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Morphological changes in a braided river of the Italian Alps during the last two centuries and related dynamics of riparian vegetation

Comiti Francesco[1], Da Canal Marco[1], Surian Nicola[2], Mao Luca[1], Mario A. Lenzi[1]

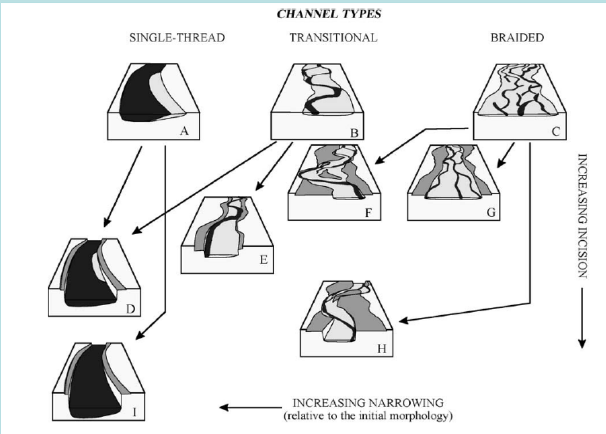
[1]*Dept. of Land and Agroforest Environments – University of Padova – Italy (francesco.comiti@unipd.it; luca.mao@unipd.it; marioaristide.lenzi@unipd.it)*

[2]*Dept. Geography – University of Padova – Italy (nicola.surian@unipd.it)*

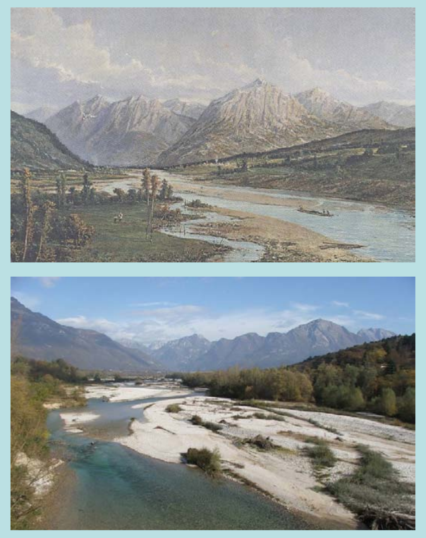
1. Introduction: channel evolution, riparian forests and in-channel wood

Braided rivers are characterised by a highly dynamic response to changes – both natural and human-induced – in their drainage basin. Several braided channels originate in the Eastern Italian Alps, a tectonically active mountain range where high erosion rates supply large amounts of coarse sediment to the fluvial systems. These rivers, like most channel networks in Italy and Europe, underwent major transformation during the last century, mostly as a consequence of human impacts both at the basin and at the channel scale.

- The general pattern of channel adjustment includes channel narrowing, bed incision, and shift towards a wandering/single thread type (Surian and Rinaldi, 2003, see adjacent figure).
- Accompanying channel narrowing and incision, vegetation encroachment took place within the former river channels, and thick riparian woodlands are now present in many locations within the river corridor of these Alpine rivers, on islands and on floodplains.
- Although these riparian forests may bring about benefits in terms of biological diversity within the river ecosystem, they pose several problems from a hydraulic perspective, one of which is they represent source of woody debris that may clog critical sections downstream (e.g., bridges, hydraulic structures)



(from Surian & Rinaldi, 2003, Morphological response to river engineering and management in alluvial channels in Italy, Geomorphology 50-4)



The Piave river from Belluno looking upstream: late 19th century (above) and 2006 (below)

Across Italy, river maintenance activities such as removal of riparian trees and of stranded wood are being justified for the reduction of hydraulic hazards, but actually lack any sound scientific method, and the economic rationale (cost-benefit balance) itself is arguable. Furthermore, a modern perspective on river management aims at restoring natural processes occurring within the fluvial corridor such as bank erosion and wood input.

