drought risks while preventing land overheating. In Slovakia, efforts to enhance land water retention capacity date back to the 16th century. For example, the Turček water supply system in the Upper Turiec region collected water from 11 valleys and redirected it along contour lines to the Kremnica mines. Similarly, Samuel Mikovíni designed an ingenious system in the Štiavnické hills near Banská Štiavnica, where he used dykes to capture rainwater and channel it into constructed reservoirs that supplied water to the local mines. These early systems primarily focused on building water retention structures in forests.

It is also important to highlight the Wallachian colonization, which significantly improved the water balance of the landscape during the Middle Ages. This system of contour-based agricultural land management became a unique element of Central European cultural heritage, demonstrating how sustainable water and land use practices can coexist.



*Figure 39 : Remains of boundaries in agricultural land that were not eliminated by the collectivization of agricultural land (Spiš)*

Rainwater harvesting measures aim to promote infiltration into the soil, thereby improving both soil moisture and groundwater reserves. Higher groundwater levels enhance spring yields, as demonstrated by the results of the DALIA project. Soil water also increases vegetation transpiration and helps regulate the local microclimate. In agricultural fields, it is advisable to design a combination of solutions, including infiltration pits, wetlands, ridges, contour infiltration strips, and small water reservoirs.

After 1989, new and innovative water management solutions based on ecosystem principles began to emerge. However, from a historical perspective, these concepts are not entirely new, such technologies have been used for centuries, with varying levels of application over time. The goal is to collect rainwater in small terrain micro-reservoirs, supplied by runoff from nearby drainage areas, located in sites with sufficient capacity and appropriate slope. These principles should be incorporated into local land-use regulations in every municipality. Ideally, this would be done through the adoption of a General Binding Regulation (VZN) - a draft of which is provided in Appendix 2.

## Microreservoirs and Wetlands

Micro-reservoirs are best suited for gently sloping or nearly flat areas with low runoff potential, such as along footpaths, in landscaped zones, parks, and near parking lots. They can also be installed in areas with higher water concentration if arranged in series, allowing overflow from one reservoir to another. However, micro-reservoirs are generally not suitable for alluvial plains, depressions, or locations exposed to heavy runoff during intense rainfall. Each site is unique, and the appropriate combination of rainwater harvesting methods must be selected based on local conditions. Over time, micro-reservoirs naturally evolve into wetlands and buffer zones, providing valuable habitats for wildlife and enhancing local biodiversity.

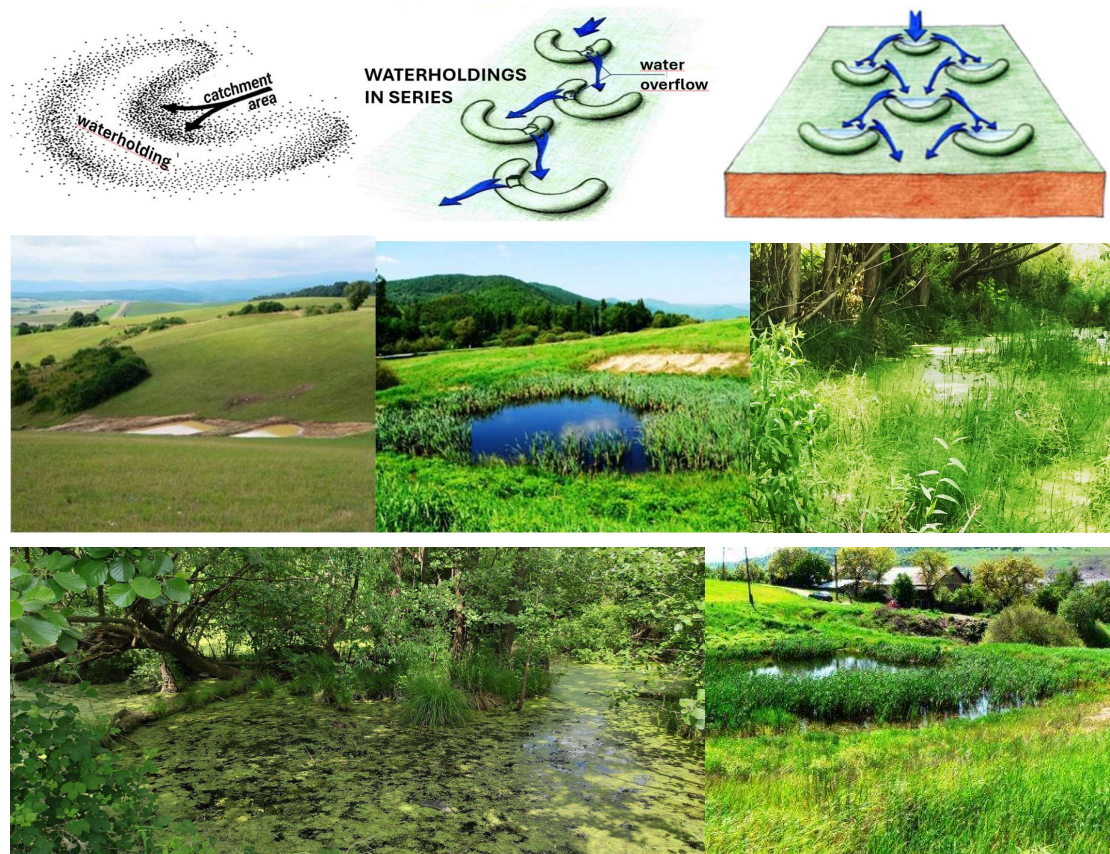


Figure 40 : Schemes of micro-reservoirs and wetlands in agricultural landscapes (Ožďany, Lubenik)

## Contour soaking belts

On permanent grasslands and arable land, we recommend establishing contour infiltration strips, ideally planted with fruit trees. These strips should be spaced approximately every 50 meters, with additional intermittent sections every 20 meters to ensure that the collected rainwater remains in place and does not run off.



