# Exploring interactions between hydrogeomorphological processes and riparian vegetation along the Fiume Tagliamento, Italy, using remotely sensed data

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## 1. Trees as riparian engineers

Riparian plants and trees can act as ecosystem engineers, strongly influencing sediment retention and fluvial landform building, facilitating the colonisation and establishment of other plant species, and inducing rapid adjustments in river channel size, position and morphology (Gurnell *et al*., 2012). Field investigations at sites on the Fiume Tagliamento, a largely unmanaged, braided gravel bed river in NE Italy (Figure 1), have shown how uprooted trees can instigate island formation following their deposition on the surface of gravel bars (Figure 2, Gurnell *et al*., 2001). However, a lack of appropriate data sets has, to date, hampered efforts to develop a fuller understanding of the bidirectional interactions between hydrogeomorphological processes and riparian vegetation across broader spatial and temporal scales.

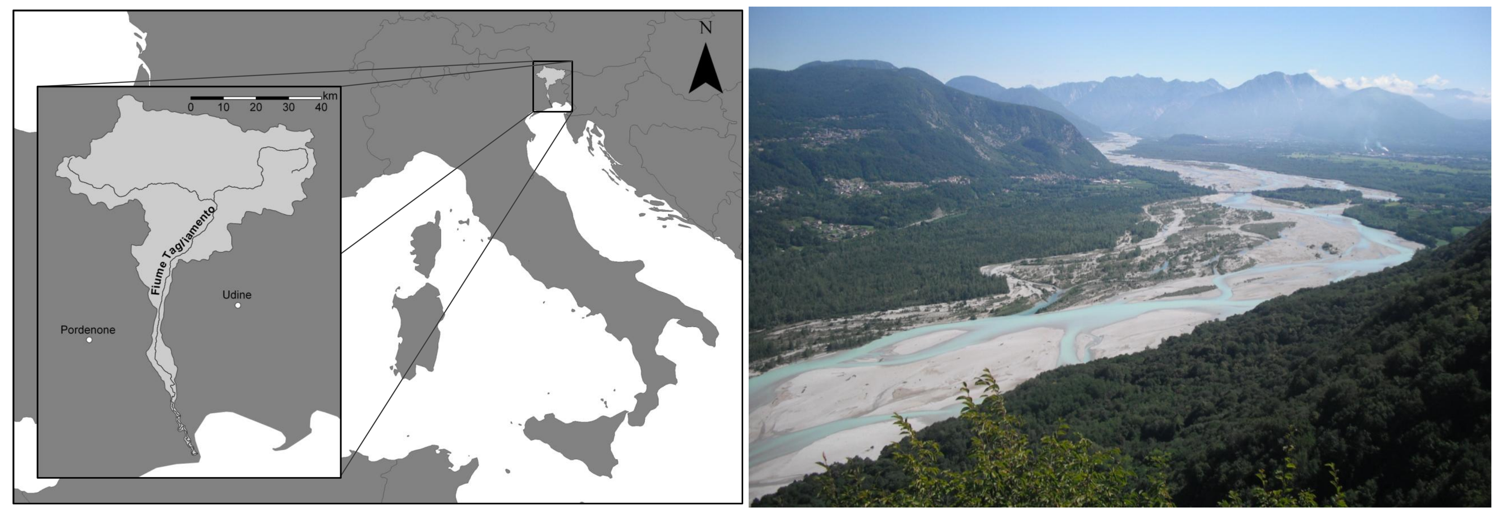


Figure 1. Fiume Tagliamento, NE Italy.

