

Advancing climate resilience through nature-based solutions within the water circular economy

A.I. Ignat¹, I. Tismanar^{1*}, L. Andronic¹

¹Department of Product Design, Mechatronics and Environment, Transilvania University of Brasov, Brasov, 500036, Romania

Presenting author email: *ioana.tismanar@unitbv.ro

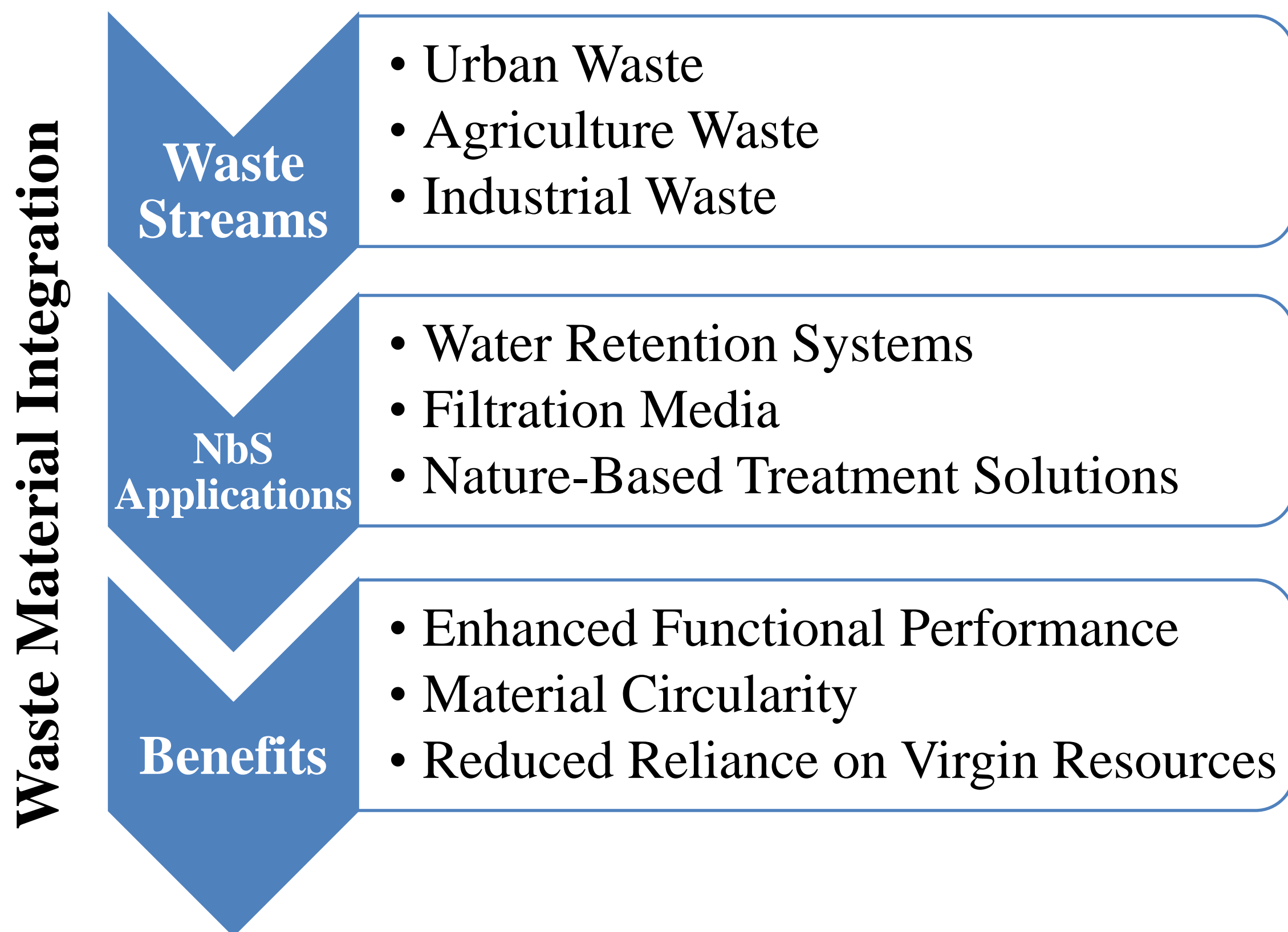


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Introduction

Sustainable and resource-efficient solutions required due to climate change mitigation and adjustment

Integration of Waste Materials into Water-Related NbS



Nature-Based Solutions (NbS) represent sustainable strategies that simultaneously improve climate resilience, water management, and biodiversity protection.

Waste-derived material valorisation supports the water circular economy by reducing the resource use and environmental impacts.