Figure 41 : Infiltration strips in agricultural landscape (Maly Saris, Lažany, Torysa)

### Small water tanks

In cadastral areas, we recommend constructing small water reservoirs that can serve as core infrastructure for recreational water zones and potential fish farming. These reservoirs should maintain a stable water level with enough storage capacity to retain part of a flood wave. They will function as eco-stabilizing elements in the agricultural landscape, helping to increase groundwater reserves. The enhanced evaporation from these reservoirs will gradually improve the local microclimate. Over time, this will encourage dew formation, which plays an important role in maintaining soil moisture during dry periods. Additionally, these reservoirs act as a preventive measure against drought and help reduce the risk of wildfires. Small water reservoirs should be designed with discharge facilities to allow controlled water management.



Figure 42 : Small water reservoirs (Okrúhle, Rakovec, Ďurčina, Košice - Ťahanovce)

Small water reservoirs in agricultural landscapes are important because they also serve as watering points for livestock and can be integrated into pasture systems. They may also support poultry farming. The placement of all these measures directly in the field should be incorporated into land development plans, forest management plans, and municipal or city spatial plans, with motivational support from local governments to encourage participation from all interested stakeholders.

### 6.3 Measures in spatial planning documentation in rural landscapes

The construction of infrastructure such as roads, parking lots, houses, and buildings is typically based on the principle of diverting rainwater to the nearest watercourse. In urban areas, rainwater that once infiltrated the soil or evaporated before development now flows across impermeable surfaces through gutters, drains, and canals directly into rivers and streams.

In years without extreme rainfall, runoff from built-up areas can exceed 50%, even though such areas cover less than 5% of Slovakia's total surface. In the Horná Rajčianka Basin, urbanization (including built-up areas and transport infrastructure) occupies 5.6%, meaning the upper part of the Rajecká Valley has roughly the same level of urbanization as the national average.

These facts must be considered when assessing how land surface changes influence desertification, the loss of water resources, and consequently overheating and climate change. Surface runoff occurs on paved areas even after rainfall as low as 10 mm, while in rural areas, forests and agricultural land, it takes much heavier rain to generate runoff. This is why urban surfaces overheat the most and why groundwater levels there drop fastest, often leading to drying wells. These areas also become heat islands, as built-up environments lack the natural thermoregulatory capacity found in healthy ecosystems.

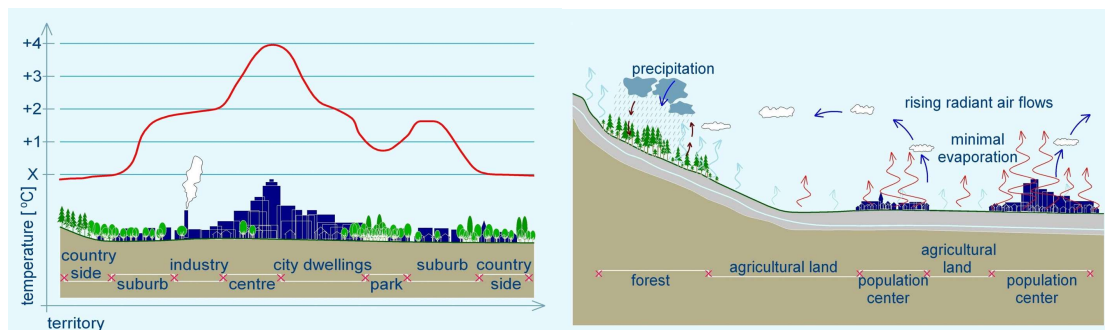


Figure 43 : Heat island over urbanized environments and subsequent decrease in precipitation and its shift to cooler environments (increase in precipitation)

This knowledge is crucial for spatial planning, as it enables better and more informed decisions about the development and revitalization of not only forested and agricultural areas but also urbanized landscapes. However, implementing measures in urban areas is both technologically and financially more demanding than in rural environments. It is worth noting that in the Kysuca River Basin, urbanized land accounts for only 4.6 percent of the area, yet it contributes up to 26% to the formation of flood waves, which is more than five times higher than the contribution of often degraded forests.



For this reason, it is important to understand the requirements of spatial planning legislation and to improve legislative standards so that spatial plans can be developed with greater consideration for climate change and climate recovery. Across Slovakia, spatial plans largely overlook the essential need to reform rainwater management, which is a serious oversight, as this omission contributes to drying rates of up to 60%.

Spatial planning must support settlement development based on the principles of sustainable development, ensuring that land and resources are used in a way that meets current needs without compromising those of future generations. During settlement development, it is essential to respect the protection and restoration of natural resources, agricultural land, and groundwater reserves, as these are key limiting factors for territorial growth.

According to Act No. 50/1976 and its 43rd amendment on spatial planning and building regulations, the spatial plan defines the spatial arrangement and functional use of land, sets out guiding principles, and proposes the coordination of activities that affect the environment, ecological stability, and the cultural and historical values of the territory. It also governs territorial development and landscape formation in line with the principles of sustainable development (§1, Article 11).

According to Article 2, §1, spatial planning creates conditions for the long-term alignment of human activities with environmental care, ecological balance, and sustainable development, ensuring the responsible use of natural resources and the preservation of natural, cultural, and civilizational values. Furthermore, Article 2, §1(g) specifies that spatial planning determines how natural resources and land are to be used so that human activities do not exceed the tolerable environmental load, thus maintaining ecological stability.

It follows that spatial plans must establish principles for using natural resources in ways that do not harm the environment, ecosystem functions, or ecological stability. In line with Section 6 of Act No. 17/1992 Coll. on the Environment, spatial plans should meet basic human needs while preserving the natural functions of ecosystems.

Therefore, spatial planning should ensure that all activities remain in lasting harmony with the environment and do not damage ecological systems or their stability. This interpretation implies that each spatial plan should include a binding section guaranteeing the sustainable protection of natural resources so that they are neither degraded nor altered. However, in practice, permanent damage to natural resources still occurs in many areas.

