

Challenges and Adaptive Solutions for the Adoption and Scaling of Nature-based Solutions in three Central and Eastern European regions: A Comparative Regional Analysis

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Abstract. Nature-based solutions (NbS) are increasingly promoted as a multi-benefit pathway for climate adaptation, disaster risk reduction, biodiversity recovery, and sustainable regional development. Yet, mainstreaming NbS into sub-national planning and investment pipelines remains uneven across Europe. This paper addresses the research question: What are the challenges and suitable adaptive solutions for the adoption of NbS in the Plovdiv, Centru, and Podravje regions, situated in Bulgaria, Romania, and Slovenia, respectively? Drawing on several EU research project ARCADIA documents, e.g., the regions' self-assessment, the comparative analysis of the fellow regions, and review materials, the study team conducted a structured comparative policy and governance analysis using the ARCADIA common assessment pillars (governance, climate risk assessment, and adaptation planning). Results show that (i) Plovdiv region (Bulgaria) combines strong EU policy alignment with fragmented regional execution and NGO-dependent coordination; (ii) Centru region (Romania) exhibits a comprehensive multi-tier governance and strategic planning orientation but is slowed by inter-agency complexity and data and monitoring gaps; and (iii) Podravje region (Slovenia) presents a coherent, performance-driven model with stronger NbS integration and monitoring, but faces constraints related to municipal-level funding boundaries, social acceptance, and local decision-maker knowledge. Across all regions, the most limiting factors include weak vertical coordination, inconsistent monitoring frameworks, and insufficiently institutionalized stakeholder platforms. The study proposes a portfolio of adaptive NbS governance and policy solutions and instruments such as clarifying mandates and establishing regional coordination hubs; adopting KPI-based and learning-oriented monitoring; developing co-innovation labs and twinning pathways for capacity building; and introducing results-based financing and blended funding structures. The paper concludes with region-specific and cross-regional recommendations to accelerate NbS mainstreaming while respecting diverse administrative architectures.

Key words: Nature-based solutions, climate adaptation, governance, policy coherence, monitoring and evaluation, regional development, ARCADIA.

Introduction

Climate change poses urgent and escalating risks across Europe, from extreme weather events to long-term ecosystem degradation. In response, Nature-based solutions (NbS) have emerged as a transformative approach to climate adaptation, le-

veraging natural processes to mitigate impacts and enhance sustainability. NbS involve protecting, restoring, or managing ecosystems to address societal challenges (such as flooding, heatwaves, or biodiversity loss) while providing co-benefits for people and nature. Integrating NbS into regional

adaptation strategies is a key element of the European Union's climate policy and Mission on Adaptation, aiming to build resilient communities through green infrastructure and ecosystem-based adaptation measures. In continental biogeographical regions of Europe, NbS are increasingly positioned as an enabling pathway for climate resilience, disaster risk reduction, and green transition strategies. However, the ability of regional and local institutions to adopt and scale NbS depends on governance arrangements, risk assessment capabilities, finance, and stakeholder mobilisation. Therefore, NbS are interventions that should be integrated into regional and municipality environmental protection programmes in order to contribute to protection, sustainable management, and ecosystems' restoration in rural and urban areas, and to address societal challenges while delivering co-benefits for biodiversity and human well-being.

This paper examines the adoption of NbS in three European regions, namely Plovdiv in Bulgaria, Centru in Romania, and Podravje in Slovenia, which serve as "fellow regions" in the EU-funded ARCADIA project (TrAnsformative climate ResilienCe by nAture-based solutions in the continental bio-geographical region, Arcadia adaptation). These regions provide a representative cross-section of governance and development contexts in Central and Southeastern Europe.