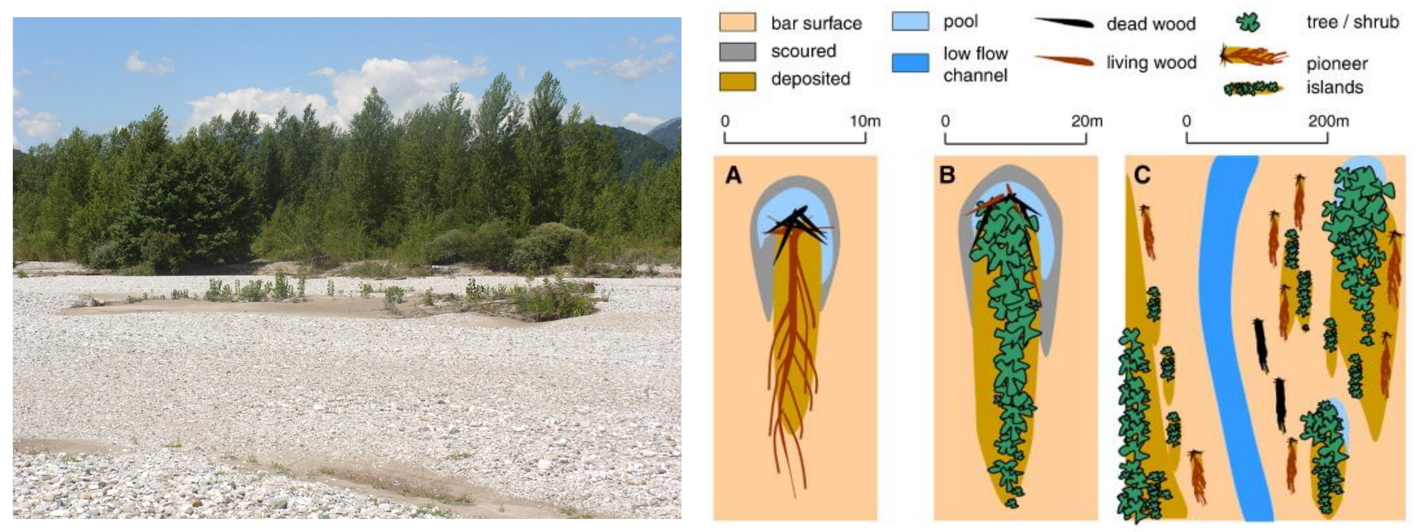


Figure 2. Pioneer (photo foreground) and mature (photo background) islands situated on a large medial bar in the Fiume Tagliamento. Pioneer islands result from the deposition of fine sediment around uprooted trees (A). Subsequent tree regeneration encourages trapping of additional fine sediment and plant propagules, leading to island growth (B). Further growth and coalescence of pioneer islands can lead to floodplain extension and/or the establishment of larger islands (C).

## 2. Quantifying spatiotemporal variation in riparian vegetation and channel morphology using remotely sensed data

Multispectral Landsat TM satellite images (30 m spatial resolution) were analysed to characterise changes in the amount and spatial distribution of riparian vegetation along the Fiume Tagliamento between 1984 and 2011 (Henshaw *et al*., in review). Vegetated areas were identified in 42 one-km reaches using a Normalized Difference Vegetation Index (NDVI)-based classification scheme (NDVI = NIR-R / NIR+R), and coverage estimates were found to compare favourably with aerial photo-derived values (Figure 3). The observed vegetation dynamics were interpreted in relation to spatial variation in river energy conditions (represented by stream power and grain size) and temporal changes in river stage and planform configuration. Calculation of Modified Normalized Difference Water Index (MNDWI) values assisted planform configuration identification (MNDWI = G-SWIR / G+SWIR).

LiDAR data were also analysed to characterise channel morphology and the spatial extent, height and structure of riparian vegetation along the river (Bertoldi *et al*., 2011). Computed bed elevation values and tree heights compared favourably with ground measurements (Figure 4). The frequency distributions of detrended bed elevation values from 19 one-km reaches were described statistically (skewness, kurtosis). Potential relationships between vegetation characteristics (height, growth rate, spatial extent) and these morphological properties were then explored.