For this reason, a special chapter should be included in every spatial plan to assess the state of natural resources, evaluate the impact of human activities on them, and propose preventive measures. The changing state of the natural environment is already evident through the degradation of water resources, extreme weather events, spatial and temporal shifts in precipitation patterns, temperature extremes, loss of biodiversity, and declining soil fertility.

We therefore recommend promoting mechanisms and methodological approaches that support the regeneration of natural resources, the restoration of water quality, the prevention of droughts and floods, the renewal of soil fertility, and the reduction of extreme weather and temperature fluctuations. These methodologies were first developed by the scientific research consortium SIM4NEXUS, which designed tools for integrated natural resource management addressing the interconnections between water, soil, energy, food, and climate. This work was commissioned by the European Commission

under the EU HORIZON 2020 Programme, aimed at preventing land degradation and mitigating heat waves and droughts.

The European Green Deal communication also emphasizes that ecosystems play a key role in regulating the climate and encourages the use of nature-based solutions. A cross-border case study between Germany, the Czech Republic, and Slovakia, conducted under the SIM4NEXUS project, examined the effects of drying in agricultural, forestry, and urban areas on both the water regime and the thermal balance of the landscape. It also explored how changes in the water regime influence the distribution of solar energy across the terrain. The study produced recommendations for modifying landscape structures at local and regional levels to support climate recovery through carbon sequestration and the regeneration of natural resources.

Poor landscape management leads to overheating, water loss, and increased carbon emissions from degraded soils. In contrast, improved water retention and the promotion of permanent vegetation can restore the landscape, increase food production, and store carbon in regenerating soils.

There is scientific evidence supporting the influence of land use and landscape structure changes on the distribution of solar energy, the water cycle, temperature dynamics, local and regional weather patterns, and carbon sequestration (Pielke, 2005<sup>6</sup>; Pielke et al., 2011<sup>7</sup>). The relationship between vegetation cover and weather, particularly the role of forests in influencing rainfall, has been examined by Sheil (2018)<sup>8</sup>. His research highlights the importance of studying the biology of evaporation, aerosols, and air mass movement in the atmosphere, as well as the processes that determine precipitation and diurnal cycles.

This is consistent with the biotic pump theory, which explains how rainfall can be sustained locally when the landscape maintains sufficient forest cover and functional vegetation to support water cycles. There is also evidence showing that the loss of vegetation and forest cover, along with land drainage, can trigger a shift from a humid to a dry climate even at the local level<sup>9</sup>.

Despite these findings, there are still many unknowns and a lack of long-term monitoring and data in this field. To address this gap and improve understanding of the relationship between water, vegetation, and climate, it is necessary to pursue multiple research objectives and develop comprehensive, integrated scientific studies. Nonetheless, it is already essential to promote innovations in land use that can sustainably regenerate natural resources. Research over the past decade has deepened understanding of how vegetation influences temperature dynamics, evapotranspiration, and sensible heat flows across different types of land cover.

Such research shows that evapotranspiration is a powerful process that helps equalize temperature and air pressure differences, while the sensible heat generated on drained and overheated surfaces lifts moisture into the upper atmosphere and blocks the inflow

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<sup>6</sup> PIELKE Sr., RA (2005) 'Land use and climate change', *Science*, Vol. 5754, no. 310, pp. 1625-1626.

<sup>7</sup> PIELKE Sr., RA et al. (2011): Land use/land cover changes and climate: modeling analysis and observational evidence. *WIREs Clim Change* 2, p. 828–850.

<sup>8</sup> SHIEL, D 2018 Forests, atmospheric water and an uncertain future: the new biology of the global water cycle *Forest Ecosystems* volume 5, Article number: 19 (2018)

<sup>9</sup> KRAVČÍK M., Pokorný J., Kohutiar J., Kováč M., Tóth E., New Water Paradigm – Water for the Recovery of the Climate, 2007 ([http://www.waterparadigm.org/download/Water\\_for\\_the\\_Recovery\\_of\\_the\\_Climate\\_A\\_New\\_Water\\_Paradigm.pdf](http://www.waterparadigm.org/download/Water_for_the_Recovery_of_the_Climate_A_New_Water_Paradigm.pdf))

of moist oceanic air (Pokorný, 2019<sup>10</sup>). Satellite imagery has made it possible to accurately assess land cover and related temperature changes dating back to the 1980s<sup>11</sup>. This evidence underscores the need to retain more water in the landscape.

Restoring degraded landscapes through rainwater retention gives every municipality the opportunity to design territorial development that fully integrates land use principles into spatial planning. This ensures that economic activity and land use do not exceed the carrying capacity of the area and that they actively contribute to regenerating natural resources across all types of landscapes.

Rainwater retention in degraded ecosystems is one of the most effective ways to restore vegetation, increase carbon sequestration, improve soil and groundwater quality, revive springs, and purify the air. It also enables the conversion of solar energy into latent heat, which is released as water evaporates and is transported into the cooler upper layers of the atmosphere. At the dew point, this latent energy is transformed back into sensible heat, producing precipitation that returns to the ground and nourishes ecosystems<sup>12</sup>. This process stimulates vegetation growth, enhances carbon storage, and regulates land temperature. Moreover, cloud cover reduces the amount of solar radiation reaching the earth's surface, further contributing to climate stability<sup>13</sup>.

This functional model should not only be described in strategic documents and assessed through research but also put into practice through the spatial planning documentation of municipalities and towns. The Land Use Planning Act already allows for such changes in rainwater management within the existing legislative framework. It is essential to recognize that rainwater is a life-giving resource, not waste. It revitalizes ecosystems, enables photosynthesis and vegetation growth, regulates landscape temperature, and drives the biological and chemical processes that sustain life in the soil. It also influences cloud formation and rainfall production.

Rainwater is the common factor linking ecosystem restoration, CO<sub>2</sub> reduction, and landscape temperature regulation. Currently, most rainwater flows away from land without benefit, contributing to local flooding and eventually reaching rivers and oceans, where it raises sea levels instead of remaining within ecosystems. Implementing measures that allow rainwater to stay in the landscape and benefit plants is precisely what spatial planning frameworks should define through local regulations.