Plovdiv region, located in center-southern Bulgaria, is a major agricultural and industrial hub that is actively pursuing water sustainability and green initiatives (e.g. a carbon-neutral industrial park and afforestation efforts) to promote a greener region. Centru region in central Romania emphasizes sustainable development, prioritizing environmental protection, energy efficiency, and biodiversity conservation through initiatives like expanding urban green spaces, green buildings, and sustainable mobility, supported by EU projects and innovation platforms. Podravje Region in northeastern Slovenia, traversed by the Drava River, focuses on biodiversity protection and flood risk management via NbS projects. Its main city, Maribor, is leading sustainable energy initiatives as part of the Covenant of Mayors for Climate and Energy. Despite these promising efforts, each region faces distinct challenges in embedding NbS into their climate adaptation frameworks.

The theoretical framework underpinning this study is an integration of climate adaptation planning theory, ecosystem-based adaptation/NbS concepts, and multi-level governance for sustainability. The study assumes that successful NbS adoption depends on factors such as policy integration (mainstreaming NbS into existing climate and development plans), stakeholder engagement (ensuring broad ownership and input), knowledge availability (scientific and local knowledge about ecosystem services and risks), and supportive institutions (financing mechanisms, regulations, and monitoring systems). These factors are examined in each region to understand the practical manifestation of the theory and to identify gaps between the ideal enabling conditions for NbS and the current reality in Plovdiv, Centru, and Podravje.

The paper also undertakes a comparative analysis of three regions to identify shared and context-specific barriers, to address the key region-specific and common challenges and to formulate actionable adaptive solutions for NbS adoption and mainstreaming. The analysis is oriented toward environmental science and regional development audiences and is designed to support policy learning and implementation.

Materials and methods

Data sources

The study uses project studies and documents as primary sources such as self-assessment reports prepared under the ARCADIA common assessment framework, the comparative scoping policy review across the three fellow regions, and other studies describing the twinning mechanism and enabling conditions for transformative NbS adoption.

The applied Analytical Framework relies on a structured qualitative comparative analysis aligned with the ARCADIA assessment pillars: Governance; Climate Risk Assessment (CRA); and Adaptation Planning. The fellow regions coordinating institutions, i.e., Agricultural University of Plovdiv (Bulgaria), ADR Centru (Romania), and Scientific Research Centre Bistra Ptuj (Slovenia), were responsible for preparing and delivering the self-assessment reports on the NbS development at national level, based on the Analytical Framework. To enable cross-regional comparability, the paper groups evidence into a set of crite-

ria: (a) governance model and institutional roles; (b) legislative and strategic alignment; (c) CRA scope and monitoring systems; (d) NbS integration in plans and pipelines; (e) stakeholder engagement and coordination platforms; (f) financing mechanisms and performance monitoring; and (g) implementation challenges and adaptive solutions.

The analysis is based upon information provided in and available from the project reports. Where regional practices are described at different levels of specificity, the study prioritizes the comparative synthesis already validated within the project reports and takes into account the fellow regions' self-assessment for region-specific details.

Table 1. Core regional features (as reported in ARCADIA D10.1).

Criterion	Plovdiv (BG)	Centru (RO)	Podravje (SI)
Resident population (2024)	631,516	2,288,061	329,753
Surface area (km ²)	5,972.9	34,082	2,170
Density (inhab./km ²)	106.6	67.1	152
Municipalities	18	57	41
Urbanisation rate (%)	~71.2	55.4	54.03

Source: ARCADIA comparative analysis of fellow regions' scoping policy reviews.

Regional context and baseline NbS readiness

Plovdiv region

Plovdiv region in central Bulgaria includes 18 municipalities and the country's second largest city. The region recognises NbS for flood risk reduction, water retention, biodiversity, and urban heat mitigation, yet the self-assessment notes the absence of consolidated national or regional adaptation strategies and highlights constraints from political instability and limited regional coordination capacity. In practice, NGOs and academia play a compensatory role in mobilising and delivering NbS pilots, with Agricultural University-Plovdiv acting as a key hub for EU-funded project implementation.

Centru region

Centru region comprises six Romanian counties and features an evolving strategic vision rooted in the regional development programme and smart specialisation priorities. The region shows strong alignment with national strategies and EU frameworks, and allocates substantial resources to green investments. Key readiness constraints emphasised in the comparative analysis include limited regional access to data and methodologies, the need to expand hydro-meteorological monitoring and warning infrastructure, and uneven awareness of NbS among potential adopters.