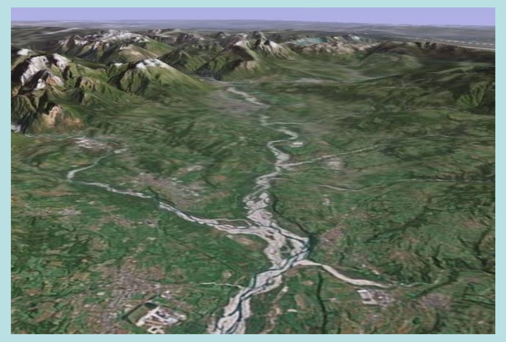
It thus becomes relevant to understand the extent to which the forested areas on floodplains and islands in braided Alpine rivers are due to recent human impacts (e.g. flow regulation, watershed erosion control projects, sediment trapped by dams, gravel mining) rather than a natural characteristic of these river systems.

This study focuses on the morphological changes occurred in a gravel bed river of the Eastern Italian Alps (the Piave river, in the "Vallone Bellunese" synclinal), now covered with abundant riparian vegetation and forested islands that may represent important source of wood during floods.

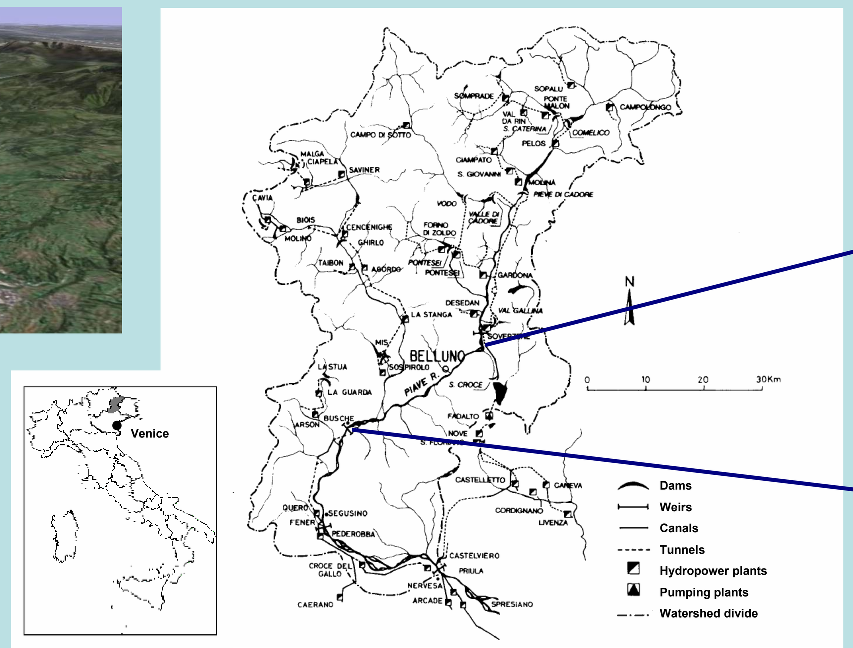
2. Study site: the Piave river (Eastern Italian Alps)

The upper Piave basin (drainage area of 3,200 km^2) has been inhabited since prehistoric times. Its forest cover reached a minimum probably during the 19th century because of wood exploitation, cropping and farming. During 1930s-1950s dams were built along its channel network, intercepting sediments from 54% of the basin area. Between 1960s and 1980s intense gravel mining was carried out. Natural and artificial reforestation have been taking place after World War I, most effectively after 1950s. Erosion and torrent control works started in the 1930s, but massively only after 1970s.

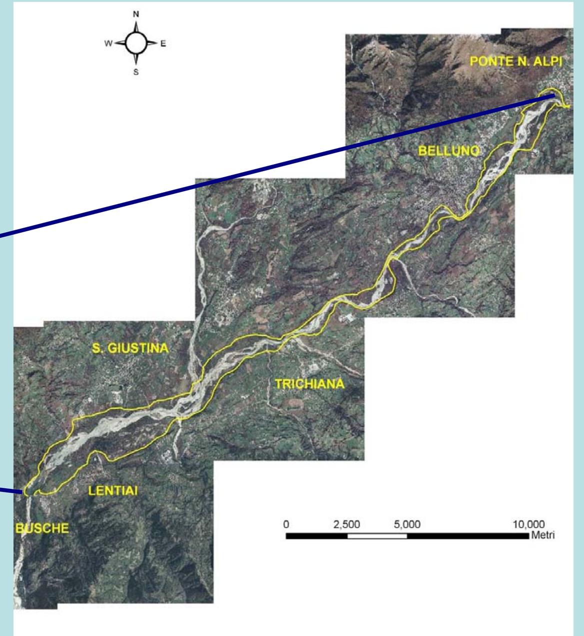
The study reach is 30-km long, and represents the intermediate course of the river within the montane district. At the beginning of the 20th century, it was characterised by a wide, braided active channel mostly confined by climatic terraces. In-channel vegetation was apparently scarce.