Enhancing the capacity of degraded land to retain rainwater increases soil and groundwater fertility, providing more water for photosynthesis. This leads to greater biomass production and its accumulation in moist soil, where carbon becomes stored in both vegetation and soil. During photosynthesis, plants release water vapor through transpiration, which transforms solar energy into latent heat that is carried into the cooler layers of the atmosphere. There, clouds form, reducing the amount of solar radiation that reaches the ground.

<sup>10</sup> POKORMÝ, J., (2019): Evapotranspiration. In: Fath, BD(editor in chief) Encyclopedia of Ecology, 2nd<sup>edition</sup>, vol.2, pp. 292–303. Oxford: Elsevier.

<sup>11</sup>( <https://landsat.gsfc.nasa.gov/> )

<sup>12</sup> MITSH WJ, HERNANDEZ MI (2013) Landscape and climate change threats to wetlands of North and Central America. *Aquat Sci* 75: 133–149

<sup>13</sup> MAKARIEVA AM, Gorshkov VG, Sheil D, Nobre AD, Bunyard P, Li BL, 2014.: Why Does Air Passage over Forest Yield More Rain? Examining the Coupling between Rainfall, Pressure, and Atmospheric Moisture Content\*. *Journal of Hydrometeorology*, 15(1): 411-426. DOI: 10.1175/JHM-D-12-0190.1

As a result, sensible heat production decreases, surface temperatures remain lower, and the air cools. Understanding this process allows us to identify how a new, currently missing layer can be integrated into spatial plans to address water and climate needs.

The most effective way to reflect this requirement in land use is through legislative standards at both national and local levels. At the local level, it is advisable to adopt generally binding regulations that define how land is used in both external landscapes (forestry and agricultural areas) and internal ones (urban environments). These local measures should be supported by national legislation.

We recommend that local governments adopt such legislative standards. A draft of a generally binding regulation aimed at improving the climate of cities, towns, districts, and municipalities is provided in Appendix 2.

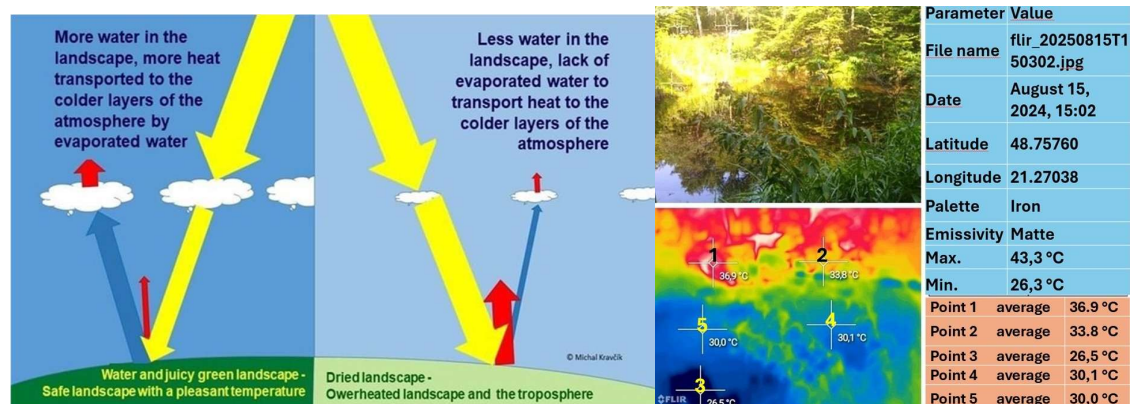


Figure 44 : Comparison of solar energy transformation in humid and dry landscapes. (A) More water in the landscape, more solar heat consumed for evaporation and conversion of solar energy to latent heat and less heat released to the troposphere, (B) Less water in the landscape, less solar energy consumed for water evaporation and more heat released to the troposphere.

#### 6.4 Measures in the urban area

A rainwater management system in urban areas can be implemented through structures that recycle water within the environment where it falls. These systems are based on natural processes that rely on vegetation and soil mechanisms.

For urban environments, several innovative solutions are proposed. While these approaches are not yet common in Slovakia, they are widely used internationally for managing rainwater within city infrastructure. We have selected several best practice examples, known globally as BMPs (Best Management Practices). Many of these systems can be adapted in different ways. For example, vegetated ditches have several variations that all operate on the same principle of collecting rainwater and allowing it to infiltrate or evaporate.

These examples provide inspiration for improving rainwater retention in cities and municipalities. The key principle is to retain rainwater from roofs and paved surfaces in suitable urban areas, allowing it to remain and evaporate through vegetation. This process helps clean the air, increases latent heat production, and transfers that heat to higher layers of the atmosphere, thereby helping to regulate urban temperatures.

## Reducing flood runoff by retaining rainwater in reservoirs and transportation infrastructure

Construction logistics, building methods, and measures to prevent erosion and subsequent sedimentation are essential for ensuring long-term functionality. An example from Austria shows how rainwater from roads can be collected in artificially created ecosystems, where it is allowed to accumulate, seep into the ground, and evaporate naturally.



*Figure 45 : Rainwater collection in tanks from transport infrastructure (example Austria)*

Studies conducted worldwide confirm that this system is also highly effective in reducing contaminants such as total suspended solids, metals, diesel residues, and oils. With proper design, implementation, and maintenance, supported by filtration systems, it is possible to significantly reduce runoff intensity, replenish groundwater, and improve its quality.

### Soaking pool

A seepage basin is a shallow reservoir designed to collect and infiltrate rainwater, typically located on flat, undisturbed ground with relatively permeable soils. These basins serve as temporary water retention areas for collecting and treating rainwater. Their size and shape can vary, ranging from one larger basin to several smaller ones distributed across a site. It is best to integrate seepage basins into the natural terrain and surroundings in a subtle, unobtrusive way.

