Understanding landscape evolution by using DEM analysis, low order channels gradient and Asymmetry Factor: the case study of the upper Scrivia river basin (Northern Apennines, Italy).

Andrea Mandarino, Francesca Ferraris, Marco Firpo
Department of Earth, Environment and Life Sciences
University of Genova
Genova, Italy
andrea.mandarino.fiumi@gmail.com

Abstract—**The main aim of this study is to detect morpho-tectonic elements by using geomorphometry tools and GIS analysis to investigate and describe recent changes of the Earth surface relief. In particular, we search geomorphic evidences of active tectonics throughout active tectonics and classic morphometric indices.**

The upper Scrivia river basin is located along the Adriatic side of the Northern Apennines and shows peculiar landforms often controlled by both tectonics and lithology. Geologically this is a really interesting area, just to the East of the Sestri-Voltaggio Line, the boundary between the Ligurian Alps and the Northern Apennines.

After a general characterization and a zoning of the study area with respect to channels order, we used GIS software to calculate the Asymmetry Factor and its distribution and to analyze the second order channels gradient, both connected to active tectonics.

We recognized a general prevalence of regional tectonics on local tectonics. The gradient map of second order channels suggests recent uplift in the SE sector. The high second order channels gradient values near to the mouth of the studied sector may be connected, on the contrary, to the base level changes related to the Quaternary network evolution of the Po plain.

Preliminary results underline the importance of morphometry to detect large-scale information about landscape evolution and its applicability in different contests. The low order channels gradient may also give useful information about natural hazard assessment.

I. Introduction

The upper Scrivia river basin is located along the Adriatic side of the Northern Apennines, just to the E of the Sestri-Voltaggio Line that divides them from Ligurian Alps (Fig. 1). The study area spreads over 293 km2 and shows particular landforms often controlled by tectonics and lithology: wide valleys characterize areas with a clayey bedrock (Mignanego Mudstone, Montanesi Mudstone and Ronco Fm), while, on the contrary, steep slopes and narrow valleys form on the marly limestones of the 'Monte Antola Formation' and on the Oligocene conglomerates of the Tertiary Piedmont Basin (Savignone conglomerates and Molare Formation). The main trunk channel is drawn upon the Scrivia fault and the Scrivia-Fontanabuona Line [1]. This region shows a transition from Mediterranean to continental climate with hot summers, cold winters and absence of arid season (maximum rainfall registered in autumn).

Aim of this research is to investigate the basin anomalies and morphotectonic evidences by using GIS analysis and geomorphometry tools, in order to reconstruct the recent evolution of the area and, eventually, of the entire region.

II. Materials and methods

GIS analysis started with the Horton-Strahler hierarchization of streams, working on the digitalized network deriving from 1:10000 topographic maps (CTR Liguria, 2007). We used both Quantum GIS 1.8 and 2.4 (QGIS) © and Arc GIS 9.2 ® investigating both the compatibility and the potentialities of the different tools. A geological map (Fig. 2) has been derived from the available maps (1:100.000 Carta Geologica d'Italia and CARG - Genova, Bargagli - 1:50.000) [2,3]. An high resolution DEM (cell size 5 m: Cartographic office of the Liguria Region) has been used to perform a detailed terrain analysis in QGIS starting from classic slopes maps, aspect and gradient maps (Fig. 3). Ultimately, rectified aerial photographs (open data from Geoportale Nazionale) were used to map the main morpho-structural lineaments.

