PRELIMINARY RESULTS OF A STUDY OF THE MORPHOLOGIC - PLANIMETRIC VARIATION OF A CENTRAL ITALY CREEK

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ABSTRACT. We show the results of morfologic - planimetric variations of the Virginio Creek (Central Italy, Florence). The use of historic maps and aerial photographs helped to evaluate and quantify the active morphologic processes in the studied reach. For this kind of aim, Grass GIS, used in the geocoding, digitizing and measuring phases, is a good work instrument.

1. INTRODUCTION

The study of rivers morphologic - planimetric variations through time is fundamental to understanding fluvial systems. Maps and aerial photographs allow to study contemporary fluvial processes with a larger time perspective [Petts, 1989, Hooke & Redmond, 1989].

To examine the cartographic database it is necessary to bring data to a common scale and this procedure is today made much simpler by the use of GIS.

Grass is a good work instrument. The procedure used in this work can be considered extremely intuitable and absolutely similar to that adopted, using non GPL software, by other researchers [Downward et al., 1994, Leys & Werrity, 1999, Werritty & Leys, 2001, Winterbottom, 2000, Surian, 2002].

We are reporting the preliminare results of a research carried out along a reach of the Virginio Creek (Chianti Hills, near Florence). The Virginio Creek experimental basin is an important watershed to measure hydrological and sedimentary parameters and a lot of research teams have worked on it.

2. RESEARCH PREAMBLE

The impetus for the research came from the evidence that, as observed by numerous other authors for different rivers [Cencetti et al., 1992, Bravard et al., 1997,

FIGURE 2.1. Creek reach extremely incised. You can note the high left banks and the outcropping of overconsolidated pliocenic clay

Surian, 1999, Rinaldi & Simon, 1998, Winterbottom, 2000, Surian, 2002, Arnaud-Fassetta, 2003, Surian & Rinaldi, 2003], the geomorphological survey shows the evidence of a remarkable thalweg lowering (the thalweg is the line that joins the max depth points along the channel) and of a simultaneous reduction of the active area width, which is the part of the river width characterized by the presence of gravel and sand sedimentary bodies and by the absence of vegetation [Winterbottom, 2000].

Field indicators of these phenomenon are: the abandonment of the alluvial plain, the presence of numerous different order terraces, the bedrock outcropping along the water course (see figure 2.1), the evidence of suspended paleo river bed, and so on. The field geomorphologic analysis, however, can show all these phenomenon, but can't quantify them.

The study of fluvial forms and creek morphologic classification [Rosgen, 1994, Rosgen, 1996] have confirmed the field observations. Indeed, all the considered reaches can't be classified into the Rosgen model, which, as is well known, has been derived from natural formed rivers. The cross sections morphology is typical of a sinuous river, but the Virginio creek is straight, that is planimetric behaviour of a braided river. This observation fits with a quick analysis of the historic maps of the river. The 1930 map, indeed, show that, in that period, the water course was characterized by the presence of numerous sedimentary bodies (also longitudinal), large width and straight planform path.

3. Used cartographic sources

On the basis of these considerations we started to research the planimetric evolution of the Virginio Creek.

We have used three cartographic sources:

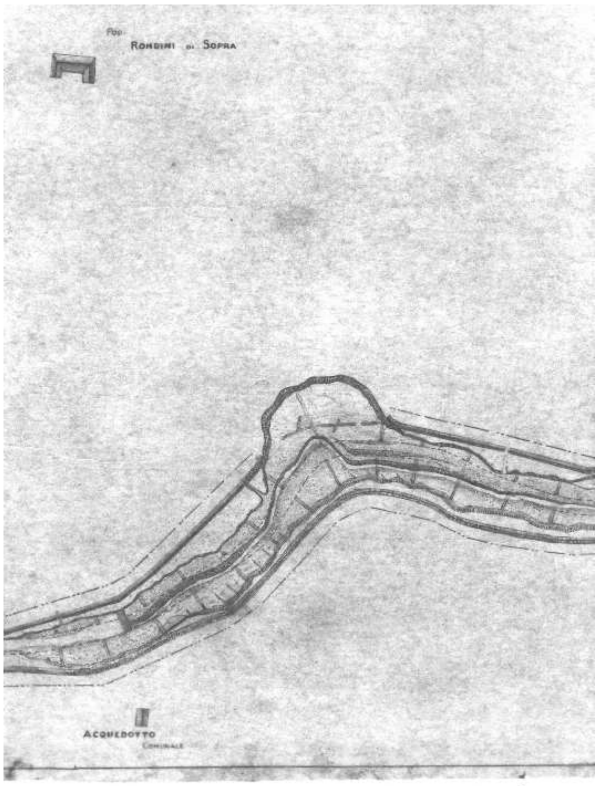
- aerial photographs taken during a dedicated fly carried out in 2001 (scale 1:3000);
- aerial photographs taken during a dedicated fly carried out in 1982 (scale 1:3000);
- Historic map, about a "restoration project", in 1930 (scale 1:2000), see figure 3.1.