If infiltration basins lack vegetation and require excavation, planting should be introduced. Vegetation improves water quality, enhances evaporation through transpiration, and supports infiltration. Suitable plantings can include anything from meadow mixtures to more substantial forest species. The planting plan should carefully consider the expected hydrological variability within the basin, the characteristics of native plant communities, the site's aesthetics, and other landscape goals. The use of lawn mowers is not recommended, as soil compaction caused by mowing and maintenance would reduce the basin's infiltration capacity.

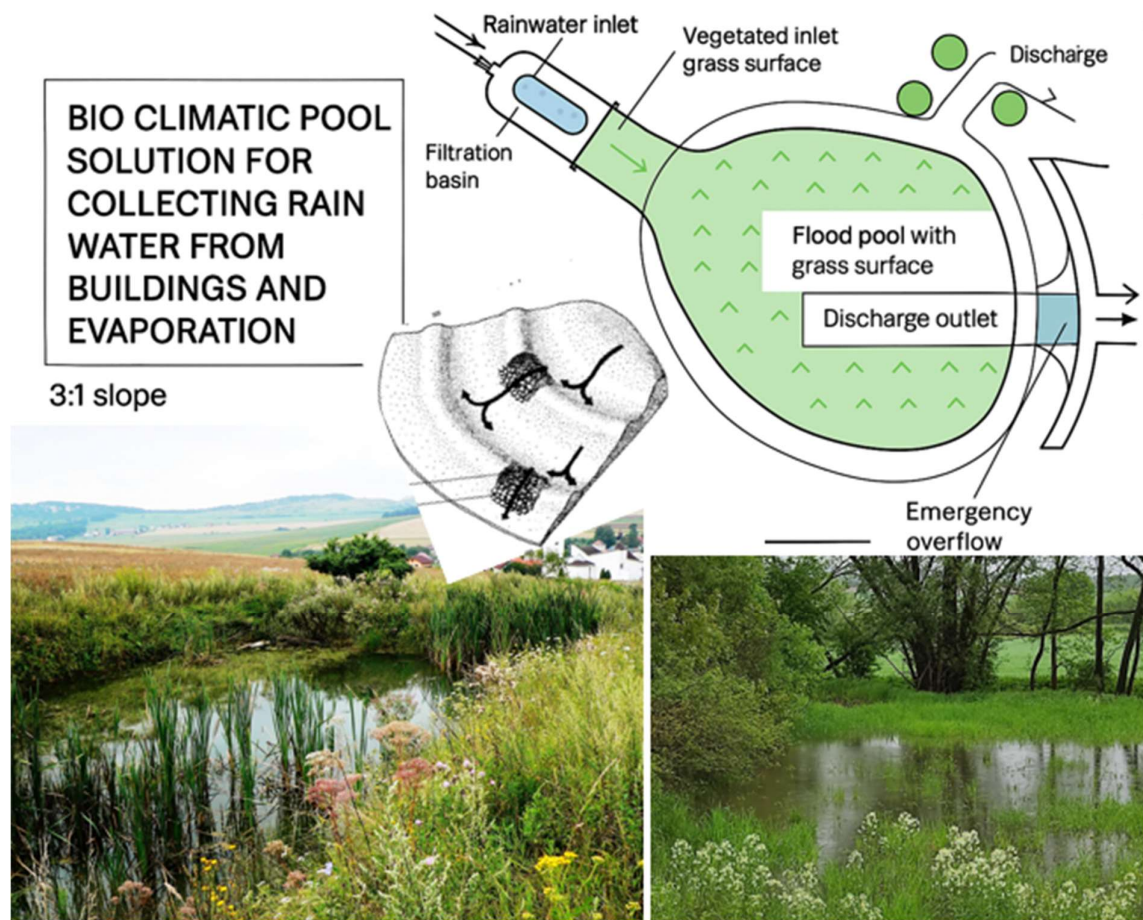


Figure 46 : Rainwater harvesting into depressions from urban environments and transport infrastructure

### Grassy hollows

Grass ditches are essentially standard drainage channels, ideally built on a very gentle slope. They are generally less expensive than ditches with taller or denser vegetation but offer much less capacity for infiltration and contaminant removal. For this reason, grass ditches should be used mainly as a pre-treatment step before other structural solutions. The design of grass ditches is often based on controlling flow velocity. Where appropriate, they are preferred over catch basins and pipes because they can effectively slow the flow of water across a property.

### Wetlands

Wetlands are essentially basic linear water retention units. Their design typically includes shallow, permanently wet areas or ponds that support marsh vegetation, which is highly effective at removing contaminants. A high water table or poorly drained soil is necessary for wetland construction. One drawback of wetlands, particularly in residential and commercial areas, is that they can create favorable conditions for mosquito breeding.

### Subsurface infiltration bed

A subsurface infiltration bed temporarily collects and discharges rainwater through a system of collection pipes installed in a seepage layer below the surface. Appropriately selected and distributed moisture-loving vegetation can enhance evaporation through

transpiration, with some plant species capable of transpiring up to 3,000 millimeters of water annually.



Figure 47 : Collected rainwater into green areas. Example Košice

A subsurface infiltration bed typically consists of a vegetated, highly permeable soil layer placed over a permeable gravel bed that temporarily stores collected rainwater. These systems are ideal for large, generally flat open spaces such as meadows, lawns, or playgrounds located downslope from nearby impervious surfaces. Subsurface infiltration beds can also be arranged in a stepped or terraced pattern along a slope, as long as the base of each bed remains level. Rainwater collected from nearby impervious areas such as roofs, parking lots, roads, or sidewalks can be directed into the infiltration bed, where it is distributed through a network of perforated pipes.

The infiltration layer is usually made from uniformly sized, clean-washed quarry stone, though other suitable materials can also be used. Properly designed, constructed, and maintained subsurface infiltration beds can serve as effective examples of how to manage runoff volume, flow rate, and water quality. In addition to replenishing groundwater aquifers, these systems can enhance the use of open spaces, creating multifunctional areas for recreation and relaxation. Their added value lies in their ability to remain functional and beneficial throughout the entire year.