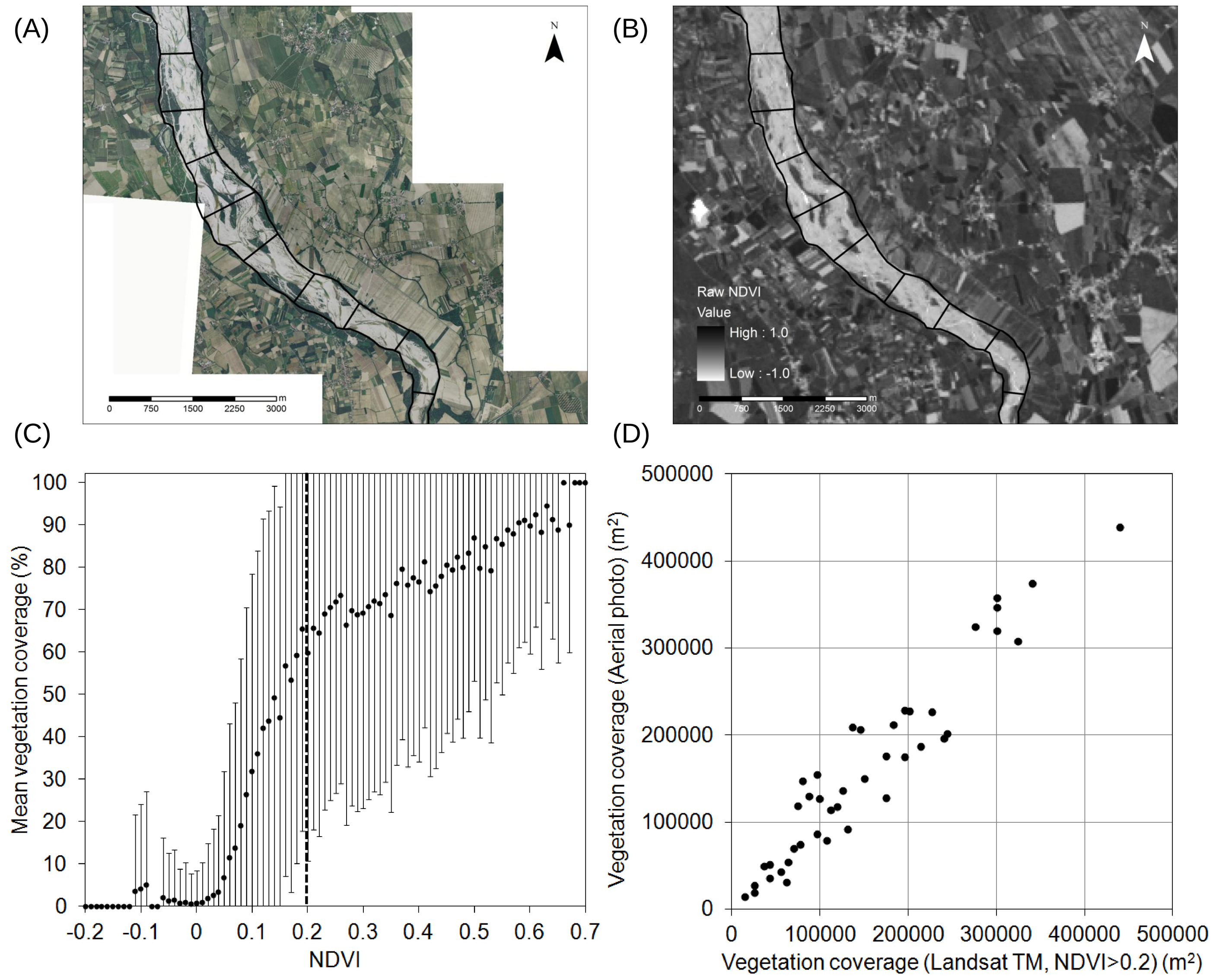


Figure 3. (A) Aerial photo of Fiume Tagliamento near San Vito al Tagliamento. (B) Spatial distribution of Landsat TM-derived NDVI values. (C) Relationship between Landsat TM pixel NDVI and mean vegetation coverage estimated from aerial photo (error bars represent +/- one standard deviation). (D) Comparison between aerial photo- and Landsat TM-derived vegetation coverage for 42 one-km reaches (NDVI threshold = 0.2).