In: Geomorphometry for Geosciences, Jasiewicz J., Zwoliński Zb., Mitasova H., Hengl T. (eds), 2015. Adam Mickiewicz University in Poznań - Institute of Geoecology and Geoinformation, International Society for Geomorphometry, Poznań

To perform detailed analyses the upper Scrivia basin has been divided in smaller sectors, corresponding to the hydrographic basins of fifth order channels. Each of these sixteen basins has been processed with the QGIS plugin "Zonal Statistics" and average slope and elevation have been derived, as well as drainage density [4] and the main indices related to the basins shape (i.e. circularity ratio) [5]. Considering the well known connection between asymmetrical extension of right and left slopes of a river basin and regional tilting phenomena [6] we computed the Asymmetry Factor for the entire basin and for each one of the sixteen sub-basins (Fig. 4), using the equation

$$AF = 100\ (Ar/At), \quad (1)$$

with Ar as right area and At as total area. AF > 50 implies tilt down to the left of basin (looking downstream).

Lastly, we analyzed the low order channels gradient, known in literature to be connected to relative tectonic activity of mountains fronts [7,8]. Low order channel gradients are the aptest to register changes due to long-term uplift, increasing streams order the channels gradients are less altered by tectonics [6]. During rapid uplift, in fact, streams are rejuvenated and stream gradient increase. While larger streams are able to maintain their profile forms by incising rapidly enough to adjust to lower base level, smaller tributaries are unable to rapidly readapt, hence, they accumulate the effect of base level fall and have steepest profiles in the areas of highest uplift rates [9 and references therein]. In this study we used second order channel gradients because first order channels deriving from the utilized maps were just traces of incision. The slope of second order channels have been computed in ArcGIS (Easy calculate, free on line tool, www.ian-ko.com) as the ratio between the difference in elevation from the head to the mouth and the stream's total length. Slopes values are returned as attributes of a points shapefile; each point is located in the centre (with respect to elevation) of the related stream.Throughout the data interpolation tool, using the Inverse Distance Weighted (IDW) method, a thematic map of gradient's trend have been created (Fig. 5,6).

III. Results

Fifth order basins as well as the entire study area are characterized by an irregular shape, first sign of rejuvenating factors affecting the landscape evolution.

Drainage density values are strictly related to bedrock types: high values are linked to clayey lithotypes while lower ones are generally connected to marly limestones. The AF distribution (Fig. 4) does not show particular trend for the 16 analysed sub-basins. On the contrary, we can observe a strong asymmetry for the entire study area (AF = 64,9%). Regional tilting seems therefore to affect the area more than local tectonics; nevertheless, the presence of major tectonic lineaments does not allow to completely exclude this element.

Maps comparison (Fig. 2,3,6) gives relevant information: the outcropping bedrock and its structural characteristics are clearly related to slopes gradient. Marly limestones, typically liable for steep slopes, show an anomalous behaviour in the centre of the study area, along a NNE-SSW lineament, where a wide and gentle topographic surface is recognizable. According to the authors [10 and references therein] this structure may be related 1) to the presence of an anticline, 2) to the load of the overlying conglomerates or, 3) to the relict of an ancient hydrographic network.

The slopes gradient map and the low-order channels map show different trends. Within large sectors relief evolution seems to be decoupled from incising waters and linked to mass movements: this is clearly evident in the central zone, where the Savignone Conglomerates widely outcrop. The low-order channels map shows several areas of correlation with respect to lithology, nevertheless areas of random distribution of channels gradient are present too. Decoupled from the geological context this parameter can be linked to tectonic forcing. On this base, a SSW-NNE band possibly undergoing recent uplift has been isolated in the SE sector of the study area; this zone, located eastward of a morphologic lineation, has uniform bedrock with various attitude and presents several faults. Lastly, the high second order channels gradient values registered near to the mouth of the studied sector seem to be connected to the base level changes related to the Quaternary network evolution of the Po plain.

IV. Conclusions

In the study area landscape evolution has been heavily driven by tectonics. This research implements the geomorphological knowledge about the Scrivia river basin, convalidating, on the one hand, the existing theories on the region evolution, and offering, on the other one, new data for further analyses.

Morphometric approach for searching data about landscape evolution and for recognizing morphotectonic evidences plays an important role in this research sector.

Low order channels gradients, compared to slope and geology evaluations seems to be a useful tool that may be used with success also for natural hazard assessment in mountain areas.