Podravje region

Podravje region in north-eastern Slovenia demonstrates a comparatively high level of NbS integration in planning and adaptation governance. The region benefits from strong expert support (including landscape architecture) and a performance-driven approach with defined mandates and monitoring. Reported gaps include constraints on whole-region integration because funding is often municipal-bounded, the need for awareness and social acceptance campaigns, limited NbS knowledge among some local decision-makers, and the need for stronger coordination between national and local authorities when planning green investments.

Results and Discussion

Governance and institutional frameworks

Governance arrangements shape how NbS are translated from policy intent into operational projects. Across the three regions, the comparative evidence indicates three distinct models: Plovdiv's decentralised multi-ministerial configuration with overlapping mandates and weak regional consolidation; Centru's multi-tier system with broad participation but coordination overhead; Podravje's centralised, performance-driven model with clearer accountability, albeit with potential rigidity for localised adaptation.

Table 2. Comparative governance and institutional features for NbS adoption.

Criterion	Plovdiv	Centru	Podravje
Governance model	Decentralised, multi-ministerial; overlapping mandates	Multi-tiered; broad participation	Centralised, performance-driven; streamlined roles
NbS integration in governance	Recognised but limited implementation	Growing recognition; hindered by coordination complexity	Mainstreamed in urban and rural planning
Stakeholder engagement pattern	Broad but uneven; high reliance on NGOs	Inclusive but bureaucratic; variable engagement across levels	Systematic and continuous; participatory mechanisms
Main governance bottleneck	Political instability; coordination voids; fragmented execution	Inter-agency misalignment; delays; communication gaps	Risk of limited flexibility; capacity constraints in small municipalities

Source synthesis from ARCADIA and Plovdiv self-assessment report.

Climate risk assessment and monitoring

CRA and monitoring influence both problem framing and the selection of NbS portfolios. Podravje stands out with more dynamic, technology-supported monitoring and cross-sectoral risk assessment, while Centru maintains strong nation-

nal data infrastructures but relies more on historical datasets and faces regional integration challenges. Plovdiv's CRA emphasises water-related hazards and EU compliance tools, but lacks a holistic multi-sectoral framework and robust local mandates for systematic evaluation (Table 3).

Table 3. Comparative CRA and monitoring features relevant to NbS selection and scaling.

Criteria	Plovdiv	Centru	Podravje
Dominant hazard focus	Floods, droughts, water quality; agricultural vulnerability	Multi-hazard (floods, droughts, heat), DRR & transition	Water, biodiversity, land degradation; cascading impacts
Monitoring systems	EU-aligned, water-centric; limited integrated regional platforms	Multi-agency networks; early warning; needs consolidation	Tech-driven (satellites/sensors); integrated platforms and KPIs
Local governance involvement	Limited: primarily municipalities	Strong county-level involvement	Active cooperation with NGOs, municipalities, business
NbS integration in CRA	Minimal (policy recognition more than practice)	Emerging but uneven	High: embedded in CRA and planning cycles

Source: ARCADIA comparative CRA analysis.

Adaptation planning, policy coherence and implementation pipelines

Adaptation planning translates risk knowledge into prioritised measures and investment pipelines. The comparative analysis indicates that

Plovdiv lacks a consolidated regional adaptation strategy and depends on fragmented local plans and project-driven initiatives; Centru has a stronger strategic planning architecture connected to funding cycles and regional development pro-

gramming; and Podravje embeds NbS within planning and land-use regulation, supported by performance-based evaluation, but may require mechanisms for locally tailored innovation.

Financing and resource allocation

Financing is a decisive constraint for NbS scaling because benefits are often diffuse while

costs are front-loaded. Plovdiv and Centru have access to multiple EU and national instruments but experience fragmentation in disbursement, monitoring, and accountability. Podravje, by contrast, links resources to performance metrics and uses more systematic audits and stakeholder review, improving predictability while risking reduced flexibility for local priorities (Table 4).