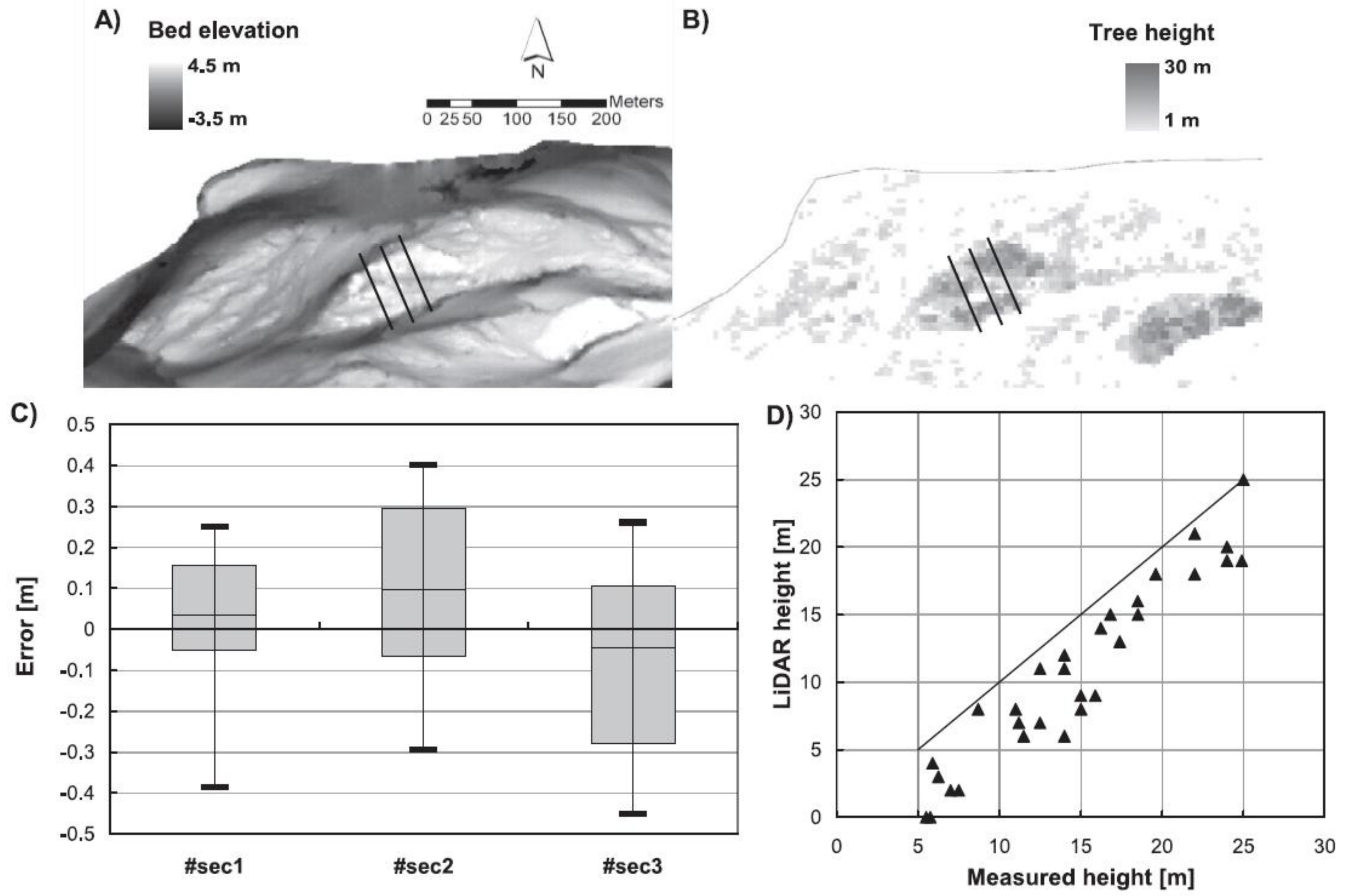


Figure 4. (A) DEM of Fiume Tagliamento bed surface following identification and stripping of vegetation. (B) Height estimates for identified vegetation. (C) Box-and-whisker plots of differences between surveyed and LiDAR-derived bed elevation values along three transects shown in A and B. (D) Comparison between measured (2010) and LiDAR-derived (2005) tree heights.