A. Figures and Tables

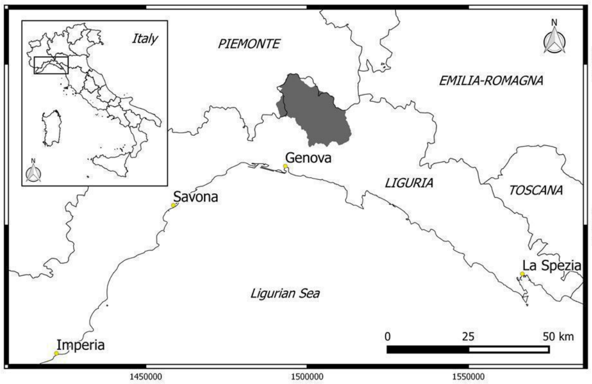

Figure 1. Study area

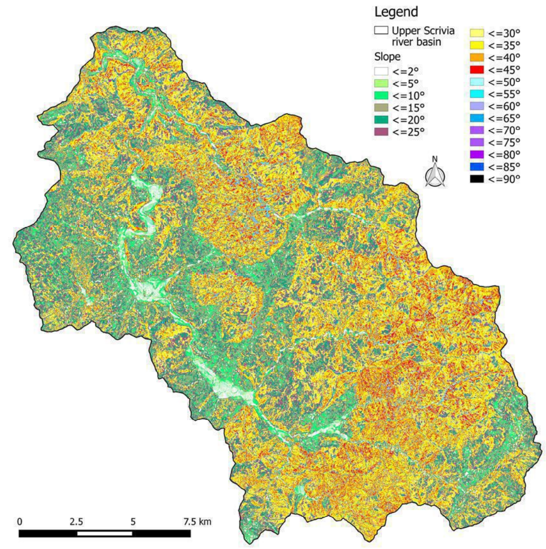

Figure 3. Slopes gradient map

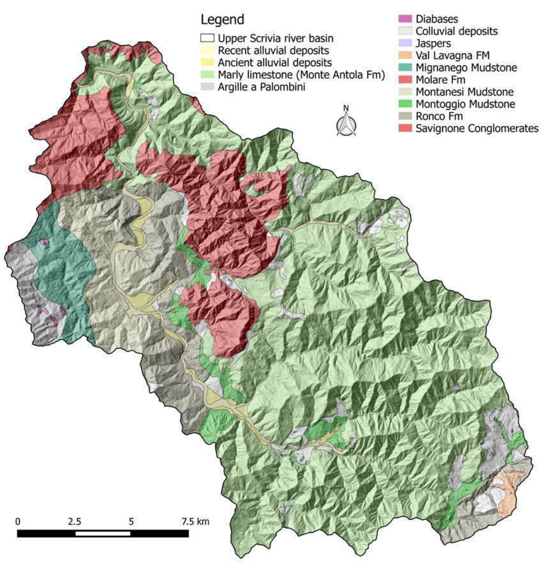

Figure 2. Geological map

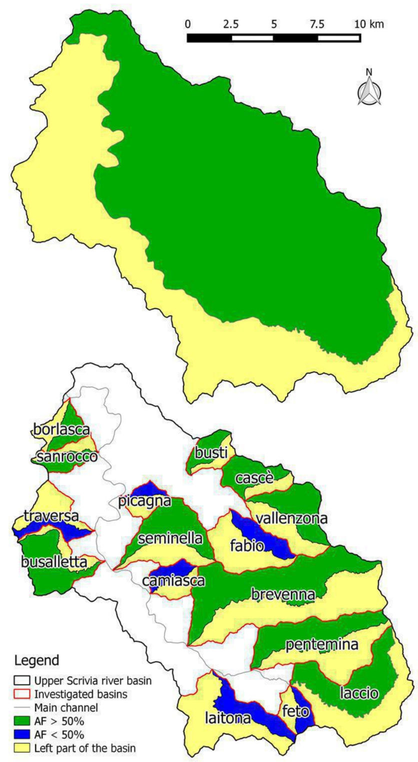

Figure 4. AF map

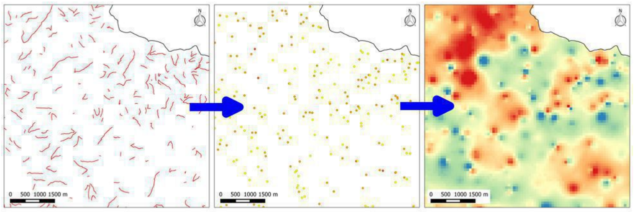

Figure 5. Phases to obtain Fig. 6

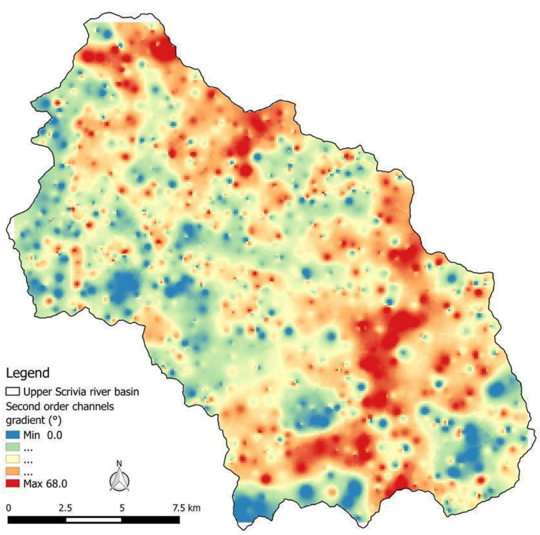

Figure 6. Second order channels gradient map

REFERENCES

[1] Capponi, G., Crispini, L., Federico, L., Piazza, M. and L. Amandola, 2009. "Late alpine tectonics in the Ligurian Alps: constraints from the TPB Conglomerates". Geological Journal, 44, 211-224 p.

[2] Boni, A., Braga, G., Conti, S., Gelati, R., Marchetti,G. and L. Passeri, 1969. "Note illustrative alla Carta Geologica d'Italia, Fogli 83 Rapallo e 94 Chiavari". Servizio Geologico d'Italia, Roma, 89 pp.

[3] ISPRA, "Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, Foglio 214 Bargagli". Edited by Elter P., Marroni M. e Pandolfi L. – Servizio Geologico d'Italia, in press.

[4] Horton, R. L., 1945. "Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology". Geol. Soc. Am Bull., 56, 275-370 p.