Table 4. Comparative financing and performance management conditions for NbS.

Category	Plovdiv	Centru	Podravje
Funding sources	EU Operational Programmes; national budget; international funds	Environment Fund; Just Transition; EU Cohesion/Regional Program	EU + national + PPPs; integrated green investments
Allocation mechanism	Fragmented; slow disbursement; weak regional integration	Comprehensive but fragmented; overlaps complicate delivery	Streamlined; centrally coordinated; aligned with KPIs
Performance monitoring	Weak; inconsistent evaluation frameworks	Moderate; exists but needs consolidation	Strong; KPI-linked; regular audits; adaptive mechanisms
Transparency & accountability	Limited; bureaucracy reduces visibility	Moderate; siloed reporting	High; transparent linkage to outcomes; consultations

Source: ARCADIA comparative funding analysis.

Challenges and suitable adaptive solutions

Building on the comparative results, this section synthesizes: (i) cross-cutting challenges that recur across the three regions and (ii) adaptive solutions that can be implemented within existing

administrative architectures. Solutions are formulated as policy- and practice-oriented interventions, emphasising feasibility in the short to medium term while supporting longer-term transformative capacity (Table 5).

Table 5. Challenges and adaptive solutions for NbS adoption (comparative matrix).

Challenge area (criteria)	Plovdiv main manifestations	Centru main manifestations	Podravje main manifestations	Adaptive solutions (transferable options)
Governance coherence & mandates	Overlapping institutional roles; NGO-dependent coordination; lack of unified regional strategy	Multi-tier complexity; inter-agency misalignment; delays and communication gaps	Strong central coherence but potential rigidity for local tailoring	Clarify regional roles and create a standing regional NbS coordination unit; formalise inter-agency protocols; introduce 'adaptive governance' loops (annual review + revision) with stakeholder panels.

Stakeholder platforms & legitimacy	Broad stakeholder base but uneven engagement; limited unified forums	Formal platforms exist but local engagement inconsistent; awareness gaps	Systematic engagement; yet social acceptance and visibility need strengthening	Establish regular regional NbS forums (quadruple-helix), participatory mapping, and open calls for citizen-led micro-projects; pair engagement with demonstrator sites and narrative communication.
Risk assessment integration & data	Water-centric CRA; limited cross-sectoral integration; weak local mandates	Strong national datasets but limited regional access to studies/methodologies; monitoring infrastructure needs expansion	Advanced monitoring; local technical capacity uneven; needs stronger national-local coordination	Adopt shared minimum CRA datasets and a harmonised NbS-relevant indicator set; develop 'real-time to decision' pipelines; create regional data stewards and training for municipalities.
Financing, delivery & accountability	Fragmented disbursement; weak evaluation; implementation gaps	Many instruments but siloed programming; monitoring/reporting fragmentation	KPI-linked financing; but municipal boundary limits whole-region integration	Introduce results-based financing (with safeguards for equity); blended finance (EU grants + municipal + PPP); standardise project appraisal for NbS co-benefits; pool resources for cross-municipal projects.
Capacity and mainstreaming	Administrative capacity constraints; institutional continuity issues	Need for skills and methods to operationalise NbS in multiple sectors	Decision-maker NbS knowledge gaps in some municipalities	Use ARCADIA twinning and co-innovation labs as structured capacity building; embed NbS competences in municipal programmes; develop toolkits (iPDF/scorecards) and peer-to-peer learning with model regions.

Source synthesis: ARCADIA, Plovidiv self-assessment, and review materials.

Region-specific recommendations

Plovdiv

Priority actions for Plovdiv focus on governance consolidation and institutionalization of NbS. First, establish a formal regional NbS coordination platform co-hosted by the regional administration and key knowledge institutions (e.g., universities), with defined responsibilities across ministries and municipalities. Second, move from project-based pilots to a regional NbS roadmap with agreed targets, linked to municipal investment programming and monitoring indicators. Third, strengthen performance monitoring and transparency through a standard KPI set and annual public reporting. Finally, scale NGO-led innovations by integrating them into government-led plans and stable funding lines.

