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[*Invited Lecture*]

Tracing the Path from Soil Erosion to Drinking Water Risk: A Modelling Framework for Water Safety Planning

Dejan Vasović^{1*}, Ana Stojanović¹, Sladjan Hristov²

¹University of Niš, Faculty of Occupational Safety, 18000 Niš, Republic of Serbia

²Ministry of Defence, 11000 Belgrade, Republic of Serbia

*Correspondence: dejan.vasovic@znrfak.ni.ac.rs

Abstract: Soil erosion is a major global land degradation process with significant implications for surface water quality, particularly in reservoirs where sediments and associated pollutants accumulate over time. Erosion modelling can therefore support the identification of upstream hazards relevant to drinking-water source protection and Water Safety Planning. Various empirical, semi-empirical, and physically based models are available, but their applicability depends on catchment characteristics and data availability. This study proposes a GIS-based methodological framework using the Erosion Potential Method (EPM), selected for its suitability for catchment-scale assessment under limited data conditions. The framework links spatial patterns of erosion intensity and sediment production with the identification of potential hazards and critical areas within the Water Safety Plan planning process. Its applicability is demonstrated in the Veliki Ržav catchment in Republic of Serbia, an important regional public water resource system. The proposed approach highlights the potential of integrating soil erosion assessment into preventive, risk-based drinking-water management and catchment protection strategies.

Keywords: Soil erosion, Erosion Potential Method (EPM), Reservoir water quality, Water Safety Plans, Catchment management.

Introduction

Soil erosion is among the most significant forms of land degradation, affecting both terrestrial ecosystems and downstream water resources (Milentijević et al., 2021). The detachment and transport of soil particles contribute to increased sediment loads, turbidity, nutrient transport, and the mobilization of contaminants, thereby creating potential pressures on surface water quality (Rodrigo-Comino, 2019). These effects are particularly relevant in reservoir systems, where sediment accumulation may reduce storage capacity and influence the quality and security of water resources intended for multiple uses, including drinking-water supply (Buggiarin et al., 2022). The assessment of soil erosion has therefore become an important component of integrated catchment management (Rodrigo-Comino, Senciales-González and Ruiz-Sinoga, 2020). A variety of empirical, semi-empirical, and physically based approaches are available, including the Universal Soil Loss Equation and its revised forms, WEPP, SWAT-based modelling, and other regionally adapted methods (Liu et al., 2026). However, the applicability of individual models depends on data availability, spatial scale, catchment characteristics, and the intended purpose of the assessment (Debebe, Yirgu and Debele, 2025). For catchments with limited monitoring data, the Erosion Potential Method (EPM) represents a practical approach for estimating erosion intensity and sediment production. This study develops a methodological link between catchment-scale soil erosion modelling and the preventive principles of Water Safety Plans - WSPs (Karkori, 2024). Using the Veliki Ržav catchment in Serbia as an illustrative case, the research applies the EPM within a GIS environment to identify areas of elevated erosion potential and considers their relevance for hazard identification and risk-based source water protection.

Methods and data

The methodological framework was designed to connect spatial soil erosion assessment with the early planning stages of a Water Safety Plan (Mohammed, Gashaw and Yimam, 2025). The Veliki Ržav catchment in Serbia was selected as a case study due to its importance as a regional water resource and the relevance of catchment conditions for downstream water management. Soil erosion was assessed using the Erosion Potential Method (EPM), which estimates the intensity of erosion and potential annual sediment production based on factors describing soil and geological characteristics, land use and vegetation cover, topographic conditions, and visible erosion processes (Chen, 2025). The method uses the following quantitative environmental factors: geological and pedological characteristics, soil cover, coefficient of visible erosion traces, climatic factors (mean annual temperature and mean annual precipitation) and topographic factor. Based on these factors, the erosion coefficient (Z), the total and mean annual production of erosion material (W_{god}), as well as the mean annual volume of total quantities of entrained and suspended sediment (G_{god}) are calculated. Relevant spatial and environmental data were prepared and integrated within a Geographic Information System (GIS). The individual EPM parameters were spatially analyzed and combined to generate an erosion coefficient and classify the catchment according to erosion intensity. The resulting spatial distribution of erosion potential was subsequently interpreted from a water safety and early warning perspective (Vasović, Ristić and Bajrić, 2021). Areas characterized by higher erosion intensity were considered potential upstream hazard zones because of their greater capacity to generate and transport sediment, potentially contributing to increased sediment loads and associated deterioration of downstream water quality. The methodological framework consequently links erosion modelling with hazard identification, the prioritization of critical source areas and the development of targeted preventive catchment protection measures. This approach enables the identification of

locations where soil conservation and land management interventions may be most effective, thereby supporting proactive risk reduction.

Results and discussion

The results of erosion modelling provide information that extends beyond the conventional assessment of soil loss. When interpreted in the context of drinking-water source protection, spatial patterns of erosion intensity can support the identification of areas where land degradation may contribute to increased sediment loads and potential water quality deterioration. This is particularly important for reservoir and accumulation systems, where sediments may be retained and associated pollutants may accumulate over extended periods. The EPM offers particular advantages for this purpose because it can be applied at the catchment scale using comparatively accessible environmental and spatial data. Although more complex models may provide detailed representations of hydrological and sediment transport processes, their application can require extensive calibration and long-term monitoring datasets. The EPM therefore represents a potentially suitable alternative for preliminary assessments and for identifying priority areas requiring further investigation or management intervention. From a Water Safety Plan perspective, the integration of erosion modelling supports a preventive approach by moving risk identification upstream into the catchment. Rather than responding exclusively to changes detected at the reservoir or water treatment stage, erosion-prone areas can be recognized as potential sources of water quality hazards. This information may assist water suppliers and catchment managers in prioritizing monitoring, land management, and erosion control measures.

Conclusions

This study proposes a methodological framework for integrating soil erosion modelling into catchment-based drinking-water safety management. Soil erosion should not be considered exclusively as a land degradation issue, as sediment mobilization may also represent an important upstream pressure affecting reservoir water quality and the reliability of drinking-water resources. The application of the Erosion Potential Method within a GIS environment provides a practical approach for identifying spatial patterns of erosion intensity and potential critical areas within a catchment. Its relatively accessible data requirements make the method particularly relevant for preliminary or screening-level assessments in data-limited environments.

By linking erosion-prone areas with the hazard identification and preventive planning stages of Water Safety Plans, the proposed framework contributes to a more integrated approach to source water protection. The Veliki Ržav catchment demonstrates the potential applicability of this concept within the Serbian context, while the methodology may also be transferable to other reservoir catchments. Ultimately, integrating erosion assessment into Water Safety Planning can support earlier intervention, targeted catchment management, and improved protection of drinking-water resources.

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