The valley of the Piave river in the study section, from downstream.
The river corridor is constrained by post-glacial fluvial terraces and, to a lesser extent, directly by hillslopes..



Map of the Piave basin with its dense network of hydraulic structures for hydropower generation, built between 1930s-1960s



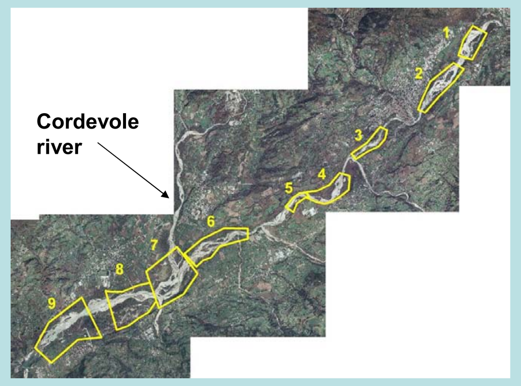
Aerial photo of the study reach. The extension of the stream corridor is reported, within which land use evolution was assessed.

Channel characteristics

- Mean gradient: 0.4%
- Width: 100m – 1,000m
- Grain size: 20<D_{50}<50 mm
- Channel type: braided, wandering
- Q_{max}: ~4,000 m^{3}s^{-1} (1966 flood)
- Q_2: ~ 700 m^{3}s^{-1}

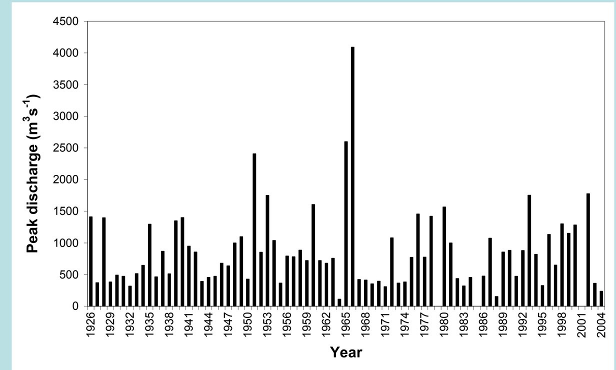
3. Methods

Nine sets of historical maps and aerial photos (from 1805 to 2003) were used to determine changes in the Piave river corridor (active channel width, vegetation type and cover, island areas and number). They were georeferenced, interpreted and edited by a GIS software. 9 sub-reaches differing for channel width and morphology were also identified and analysed separately. Two series of cross-sections (1935-2003) allowed to get insights into the vertical evolution of the streambed. Discharge data (from 1926) permitted to assess the possible effect of flow regulation on formative discharge.