### Dry Wells

A dry well, also known as a seepage pit, is an infiltration system designed for the temporary storage and infiltration of rainwater runoff from roofs and other paved surfaces. It serves as a subsurface storage unit that collects, holds, and gradually releases rainwater into the surrounding soil. When used to capture roof runoff, gutters are typically connected directly to the dry well, which may consist of an excavated pit filled with structured aggregate (3–5 cm fraction) wrapped in geotextile fabric. The stored water then infiltrates into the surrounding ground.

To maintain a safe water level, a dry well can be fitted with a safety overflow that connects to a larger infiltration area or another drainage feature, allowing excess water to flow away by gravity. By capturing runoff directly at its source, dry wells significantly reduce the volume of rainwater discharged from roofs and paved surfaces.

Reducing runoff volume also lowers flow velocity and improves water quality. However, as with all infiltration methods, dry wells are not suitable for areas with high pollutant loads or sediment accumulation. For safety and structural reasons, dry wells should be located at least 10 meters away from buildings.



Figure 48 : Collecting rainwater into a stone retention tank

### Rain gardens – bioclimatic gardens

A rain garden, also known as a bioretention area, is a shallow excavated surface depression planted with carefully selected native vegetation that captures and treats rainwater runoff. Rain gardens can be designed with a high degree of flexibility and can be easily integrated into various types of sites. They can also be effectively combined with other stormwater management systems such as porous asphalt parking areas or infiltration ditches.



Figure 49 : Bioclimatic gardens - collecting rainwater from buildings into greenery

Rain garden vegetation filters runoff to improve water quality and transpires moisture to regulate water quantity, while plant root systems enhance infiltration. The plants absorb pollutants, and the soil medium filters out impurities while allowing rainwater to be collected and infiltrated. The underlying bed provides additional storage capacity and volume control. Properly designed bioretention systems mimic the structure of a

natural forest ecosystem in terms of species diversity, density, and vegetation distribution. By using native species, these systems are more resistant to pests, diseases, pollutants, and climatic stress.

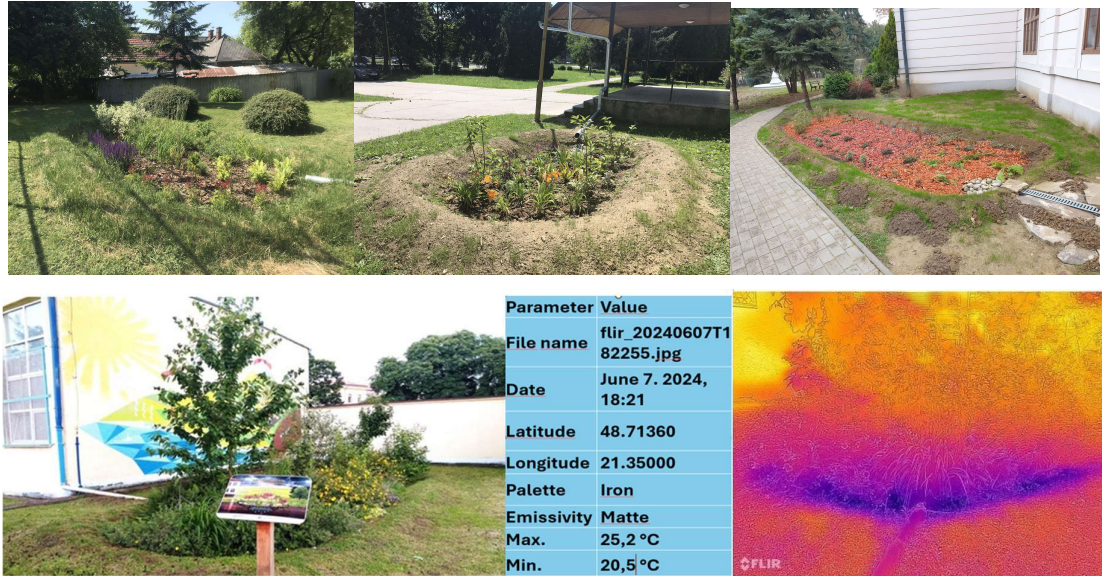


Figure 50 : Examples of rain gardens implemented in secondary schools in the Košice region

Rainwater from roads can also be used to irrigate existing vegetation around roads. This is a rainwater management method that captures runoff and provides a shallow dam in an excavated mulch area around a tree or shrub .

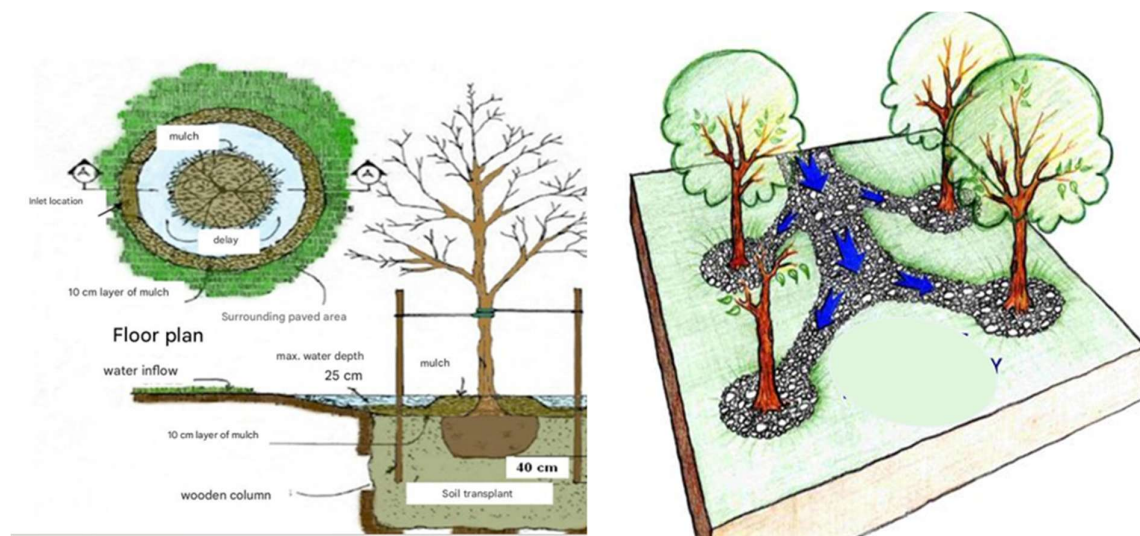


Figure 51 : Example of rainwater collection in the root zone of a tree

## Bioretention in curbsless parking lots

The rain garden is placed next to a curbsless parking lot, allowing rainwater to flow broadly and directly into the garden. Shallow steps help slow the inflow to a manageable speed, and this design can be combined with a shallow depression to control the total amount of incoming water.

