Can appropriate assessment drive hydraulic risk management towards nature-based solutions? A case study in a Natura 2000 site in central Italy.

NH3.13 - Nature-based and bio-based solutions for geohazard mitigation on slopes and streambanks.

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Abstract

Flooding is a natural hazard stemming from heavy rainfall, with a growing global impact due to shifts in land use, particularly urbanization and climate change. Traditional flood damage control methods have predominantly relied on “grey” solutions, involving extensive use of concrete structures, either reinforced or not. The sustainability paradigm has prompted a shift towards solutions inspired by nature, where ecological approaches are integrated with engineering design to enhance risk management. In this context, striking a harmonious balance between the “security objective” and biodiversity preservation, especially in areas governed by the European Council Directive 92/43/EEC, emerges as paramount.

This case study focuses on the hydraulic-integrated environmental restoration of the Rio Santa Croce stream, encompassed within a Natura 2000 site (code IT6040024), located in Latina, Italy (Lat. 41.27°N, Long 13.71°E WGS 84). It serves as an illustrative example of how the Natura 2000 network, often perceived merely as a restriction by authorities, technicians and local communities, can be transformed into a valuable tool for steering hydraulic risk management towards nature-based solutions (NbS). This transformation could be achieved through the appropriate assessment (AA) regulated by Article 3 of the European Council Directive 92/43/EEC.

A multidisciplinary team, comprising professional foresters from the Società Cooperativa Trifolium a.r.l., along with professional engineers and a professional geologist, on behalf of the Province of Latina, conceived a green gabion wall to stabilize the banks of a section of the Rio Santa Croce while creating habitats for aquatic vertebrates. These retaining structures are considered environmental-friendly, offering a more sustainable option compared to traditional earth-retaining walls. By integrating vegetation and implementing special technical measures during the assembly of the baskets, the gabion wall can be classified as NBSs, providing a favorable compromise in situations where the only alternative involves conventional grey solutions.

1. Goal

The goal of this case study is to highlight the drivers and constraints for adopting Nature-based Solutions (NbS) in natural risk scenarios and identifying strategies that can facilitate their implementation. Particularly, it suggests that appropriate assessment (AA) regulated by Article 3 of the European Council Directive 92/43/EEC could represent a valid tool for steering hydraulic risk management towards NbS.

2. Introduction

NbS may be defined as actions aimed at protecting, sustainably managing, and restoring ecosystems to address societal challenges while providing benefits for human well-being and biodiversity. NbS solutions that work with nature, such as ecosystem-based adaptation, disaster risk reduction, as well as green and blue infrastructures. One of the societal challenges addressed by NbS is the reduction of floods risk. However, the application of NbS faces obstacles in establishing itself in contexts where natural hazards threaten human life. This leads to the persistent use of traditional approaches, making it challenging to strike a balance between security demands and biodiversity conservation. Although considerable research has been devoted at identifying and evaluating NbS and their effectiveness, there remains a notable gap in literature regarding the design, implementation, and scaling-up of these solutions [1]. Hence, the poster focuses on the hydraulic-integrated environmental restoration of the Rio Santa Croce (contracting authority Province of Latina). The aim is to showcase how the Natura 2000 network could be strategic for steering hydraulic risk management towards NbS, thus offering insights for broader implementation.

3. Study area

The Rio Santa Croce is a stream located in Latina, Italy (41.27°N, 13.71°E). Its main stem extends 1.2 km, flowing north-southwest from Capodacqua di Spigno source into the Tyrrhenian Sea, where it forms a narrow estuary at its mouth. The catchment area is approximately 35.3 km², with a diverse topography, including rugged mountainous terrains, as well as an alluvial plain that is heavily urbanized. Elevations range from approximately 0 m amsl to over 1,200 m amsl. In the sector analyzed, the road embankment of the Appia way variant aligns with the stream bank, which has been excavated in alluvial deposits from the valley floor, showing signs of erosion. The riverbed shows moderate incision, with steep banks that terminate in sub-vertical escarpments. The study area is encompassed within a Natura 2000 site (code IT6040024); it features hazard zones classified as A1 (high hazard) by the Appennino Centrale District Basin Authority (Fig. 1).

Figure 1 – Reach of the Rio Santa Croce

4. Materials and methods

a. **Hydrology and hydraulic study**: the process included computing time of concentration, calculating storm frequencies, and determined peak flow rates for specified T_p values (30, 200, and 500 years). 2D modeling was conducted using HEC-RAS, employing a finite volume algorithm to delineate water surface elevations for specified T_p;

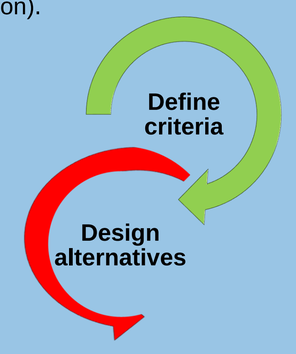
b. **Gological investigations**: to identify soil types, a multi-channel analysis of surface waves surveys (MASW) was performed usng a 24-bit seismograph with the MAE A6000S equipment. The surveys had a spread length of 31.25 m, an offset and spacing of 1.25 m, and a direction of N 210° E, with a maximum investigation depth of 37 m. Seismic data proccess was carried out by SurfSeis software;

c. **Appropriate Assessment** (Article 3 of the European Council Directive 92/43/EEC): 7 transects were conducted to assess the presence/absence of habitats and animal species included in the European Council Directive 92/43/EEC. These assessment followed the monitoring protocols established by the Italian Institute for Environmental Protection and Research (ISPRA) [3, 4]. Habitat assessments were based on the focal species approach, while data collection methods for animals varied depending on the species (i.e. direct observations, captures, and birdsong recognition).

d. **Designing**:

→ Criteria: (1) Hydraulic risk management for reducing flood hazard; (2) Stream restoration for improving quality of fluvial ecosystem.

