
The Magra River (Italy): Effects of the 25th October 2011 Flood Event and a Preliminary Application of the IDRAIM Framework

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Abstract

The Magra River catchment experienced an extreme flood event on 25th October 2011, with return periods ranging from about 100–200 years along the Magra, and up to 500 years along some tributaries. This flood event resulted in morphological changes, flooding, damages and loss of human lives, and has further exacerbated existing conflicts in river management. Such conflicts stem from flood safety being the main management priority, but a growing recognition that preservation of channel forms and physical processes is also important for the aims of the Water Framework Directive. The objectives of this study are to: (1) document channel changes that occurred during this large flood, and analyse them in the context of the longer term (last 150 years) evolutionary trajectory of the river; (2) analyse potential conflicts between preservation of morphological functioning and dynamic mitigation of the channel resulting in increased hazards related to processes of erosion or aggradation.

Keywords

Flood • Morphological changes • WFD • IDRAIM

61.1 Introduction

A variability of channel responses to extreme floods has been reported in literature, from major (e.g. Schumm and Lichty 1963; Baker 1977; Lisle 1981) to minor adjustments (e.g. Costa and O'Connor 1995). Different responses to floods having the same magnitude were even observed within the same catchment (Costa 1974; Fuller 2008).

Understanding patterns and processes of channel response to a large flood and their relations with the river's evolutionary morphological trajectory is fundamental for predicting possible future changes, assessing hazards, and identifying possible management options.

River management is a complex issue which requires the fulfilment of quality and safety objectives according to the EU Water Framework Directive (WFD; European Commission 2000) and to the EU Floods Directive (European Commission 2007), respectively. The methodological framework IDRAIM (stream hydromorphological evaluation, analysis, and monitoring system, Rinaldi et al. 2013) promoted by the Italian National Institute for Environmental Protection and Research (ISPRA) represents a tool to support decisions on river management, as it takes into account both the objectives of environmental quality and flood risk mitigation.

Therefore, the study has a twofold objective: (1) to document channel changes that occurred during this large flood, and analyse them in the context of the longer term (last 150 years) evolutionary trajectory of the river; (2) to carry out a preliminary application of the IDRAIM methodology for supporting integrated river management.

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61.2 The Study Case

The Magra River catchment is located in north-western Italy and covers an area of 1717 km². It falls within a temperate climatic zone characterized by high flows during the autumn and a summer dry season. According to the methodological framework IDRAIM (Rinaldi et al. 2013), the river has been divided into reaches depending on their confinement, channel morphology and relevant discontinuities in terms of flow and sediment discharges. The length of the reaches ranges between 1 and 5 km.

On October 25th 2011, the Magra river catchment was affected by an extreme meteorological event, with hourly rain rates up to 130 mm h⁻¹ and event rain accumulations greater than 500 mm. These large rainfall amounts originated flash floods in the main river channels and in some of the right-side tributaries. The recurrence interval estimated in the Magra R. ranged between 30 and 200 years, having the maximum value in the municipality of Aulla. The impact of the flash flood was devastating, causing severe damage, loss of lives and significant channel changes.

61.3 Characterizing Morphological Effects of the October 2011 Flood

The morphological changes following the flood event were investigated by: (1) field surveys, including a reconstruction of the peak stage profile; (2) GIS-based analysis of aerial photos and LiDAR before and after the event; (3) topographic survey of cross-sections. The analyses, which included the reaches from Pontremoli to downstream of Aulla, were carried out at the scale of sub-reaches (scale of approximately 1 km). The latter were firstly based on the reaches defined according to the IDRAIM methodology and further partitioned according to water surface slope analyses, as suggested by Ferencevic and Ashmore (2011).

Results of the analyses based on the surveyed cross-sections showed a complex pattern of changes, with areas of aggradation and erosion alternated spatially but with prevailing aggradation.

Lateral changes which occurred during the flood event were quantified through the comparison of aerial photos before and after the flood. This analysis allowed the production of a map of the widening and the determination of the spatial distribution of the channel widening. The maximum value of retreat was about 105 m along a braided reach, which corresponds to a variation of about 48 %, whereas the average widening was 35 m corresponding to a change of about 30 %. Widening related to the different channel

morphology showed that the impact of the flood was more severe along braided and wandering morphologies.

Comparison of LiDARs before and after the flood event, also confirmed by field evidence, clearly showed that channel widening was related to two different processes: (1) bank retreat; (2) overbank sedimentation of bedload. This distinction is very important in terms of the sediment supply related to the event.