Centru

For Centru, the central leverage point is vertical and horizontal coordination across the multi-tier system. A practical approach is to consolidate monitoring and evaluation across programmes and agencies, producing a single regional NbS and adaptation dashboard aligned with the 2021–2027 funding cycle. Parallel investments are needed to strengthen access to regional data, methodologies, and decision-support tools, including expanded hydro-meteorological monitoring and early warning infrastructure. Awareness and adoption can be accelerated through regional co-innovation labs that translate strategic priorities into implementable NbS project pipelines with municipalities and private sector partners.

Podravje

Podravje should retain the strengths of its performance-driven system while increasing local flexibility and social acceptance. Municipal-bounded funding can be complemented by pooled instruments for cross-municipal NbS projects (e.g., catchment-scale water management). Social acceptance and visibility require sustained campaigns paired with demonstrator sites and citizen co-design. Capacity building for local decision-makers can be embedded in routine planning cycles via targeted training and the use of standardised NbS assessment tools.

The comparative evidence illustrates a ‘governance-capacity-finance’ nexus that shapes NbS adoption pathways. Regarding strengths, Plovdiv has a defined policy intent, Centru has a strategic ambition, and Podravje has policy cohe-

rence. Whereas challenges, Plovdiv presents a challenge in lack of coherent regional execution and stable coordination mechanisms. Centru’s challenge is the transaction costs of complexity and insufficiently consolidated monitoring and implementation. Podravje’s challenge is ensuring that centralised performance systems remain adaptive to place-specific needs and that municipal boundaries do not constrain landscape-scale NbS.

Across regions, the most transferable ‘adaptive solutions’ are those that: (i) reduce fragmentation by clarifying mandates and aligning plans with funding pipelines; (ii) upgrade monitoring from compliance reporting to learning-oriented evaluation (KPIs, audits, feedback loops); and (iii) build legitimacy and capability through structured stakeholder platforms (quadruple helix), co-innovation labs, and twinning exchanges.

These findings are consistent with the project’s emphasis on cross-sectoral collaboration, transparent financing, and integrated governance as preconditions for scaling NbS-driven climate adaptation. The twinning mechanism provides an operational pathway for knowledge transfer and for translating model region practices into fellow region contexts, particularly regarding participatory ‘water dialogues’, open calls for civic engagement, and the use of digital tools (scorecards, iPDF catalogues, and adaptation journals) for planning and monitoring.

Conclusions

This paper addressed the research question of challenges and suitable adaptive solutions for NbS adoption and mainstreaming in Plovdiv, Centru, and Podravje regions. The comparative analysis shows that institutional fragmentation, insufficient monitoring systems, and inconsistent stakeholder platforms remain the most important constraints, though they manifest differently under decentralised, multi-tiered, and centralised governance models. A combined portfolio, such as governance consolidation, KPI-based and learning oriented monitoring, results-based and blended financing, and capacity building through co-innovation labs and twinning, offers a feasible route to accelerate NbS scaling. Future work should empirically test these recommendations through regional pilots, including harmonised indicator sets and evaluation designs capable of capturing co-benefits and distributional outcomes.

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References

- ARCADIA Consortium, (2025). Comparative analysis of fellow regions’ scoping policy reviews (WP10).
Retrieved from: <https://www.arcadia-adaptation.eu/> Accessed on 05.07.2026
- ARCADIA Consortium, (2025). WP10: Mirroring the transformative processes in the fellow regions.
Retrieved from: <https://www.arcadia-adaptation.eu/> Accessed on 05.07.2026
- Agricultural University. (2024). Self-Assessment Report (completed version) for Plovdiv region (ARCADIA framework).
Retrieved from: <https://www.arcadia-adaptation.eu/> Accessed on 05.07.2026

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