It is important not to confuse bioretention areas with constructed wetlands or ponds, which permanently retain water. Bioretention systems are best suited for locations with at least moderate infiltration rates, greater than 0.3 centimeters per hour.

In cases where soil permeability is lower than 0.3 centimeters per hour, special adaptations can be used, such as integrating subsurface drainage systems or combining the bioretention area with a constructed wetland.

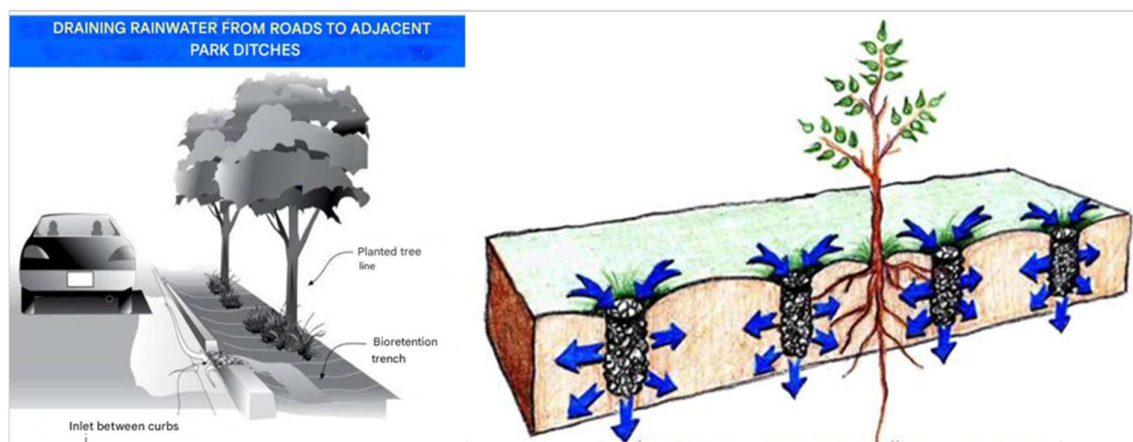


Figure 52 : Methods of collecting rainwater for infiltration into the root zones of public green spaces from paved areas

## Green roofs and walls

Rainwater harvesting, both globally and in our country, is not a new or revolutionary concept. Today, technologies in this field are so advanced that with a well-designed residential, commercial, or industrial building, it is possible to capture and use almost all rainwater that falls on the roof or surrounding land by combining several appropriate systems. A well-thought-out architectural design can benefit both the environment and people by saving money and enhancing the aesthetic value of buildings and their surroundings.

The issue of capturing rainwater from roofs is receiving increasing attention from both experts and the general public. The reason is simple and practical: growing pressure from water companies to channel rainwater and charge fees for its drainage. Such practices are already established in some EU countries and are becoming increasingly relevant in our own legislation. At the same time, society is beginning to recognize not only the economic value of drinking and utility water but also, in light of ongoing climate change, the crucial role of water in mitigating urban overheating and reducing sensible heat accumulation in large cities.

Green roofs have also been used since ancient times. In Rome, roof gardens were a common feature of patrician houses and palaces. By the mid-11th century, green roofs had spread across Italy, France, and other parts of Europe. They have a long tradition in Scandinavia, as well as in Canada, Iceland, Guatemala, and Tanzania, mainly due to their excellent thermal insulation properties. In Germany and the Czech lands, green roofs began to appear in the mid-19th century and experienced a major resurgence at the beginning of the 20th century.<sup>14</sup>

This type of roof offers a way to restore some of the natural character to built-up areas, helping to partially revitalize them and reduce the sense that buildings are disconnected from nature. Architects increasingly focus on such designs, reflecting a growing awareness of the relationship between people and the environment. It also appears that this approach will become one of the main priorities of future-oriented architecture, as the demand for more greenery in cities continues to grow.

Certain types of green roofs can also serve as roof gardens, particularly in suburban and urban settings, and fulfill two key functions. They provide additional green space and improve rainwater retention, which enhances the overall drainage system of the area. Beyond that, they have a positive impact on the urban microclimate and offer direct benefits to residents of buildings equipped with them. Green roofs help reduce pollution, increase energy efficiency by lowering heating costs in winter and cooling costs in summer, and have been shown to lessen the penetration of high-frequency electromagnetic waves. When considering their entire lifespan, they are also more cost-effective than conventional roofing systems.<sup>15</sup>



Figure 53 : Green roof at Seoul National University with vegetable cultivation

**Benefits of green roofs:**

1. Natural air conditioning effect
2. Noise absorption
3. Fire resistance
4. Shading effect
5. Protection against electromagnetic smog
6. Production of oxygen and sequestration of CO<sub>2</sub>
7. Absorption of other pollutants from the air, filtering of dust particles, and prevention from dust swirling
8. Reduction in temperature fluctuations between day and night
9. Reduction in fluctuations in air humidity
10. Creation of living spaces for insects
11. They look very aesthetic in terms of recreation and relaxation

<sup>14</sup>[http://www.linia.sk/L10\\_04/kralovna.htm](http://www.linia.sk/L10_04/kralovna.htm)

<sup>15</sup> <http://exterier.hyperbyvanie.sk/vonkajsie-rastliny/252-zelene-strechy-sa-vracaju-na-vyslnie/>

12. They can also be designed as gardens for growing flowers and vegetables

**Cons of green roofs:**

1. More structurally demanding – perfect execution of the waterproofing layer is necessary
2. Minor or major yearly maintenance required
3. It is necessary to statically strengthen the supporting structure.<sup>16</sup>

System solutions for constructing vertical vegetated walls make it possible to create diverse, aesthetically appealing, and architecturally interesting spaces that remain permanently covered with vegetation.