Morphological changes following the flood were analysed in the context of the long term evolutionary trajectory. Analyses of past channel changes are based on a time series of aerial photos, cross-sections, longitudinal profiles, and field surveys. Results of the evolutionary trends show a recent phase (last 10–15 years) dominated by aggradation and widening, following previous phases (last 100–150 years) of progressive narrowing and incision due to land use changes, the construction of dams and groynes and intensive sediment mining (Rinaldi et al. 2009).

Although the channel changes which occurred with the October 2011 flood were severe, especially in braided and wandering reaches, the comparison with the longer term evolutionary trajectory shows that the channel width is still within the range of variation that has occurred during the last 50–60 years. Changes in channel width that occurred along a series of partly-confined tributaries are more impressive, displaying numerous avulsions and, in some cases, the complete aggradation of the local alluvial plain.

61.4 Assessment of Morphological Quality and Channel Dynamics

The 25th October flood event along the Magra River has further exacerbated existing conflicts in river management arising from the complex task of developing integrated strategies which combine morphological quality and channel dynamics hazard issues according to the WFD and the EU Floods Directive. The event was therefore used as a test case of the IDRAIM methodology for hydromorphological assessment, analysis and monitoring.

A preliminary assessment of morphological quality and channel dynamics was carried out by the application of some components of IDRAIM. In a first stage, a general characterization of the fluvial system and segmentation of the river network into homogeneous reaches was carried out, based on a hierarchical spatial framework. Reaches were defined based on breaks in lateral confinement, channel morphology, and other discontinuities. A second stage started from the retrospective analysis of evolutionary trajectories carried out during the first part. The Morphological Quality Index (MQI)

Fig. 61.1 Morphological Quality Index (MQI) and the Channel Dynamics Index (MDI) distribution along the studied segment of the Magra River

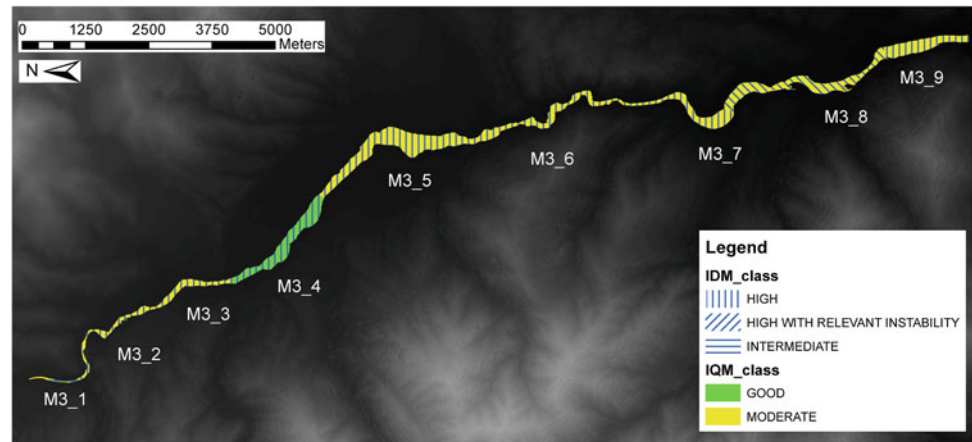


Table 61.1 Results of the preliminary assessment of morphological quality and channel dynamics

Reach	MDI	MDI classification	MQI	MQI classification
M3_1	0.52	Intermediate	0.60	Moderate
M3_2	0.70	High	0.60	Moderate
M3_3	0.64	High	0.67	Moderate
M3_4	0.73	High	0.71	Good
M3_5	0.77	High	0.65	Moderate
M3_6	0.72	High	0.68	Moderate
M3_7	0.79	High	0.69	Moderate
M3_8	0.83	High with relevant instability	0.67	Moderate
M3_9	0.70	HIGH	0.65	MODERATE

and the Morphological Dynamics Index (MDI) were used to assess present river conditions in terms of morphological quality and channel dynamics, respectively. The two indices were applied to the reaches of the Magra River in the sub-catchment upstream the town of Aulla, which was flooded during the October 2011 event. Figure 61.1 and Table 61.1 show the results of this preliminary analysis. Notwithstanding the presence of some artificialities (e.g. upstream alteration of flows), in most cases determines a moderate morphological quality index, the morphological dynamics of the Magra river at the studied segments resulted generally high (Table 61.1).

The application of the two indices will be a starting point for an integrated evaluation of conflicting factors, and represent the basis to evaluate possible scenarios of river management in terms of the mitigation of problems related to channel dynamics and morphological quality.

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