## 3. Bidirectional interactions between hydro-geomorphological processes and riparian vegetation

The amount and spatial configuration of riparian vegetation varied strongly with both location along the river and time (Henshaw *et al*., in review; Figure 5). Inverse non-linear relationships between reach stream power and bed $D_{50}$ and mean vegetation coverage (1984-2011) were observed (Figure 6), indicating the significance of local river energy conditions for vegetation establishment and survival. Vegetation coverage increased in the absence of disturbance by major floods through the growth and coalescence of islands, with spatial variation in expansion rates influenced by water availability during low flow conditions (Figures 5 and 7). Vegetation loss could not be explained as a simple function of flood magnitude and/or frequency. Instead, removal is controlled by complex channel planform adjustments that can occur over a range of competent flows (Figure 5).

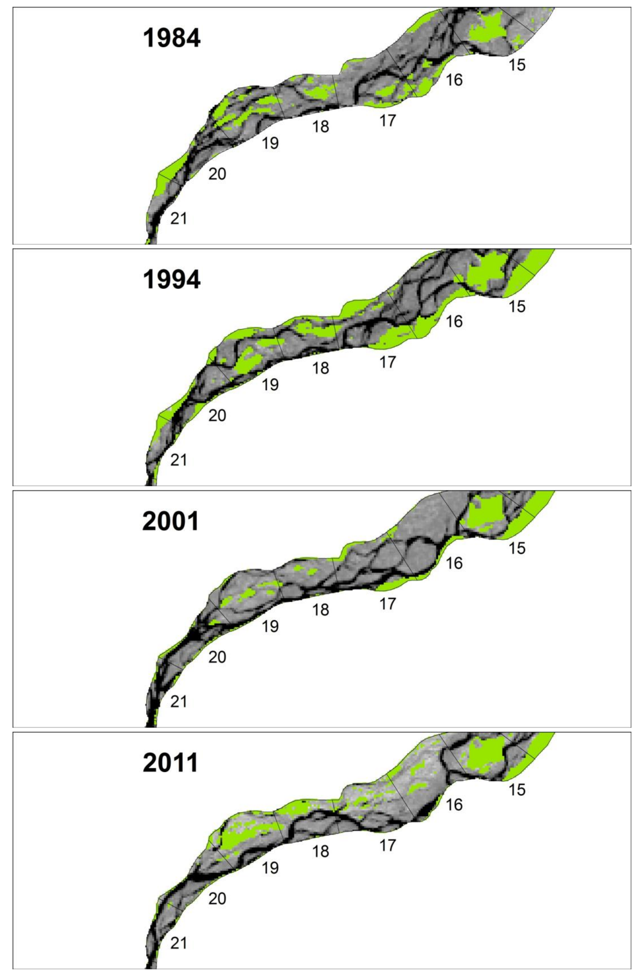


Figure 5. Processed Landsat TM images reveal temporal changes in spatial configuration of vegetation (green) and main channels (black) at Flagogna site on Fiume Tagliamento.

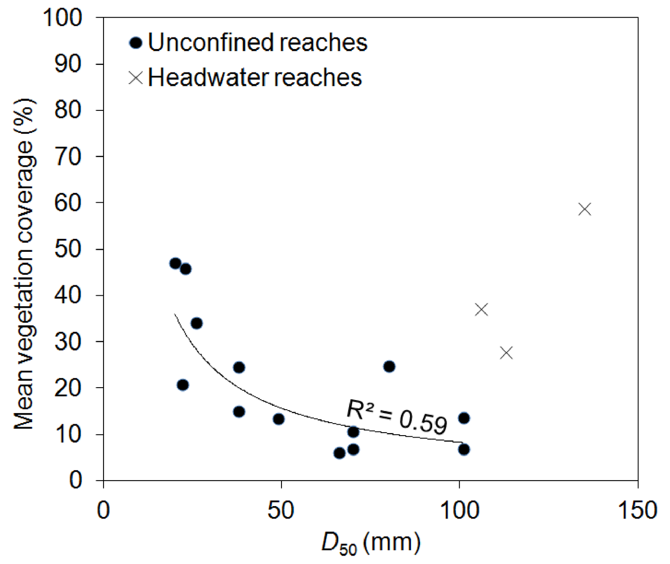


Figure 6. Relationship between reach $D_{50}$ and mean vegetation coverage during 1984-2011 study period.