[5] Strahler, A.N., 1964. "Quantitative geomorphology of drainage basins and channel networks". In: Handbook of Applied Hydrology, edited by V.T.Chow, 4, -40-74, McGraw-Hill, New York.. 200

[6] Keller, R.A., and N. Pinter, 1996. "Active tectonics, earthquakes, uplift, and landscape". Prentice-Hall Inc., Upper Saddle River, New Jersey.

[7] Frankel, K., and F.J. Pazzaglia, 2005. "Tectonic geomorphology, drainage basin metrics and active mountains front". Geogr. Fis. Dinam. Quat., 28, 7-21 p.

[8] Merritts, D., and K. Vincent, 1989. "Geomorphic response of coastal streams to low, intermediate, and high rates of uplift, Mendocino triple junction region, northern California". Geol. Soc. Am. Bull., 101, 1373-1388 p.

[9] Ferraris, F., Firpo, M. and F. Pazzaglia, 2012. "DEM analyses and morphotectonic interpretation: The Plio-Quaternary evolution of the eastern Ligurian Alps, Italy". Geomorphology, doi:10.1016/j.geomorph.2012.01.009

[10] Sacchini, A., 2012. "Dinamica geomorfologica con particolare riferimento alle deformazioni gravitative profonde di versante in alta valle Scrivia (Appennino Ligure)". Ph-D thesis, University of Genova, 277 p.