A vertical garden system consists of prefabricated aluminum panels, often called cassettes or facade baskets, which are factory-filled with substrate and planted on-site. The panels are mounted onto suspension profiles fixed to the wall or facade, while the irrigation system is installed in horizontal gaps between the panels and connected to gutters.

Vertical gardens provide an efficient way to use walls and facades while serving as both architectural and ecological features. In addition to enhancing the visual appeal of a building, they can positively influence human health, reduce noise through lower sound reflectivity, and improve the microclimate both inside and around the building. They also protect facades from overheating in summer and excessive cooling in winter, increase air humidity, filter smog, capture and trap airborne dust and pollutants, absorb CO<sub>2</sub>, and release oxygen. Moreover, they help capture rainwater, reduce runoff into sewers, boost plant diversity in cities, and protect facades from graffiti. The open diffusion system of such facades allows for the cultivation of almost all common plant species on building walls.



Figure 54 : Green building, Likos , Slavkov u Brna<sup>17</sup>

<sup>16</sup>[http://sk.wikipedia.org/wiki/Green\\_roof](http://sk.wikipedia.org/wiki/Green_roof)

<sup>17</sup> [www.liko-s.cz](http://www.liko-s.cz)



## 7 Conclusion

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Water resources across Slovakia are limited and face growing risks in meeting the long-term water needs of people, agriculture, ecosystems, and the climate. Land use practices and changes in landscape structure have disrupted the natural hydrological functions of ecosystems. In the Kysuce region, there have also been noticeable temporal and spatial shifts in rainfall patterns, with more frequent intense storms, longer dry periods, and the formation of extensive heat islands.

These locally intense rains often lead to flash floods, while prolonged dry periods cause droughts, typically occurring in spring and autumn. Extreme torrential rains, on the other hand, tend to appear between May and late summer, sometimes multiple times per season. As a result, the landscape alternates between water scarcity and excess. To address this, rainwater must be retained and its runoff slowed whenever rainfall is abundant, which will help increase the region's overall water reserves.

The challenge for the Kysuce region is to respond effectively to climate change by using land in a way that ensures sufficient water availability for people and nature, thereby securing the region's capacity to produce enough food.

The most effective solution is ecosystem-based water restoration in the damaged landscapes of each municipality's cadastre. In line with international commitments, land use systems must be designed to ensure sufficient water resources within the next ten years and to guarantee water, food, environmental, and climate security at both local and regional levels.

This approach aligns with global frameworks such as the United Nations General Assembly Resolution 73/284, which declared 2021–2030 the “UN Decade on Ecosystem Restoration.” The resolution, signed by the Slovak Republic on March 1, 2019, calls for stronger action to prevent, halt, and reverse ecosystem degradation while raising awareness of the importance of watershed and soil restoration. Active participation by state ministries, local governments, non-governmental organizations, and private enterprises in landscape revitalization is seen as a key strategy to achieving these goals.

The proposed Kysuca River Basin Management Plan fully embodies these principles. Globally, similar efforts are underway to strengthen landscape resilience across all continents under the “United Nations Decade on Ecosystem Restoration and Revitalization.” A working group led by the Food and Agriculture Organization of the United Nations (FAO) has been established to develop best practices and coordinate these actions. On October 29, 2020, FAO reiterated its call for increased efforts to restore and revitalize landscapes and forests, emphasizing the essential role of wetlands in ecosystem recovery. Wetlands, such as swamps, ponds, lakes, floodplains, marshes, and riparian forests play a vital role in maintaining ecological balance and water retention.

Accordingly, the goal of this plan is for local governments in the Kysuca River Basin to take the lead in implementing solutions that provide broad social and environmental benefits for all stakeholders, guided by the principle “act locally, think globally.”

We must recognize that the degradation of natural resources such as the loss of soil fertility, extreme weather fluctuations, and declining environmental safety poses serious risks that affect everyone. These threats must be addressed and managed through concrete actions at the local level. For this reason, this plan focuses on implementing comprehensive natural resource management strategies that can systematically restore what has been damaged by poor political decisions at the national level.



Success depends on our ability to apply the three fundamental pillars of natural resource management, water, energy, and food, at the local level through methodological, managerial, and practical measures. The interconnection between these three pillars, known as the Water-Energy-Food (WEF) Nexus, has gained increasing attention internationally. The concept was first introduced at the World Economic Forum in 2011, which called for integrated solutions to address economic growth challenges linked to water, energy, and food. The Forum's report, "Water Security: The Water-Food-Energy-Climate Nexus," emphasized that an integrated approach to managing these resources enhances security, efficiency, poverty reduction, and sustainable resource management across all sectors.

Achieving sustainability within the WEF Nexus requires collaboration between scientists from natural, social, and economic disciplines, combined with practical implementation at the local level. It is equally important to translate research findings into real-world applications, a principle that guides the DALIA research project, which focuses on transferring scientific knowledge to local communities.

The goal is to strengthen the connections not only between water, energy, and food but also between weather, climate change, and biodiversity. The plan outlines comprehensive solutions following the WEF framework, recognizing that climate change directly affects water availability, soil fertility, extreme heat, and the frequency of natural disasters. A key recommendation is to promote integrated public policies at the local level that link water, energy, and food management to ensure sustainable solutions for current and future generations.

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Photos - Archive of NGO People and Water



## List of Attachments:

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**Annex 1:** Plan of water retention measures in the cadastres of individual municipalities/cities in Kysuca River Basin

**Annex 2:** General binding regulation on the mitigation of negative consequences of climate change, preventing floods and droughts in cadastral territory of a municipality/city

**Annex 3:** Examples of good practice