Cost-benefit analysis – key economic indicators

- capital expenditure (CAPEX)
- operational expenditure (OPEX)
- opportunity costs
- benefit–cost ratios (BCR)
- net present value (NPV)

Indicates whether the proposed solution is viable

No.	Waste-Derived Materials	NbS Application	Function in Water Circular Economy
1	Biochar from agricultural waste	Constructed wetlands	Pollutant adsorption and water reuse
2	Compost from organic waste	Soil-based NbS	Nutrient recovery and water retention
3	Recycled concrete aggregates	Urban water retention systems	Stormwater management and flood mitigation
4	Industrial by-product slag	Permeable reactive barriers	Heavy metal removal from water
5	Waste-derived activated carbon	Nature-based filtration systems	Advanced water treatment and reuse
6	Agricultural residues (straw, husks)	Green infrastructure substrates	Enhanced infiltration and evapotranspiration
7	Sewage sludge biochar	NbS for wastewater polishing	Nutrient capture and circular reuse
8	Recycled glass media	Nature-based filtration beds	Improved hydraulic performance and reuse

Results & Discussion

WATER RETENTION BASINS AND PONDS (STORAGE PONDS) SOLUTION



Structures designed to manage stormwater runoff, mitigate flooding and to enhance water quality

Site suitability, scale and coverage

Challenges this NbS addresses

- Drought** – prevention and reduction; (serves as a backup water source, supporting local water supply and agriculture)
- Flood** – prevention and reduction; (captures excess runoff, reducing peak flood flows).
- Erosion** – prevention and reduction; (controls water surges that contribute to streambank erosion)
- Heatwaves** – mitigation; (moderates local microclimates by increasing humidity and cooling surrounding areas)
- Climate change** – mitigation; (supports carbon sequestration through aquatic vegetation growth)

Water retention basins and ponds are applicable in:

- Urban, peri-urban, and rural areas
- Agricultural landscapes requiring supplementary irrigation
- Flood-prone zones needing runoff regulation
- Areas with significant biodiversity conservation potential

Main components

- Excavated basins:** Basins and Ponds are typically excavated in strategic locations to capture and store runoff effectively.
- Lined or unlined:** Some ponds are lined with clay, plastic, or other materials to prevent seepage, while others remain unlined to allow groundwater recharge
- Overflow channels:** Designed with overflow channels to prevent flooding and manage excess water, directing it to additional storage or recharge areas
- Vegetation around the pond:** can stabilize soil, reduce evaporation, and provide habitat for wildlife.

Cost-benefit profile

Costs of implementing Water Retention Measures (WRMs)	Expected Benefits of WRMs	Economic Returns and Cost-Effectiveness
Investment cost per cubic meter of WRM: <ul style="list-style-type: none"> Urban areas: €20–28 per m³ Agricultural land: €5 per m³ Forest land: €5 per m³ Total required investment for WRMs by land type: <ul style="list-style-type: none"> Urban areas: Mean investment of €490 million Croplands: Mean investment of €440 million Forests and pastures: Significantly lower investments compared to urban areas 	Water Retention Capacity: Estimated additional water retained: <ul style="list-style-type: none"> Croplands: Mean of 88 million m³ Urban areas, forests, and pastures: Lower but significant retention capacities Reduction in Temperature (Cooling Effect): Estimated decrease in temperature due to WRMs: <ul style="list-style-type: none"> Croplands: Mean reduction of -1.6°C Forests: Mean reduction of -1.0°C Urban areas: Up to -4°C, though study results suggest ~0.2°C (likely underestimated) Increase in Agricultural Productivity: Projected increase in agricultural production: <ul style="list-style-type: none"> Croplands: €66 million per year in added productivity Pastures: €40 per hectare increase Forests: €20 per hectare increase 	Estimated Return on Investment (ROI) for WRMs: Croplands offer the best value for money, combining high water retention capacity, productivity gains, and temperature reduction effects. Expected ROI for a €400 million investment, Payback in ~13 years.

Conclusions:

- Nature-Based Solutions (NbS) have gained increasing attention as effective strategies for enhancing climate resilience while delivering multiple co-benefits, including improved water management, biodiversity conservation, ecosystem services, and carbon sequestration.
- This study investigates Nature-Based Solutions within the framework of the water circular economy.
- Water retention basins and ponds solution are engineered structures designed to manage stormwater runoff, mitigate flooding, and enhance water quality facilitating erosion control, sedimentation management, drought buffer, groundwater recharge.
- The basins can be implemented mainly in agriculture for irrigation and such investment can be amortized in 13 years.