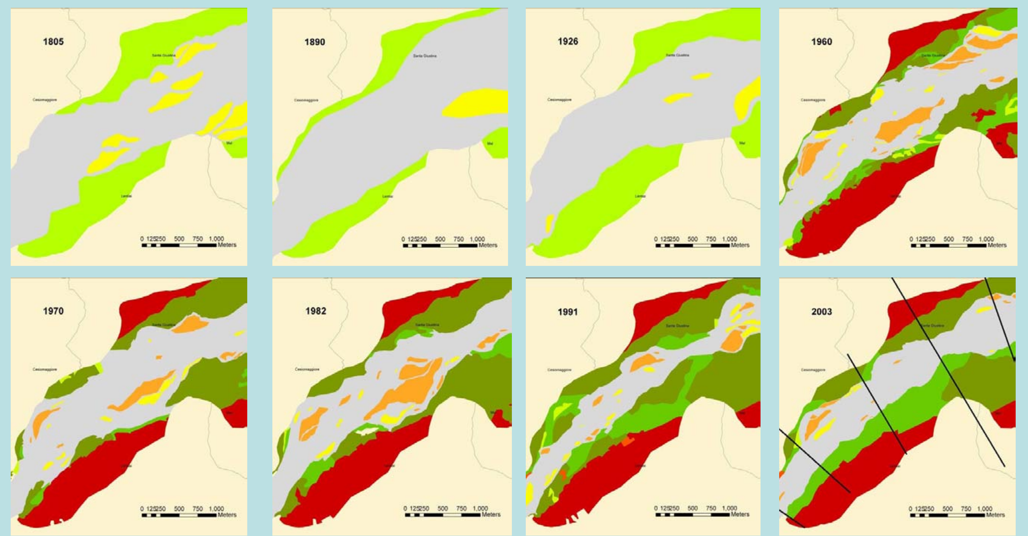
The 9 sub-reaches

Sub-reaches 4-5. From left: 1805, 1926 and 2003

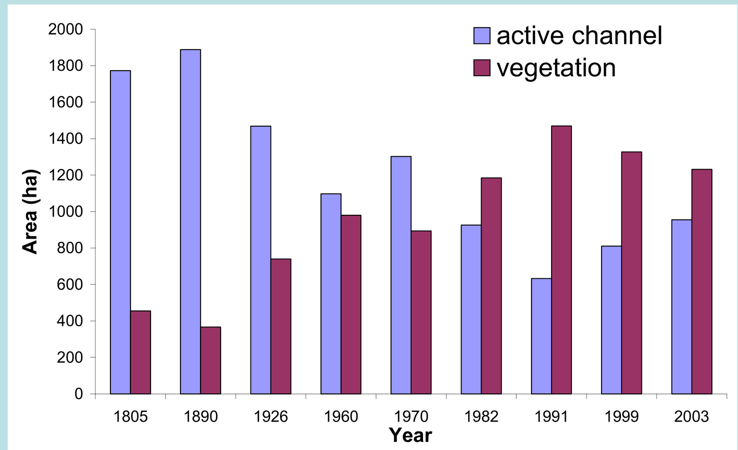


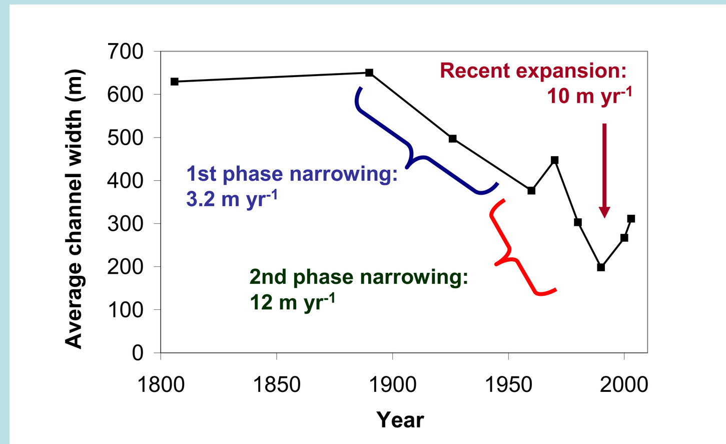
Max annual discharge (1926-2004) measured at Busche-Segusino

4. Results

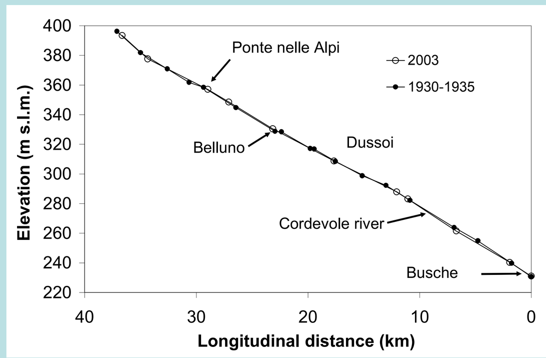


Example of channel evolution (sub-reach 9). A simplified land use classification was adopted for 1805/1890/1926. Green colors indicate vegetation patches, grey the unvegetated active channel. Low flow channels and bars were not identified.



