

IDRAIM: A Methodological Framework for Hydromorphological Analysis and Integrated River Management of Italian Streams

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Abstract

A methodological framework for hydromorphological assessment, analysis and monitoring (named IDRAIM) has been developed with the specific aim of supporting the management of river processes by integrating the objectives of both the Water Framework and Floods Directives. The framework builds on existing and up-to-date geomorphological concepts and approaches, but accounts for the specific Italian context in terms of channel adjustments and human pressures, and includes a component qualitatively addressing the hazards related to fluvial dynamics. The method was designed to be used by environmental or water agencies on a national level. The framework includes the following four phases: (1) catchment-wide characterization of the fluvial system; (2) evolutionary trajectory reconstruction and assessment of present river conditions; (3) prediction of channel evolution; (4) identification of management options.

Keywords

Hydromorphological assessment • River management • Fluvial hazard • Channel dynamics • Evolutionary trajectory

62.1 Introduction

Development of integrative approaches for river management is increasingly required by public agencies, whereas scientific frameworks that only address single objectives are in most cases doomed to failure. Most of the existing frameworks for river restoration design start from a

definition of restoration goals as a priority objective, with scarce consideration of feedbacks and integration with wider policy objectives. In European countries, recent EU directives (Water Framework Directive, Floods Directive, Renewable Energy Directive) have often conflicting objectives. This is specifically the case of the Water Framework and Floods Directives, the former aiming to improve the ecological quality of water bodies, and the latter to identify measures to mitigate flood risk.

In Italy, given the high level of urbanization, flood safety is most often the main priority in river management although there are also increasing efforts towards river restoration driven by the implementation of the Water Framework Directive. A methodological framework for hydromorphological assessment, analysis and monitoring (named IDRAIM) has been developed with the specific aim of supporting the management of river processes by integrating the objectives of both the Water Framework Directive (2000/2060) and Floods Directive (2007/2060). This paper provides a brief overview of IDRAIM methodological structure and its components.

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62.2 General Characteristics of IDRAIM Framework

The framework builds on existing geomorphological approaches developed in other countries (e.g. the River Styles Framework Brierley and Fryirs 2005), but accounts for the specific Italian context in terms of channel adjustments and human pressures, and includes a component addressing fluvial dynamics.

Some key characteristics of IDRAIM are: (1) the method embraces a catchment-wide perspective; (2) the temporal component of the analysis is explicitly accounted for; (3) channel dynamics and implications in terms of fluvial hazards are key components of the overall analysis; (4) it was designed to comply with the requirements of the Water Framework and Floods Directives, but could be used for other purposes in river management; (5) because the method is to be used for practical application by environmental or water agencies on a national level, it has been designed to be relatively simple and not excessively time consuming; however, its application should be carried out by trained personnel with an appropriate background and sufficient skills in fluvial geomorphology; (6) the method is based on an integration of GIS/remote sensing analysis and field survey.

The general structure includes the following four phases: (1) a catchment-wide characterization of the fluvial system; (2) reconstruction of evolutionary trajectory and assessment of present river conditions; (3) prediction of future channel evolution; (4) identification of river management option. Phase 1 provides the spatial context and is aimed to characterize the river system in its present conditions. Phases 2 and 3 provide the temporal context, with phase 2 investigating the past evolution and the resulting present river conditions, and phase 3 considering possible scenarios of future channel changes. Finally, phase 4 focuses on the identification of an integrative river management strategy that should take into account the results stemming from the whole analysis.

Since 2010 application of the method to several study cases covering a sufficiently wide range of physical conditions and human pressures of Italian streams enabled the testing and the refinement of the method.

62.3 Phase 1: Characterization of the Fluvial System

This phase provides the spatial context for the river system analysis, including an initial characterization and segmentation of the fluvial system. This is based on a catchment-wide, spatially hierarchical framework following the scheme proposed by Brierley and Fryirs (2005), and is consistent

with the recent adaptation to European streams (Gurnell et al. 2014) within the context of the EU project REFORM. The final product of the segmentation is the delimitation of relatively homogeneous reaches, defined as river stretches along which the present boundary conditions are sufficiently uniform (i.e. with no significant changes in valley setting, channel slope, imposed flow and sediment load).

62.4 Phase 2: Past Evolution and Present River Conditions

This phase starts from a retrospective analysis of past evolutionary trajectories of channel morphology. This analysis is particularly suitable for alluvial, relatively large, dynamic rivers, whereas in the case of small, confined streams and controlled rivers, morphological changes are generally limited and difficult to investigate. The reconstruction of evolutionary trajectories is based on a series of key parameters, including channel pattern (based on sinuosity, braiding or anabranching indices), channel width, and bed-level changes. Planimetric changes are investigated by a multi-temporal series of aerial photos, while bed-level adjustments are based on the comparison of cross-sections or longitudinal profiles, when available, and field evidence.