→ Alternatives: (1) Zero option; (2) Concrete wall; (3) Gabion wall.



5. Results

a. **Hydrology and hydraulic study**: the hydraulic simulation reveals that the stream does not have a sufficient hydraulic section for the considered flood events;

b. **Gological investigations**: the seismic prospection indicates deposits of coarse-grained soils moderately compacted, or fine-grained soils moderately cohesive with thicknesses exceeding 30 m;

c. **Appropriate Assessment:**

- Habitats: all habitats surveyed are absent due to unfavorable environmental conditions. The absence of 3140 is attributed to the presence of turbid waters and a muddy substrate. Excessive shading caused by *Arundo donax* contributes to the absence of 3260, while bank erosion accounts for the absence of 3280. Moreover, 91F0 is notably scarce, with only isolated individuals of *Fraxinus angustifolia* and *Ulmus minor* observed amidst dense populations of *Arundo donax*;

- Animal species: none of the animal species included in the Standard Data Form (SDF) were detected. The absence of *Austropotamobius pallipes* is attributed to extensive anthropogenic activities and a decrease in suitable habitats due to bank erosion. *Salmo trutta macrostigma* and *Rutilus rubilio* are also absent, likely due to the absence of seabed with gravelly sections and macrophytic vegetation. While *Alcedo atthis* was not detected, suitable sites were encountered, characterized by embankments suitable for nest excavation and prey availability among the fish fauna. *Lampetra planeri* is absent, probable due to historical seabed dredging activities that have significantly altered the habitat. Outside the species included in the SDF, *Fontinalis antipyretica*, *Salmo trutta fario*, *Natrix natrix*, *Anas platyrhynchos,* and *Gallinula choropus* were detected.

d. Designing:

→ Alternatives evaluating:

(1) Zero option: not reducing hazard level and not improving quality of fluvial ecosystem;

(2) Stream restoration: reducing hazard level and worsening quality of fluvial ecosystem;

(3) Gabion wall: reducing hazard level and improving quality of fluvial ecosystem

→ Best alternative: gabion wall.

The original design (Table 1) was implemented through mitigation measures as outlined during the AA (Fig. 2):

- Habitats: using cuttings consistent with the 3280 habitat included *Salix purpurea*, *S. cinerea*, and *S. pentandra* (Ø ≤ 12 cm; 5-10 stems/m²); hydroseeding with species of the *Paspalo-Agrostion verticillati* alliance; removing exotic species, such as *Arundo donax*.

- Animal species: striving for a bank protection resembling natural rocky outcrops, creating irregularity using gabions of different width and geometry, and incorporating gaps in the stonework (20-30 cm high) to support birdlife and aquatic species.

Table 1 – Main characteristics of the gabion wall

Retaining structure	Length	Height		Width		Fill material	
		Max	Min	Max	Min	Front	Back
-	m	m	m	m	m	-	-
Gabion wall	152.35	4.0	3.0	2.0	1.0	Limestone	Sand

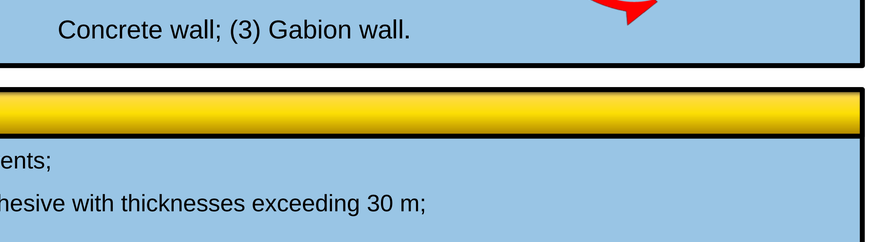


Figure 2 – Green gabion wall and others NbS designed

6. Conclusions

- Habitat quality will be improved through several measures: increasing overall vegetation, mitigating competition between native vegetation and exotic species, and creating refuges for wildlife;
- Balancing hydraulic risk management and stream restoration could enhance river morphology, thus suitable conditions for species outlined in Directive 92/43/EEC, which are currently lacking due to significant disturbances. Simultaneously, the proposed approach ensures flood control;
- An adequate monitoring strategy is needed to assess the effectiveness of the undertaken action;
- (a) NbS Drivers: multidisciplinary team, public contracting authority, and AA; (b) NbS Constraints: lack of established procedures for structural and hydraulic analyses for NbS and absence of regulatory framework.

7. References

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