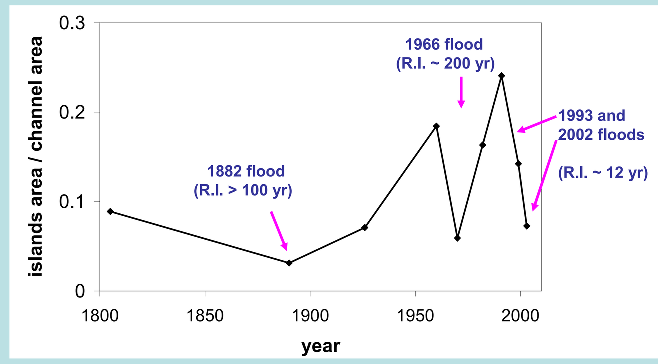


Channel extension and reach-averaged width (i.e., channel area/length) of the entire active channel dropped from late 1800s to their minimum during early 1990s, a trend interrupted only between 1960 and 1970 (1966 flood).
Channel area in 1991 was 1/3 of the initial value. Since 1991 the channel has expanded back.
The extension of riparian vegetation (shrubs and tress, on islands and floodplains) follows an opposite pattern.

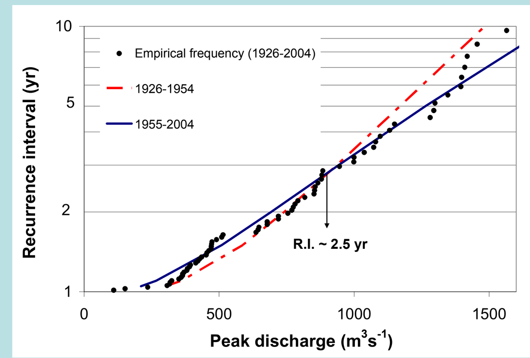


The comparison of the longitudinal profiles (1930s and 2003) shows that bed elevations are very similar.

However, the profile during the period of max channel narrowing (1980s) probably would have displayed a bed incision of about 0.5m – 1m, based on field evidences.

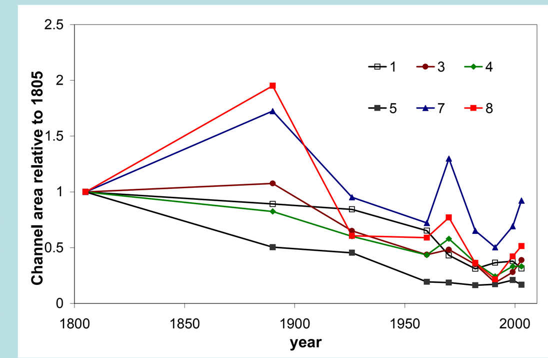


Islands extension dynamics is strongly linked to flood events occurrence. Floods with R.I. > 10-15 yr are responsible for their destruction, similarly to what found by Gurnell & Petts (2002, *Freshwater Biology*) for the near Tagliamento river.



Flow regulation does not seem to have reduced significantly channel-forming events, looking statistically at pre- and post-dams periods.

Channel narrowing and expansion occurred more intensely in the wider subreaches close to the confluence with the Cordevole river (see map in Methods).



5. Conclusions

- The coupled pattern of channel-vegetation dynamics reflects both the changing human impacts on the river system and the timing of large floods;
- Sediment supply rather than flow regime appears the key factor. It decreased after WW I for natural and artificial reforestation (*1st narrowing phase*), then much more intensely because of dam building and gravel mining (*2nd narrowing phase*). After the latter was stopped in the 1990s, and thanks to large floods, the channel has recently been expanding;
- Large islands were already present in the early XIX century, but their relative extension was much smaller (3 times) than in 1991. Present islands area is back to the early 20th century value;
- Island erosion is linked to flood events having recurrence intervals > 10-15 yr;
- Channel width and location influenced the rate of morphological change at a sub-reach scale;
- In a scenario of expanding channel area, in-channel wood is likely to increase, and thus an appropriate management of the potentially unstable riparian forests may be required.

Map showing the location of likely wood sources in case of flood events, derived by intersecting the erodible stream corridor (since 1960) with present riparian forest areas.

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