Present river conditions are investigated using a series of tools dealing with the different components of the analysis (morphological quality and dynamics), including the Morphological Quality Index (MQI), the Morphological Dynamics Index (MDI), the Event Dynamics Classification (EDC), and the fluvial morphological dynamics corridors (Rinaldi et al. 2014).

The Morphological Quality Index (MQI) (Rinaldi et al. 2013) consists of a set of 28 indicators, defined to assess longitudinal and lateral continuity, channel pattern, cross section configuration, bed structure and substrate, and vegetation in the riparian corridor.

The Morphological Dynamics Index classifies the degree of channel dynamics related to progressive changes occurring in a relatively long-term (i.e., 50–100 years), not including possible responses to extreme flood events (which are addressed in the following EDC). The index is applied only to partly confined or unconfined reaches. The structure is similar to the MQI, and is based on a set of 11 indicators assessing the main factors that control channel dynamics (e.g., river typology, bed and bank erodibility, past changes and present trends of adjustment). The Event Dynamics Classification (EDC) aims to investigate possible channel dynamics associated with extreme flood events (i.e. >100 years return period), and is applied to all river typologies (including confined channels). The classification is carried out by means of a guided procedure consisting of two phases: (1) assessment of expected types of morphological

processes and changes during the event; (2) assessment of the probability of occlusion in critical cross-sections (e.g. bridges).

The analysis of morphological dynamics is completed by the delineation of the fluvial morphological dynamics corridors. In fact, MDI and EDC provide information on the magnitude of channel dynamics in a given reach (1-D analysis), and need to be integrated with a 2-D analysis to define the areas of the fluvial corridor that will be affected by such dynamics. This is achieved by the fluvial morphological dynamics corridors, which represents a further development, adapted to the objectives of this framework, of the erodible corridor concept (Piégay et al. 2005) or the functional mobility corridor (Rinaldi et al. 2009). The fluvial morphological dynamics corridors procedure is implemented by simple GIS tools and includes a reconstruction of historical river courses and a definition of possible future erosion by calculating the mean rate of bank retreat for a given reach. For the aims of the IDRAIM framework, two different corridors are defined. The first corridor (MDC: Morphological Dynamics Corridor) is associated to progressive channel adjustments occurring during recurrent flow events (similarly to the MDI), whereas the second corridor (EDCo: Event Dynamics Corridor) is associated to extreme flood events (similarly to the EDC) and does not account for existing protection structures.

62.5 Phase 3: Future Trends

This phase considers potential future trajectories of channel morphology, in response to existing factors or to different scenarios of management, and their implications in terms of morphological quality and dynamics.

The phase is divided into two steps: (1) monitoring, consisting of periodic measurement of morphological indicators and parameters and analysis of monitored trends of adjustment; (2) modelling, consisting of prediction of possible future trends of channel evolution.

A specific tool, the Morphological Quality Index for monitoring (MQIm) has been developed in the context of the IDRAIM framework. In fact, the MQI was designed to assess the present morphological condition of a stream reach that reflects possible alterations over long time scales (i.e. last 100 years), and may not be suitable for monitoring short-term changes in the channel's condition. The MQIm has been specifically designed to take into account small changes (e.g. small portion of a reach) and short time scales (i.e. a few years), and is particularly suitable for the assessment of interventions, including restoration actions as well as flood mitigation works.

Possible scenarios of future channel changes within a temporal scale of the order of the next 50–100 years can be addressed by using a series of different modelling approaches and tools commonly used in fluvial geomorphology, including: (1) conceptual models; (2) empirical/statistical models; (3) analytical models; (4) numerical models. The selection of a given type of model depends on various factors, such as the objectives of the modelling, spatial and temporal scales, available data and resources.

62.6 Phase 4: Identification of Management Options

In this final phase, guiding principles are provided towards integrated management aimed at improving river morphological quality and/or the mitigation of hazards due to channel dynamics.

A decision-making framework has been developed, including two parallel paths with the objectives of morphological quality or safety. The first step is to formulate possible scenarios for quality enhancement or risk mitigation, followed by an evaluation of the effects of these scenarios on morphological quality and dynamics. Based on these evaluations, the best scenario at the reach scale can be identified, followed by additional considerations about the effects and the best scenario on a wider spatial scale (e.g. effects on upstream and downstream reaches). The analysis concludes with the identification of management priorities.

62.7 Conclusions

The IDRAIM methodological framework has been specifically developed for the management of river processes by integrating the objectives of both the Water Framework Directive (2000/2060) and Floods Directive (2007/2060). The framework builds on a sound geomorphological approach, with specific consideration of the temporal context, in terms of reconstructing the trajectory of past channel evolution as a base for interpreting present river conditions and possible future trends.

Specific tools have been developed for the analysis of river conditions, in terms of morphological quality and dynamics. The monitoring of morphological indicators and the assessment of future scenarios of channel evolution bring the required knowledge for the identification of possible restoration and/or risk mitigation actions. A general management framework has been developed where two parallel paths are defined for the objectives of morphological quality and risk mitigation.

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