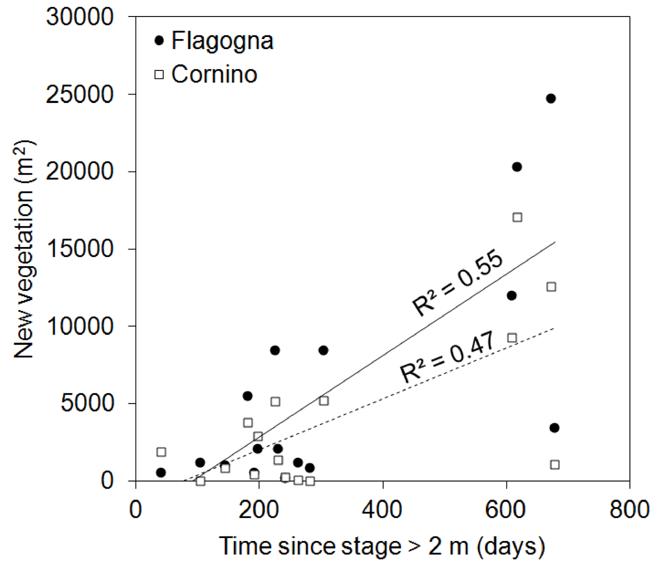


Figure 7. Relationship between time elapsed since last major flood event and amount of new vegetation at Flagogna (wet) and Cornino (dry) sites.

Reaches with little riparian vegetation were found to exhibit a different morphology from those with extensive vegetation cover (Bertoldi *et al*., 2011). Bed elevation values in the former conformed to a gamma distribution, while those in the latter showed significant departures due to the presence of secondary peaks at relatively high elevations that corresponded to vegetated areas. Furthermore, bed elevation frequency distributions were found to become progressively less negatively skewed, and change from leptokurtic to platykurtic, as vegetation growth rate, spatial extent, and height increased (Figure 8). Together, these findings illustrate how riparian vegetation performs an ecosystem engineering role along the Fiume Tagliamento by facilitating the development of islands through the trapping and reinforcement of sediment.

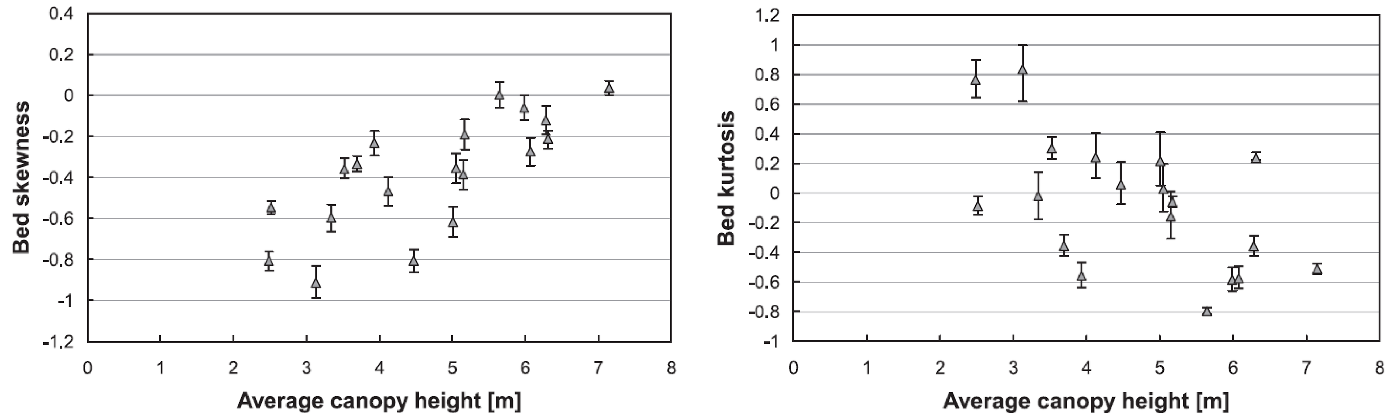


Figure 8. Relationships between average canopy height and reach-averaged bed skewness and kurtosis.

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