For each fly, the number of aerial photographs taken was around 50. The historic map, instead, is constituted by three paper documents. These two kinds of documents cover around 70% of the total Creek length.

4. Geocoding of cartographic data

4.1. **Geocoding procedures.** All the maps and aerial photographs were scanned with appropriate resolution and later imported, as not geocoded raster images, to a generic xy location. Subsequently a Gauss-Boaga-Roma40 location was created and it was used to import the Technical Regional Maps (CTR) acquired by the Tuscan local government cartographic office (1:5000 scale).

FIGURE 3.1. A sample of the 1930 historic map.



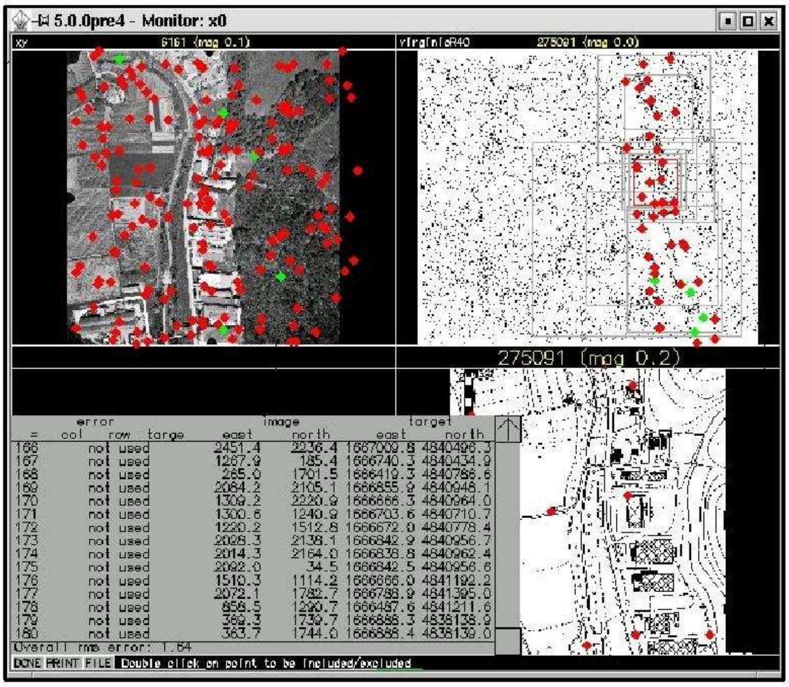
Through the Grass geocoding modules (i.group, i.target, i.points, i.rectify), the previously listed cartographic data was transformed to the Gauss-Boaga coordinate system (see figure 4.1). The operation was carried out through the *image to raster map* procedure [Neteler & Mitasova, 2002].

During this operation the errors related to the positioning of each of the GCPs (Ground Control Points) was analyzed by the use of RMS error values.

Three groups of images were created (i.group module): one for the scanned historic map files and two for the aerial photographs. This method helped to speed up the procedure. During the operations, the GCPs used for the rectification of each file were annotated.

Due to the aerial photographs large acquisition scale it wasn't possible to locate more than 5 or 6 GCPs inside each aerial photograph and, consequently, the used method for the rectification was the first order polynomial. In the case of the historic map, instead, the large number of GCPs located

FIGURE 4.1. Geocoding Phase



(more than 10 for each scanned map) enabled us to rectify the images using a second order polynomial [Downward et al., 1994].

The aerial photographs and also the historic maps, were scanned using a 300 dpi resolution, obtaining a ground cell side of around 0.25 metres and 0.21 metres respectively.

The imported file dimensions (tiff format) weren't larger than 8 and 400 MB (for each aerial photograph and historic maps respectively).

The PC used for the work (500 Mhz and 128 Mb) was more than capable of executing all the operation. For the image rectification phase (i.rectify module), Grass was extremely effective, because, working in the background, it didn't affect the PC's general performance and allowed the user to continue to work.

The accuracy of the transformations was also evaluated by comparing the position of some points located on the rectified cartographic data and the position of the same points on the 1:5000 CTR.

The aerial photographs showed an average RMS error of around 5 metres (see table 1). The historic maps, instead showed a larger average error (30

TABLE 1.

Indetermination errors in the positioning of aerial photographs

Aerial photographs 1982	$\sigma_x = 3.22$	$\sigma_y = 4.12$
Aerial photographs 2001	$\sigma_x = 2.4$	$\sigma_y = 3.03$

metres). This this big error is due to the low precision used, by the maps authors, to position the few buildings that we have then used as GCPs in the rectification process. However, the high accuracy in the representation of creek characteristics (banks, sedimentary bodies, hydraulic works), also imposed by the project, allows us to think that the water course absolute dimensions can be considered reliable. So the historic maps haven't been used to execute relative shift measures but only to evaluate absolute parameters like average width and sinuosity.

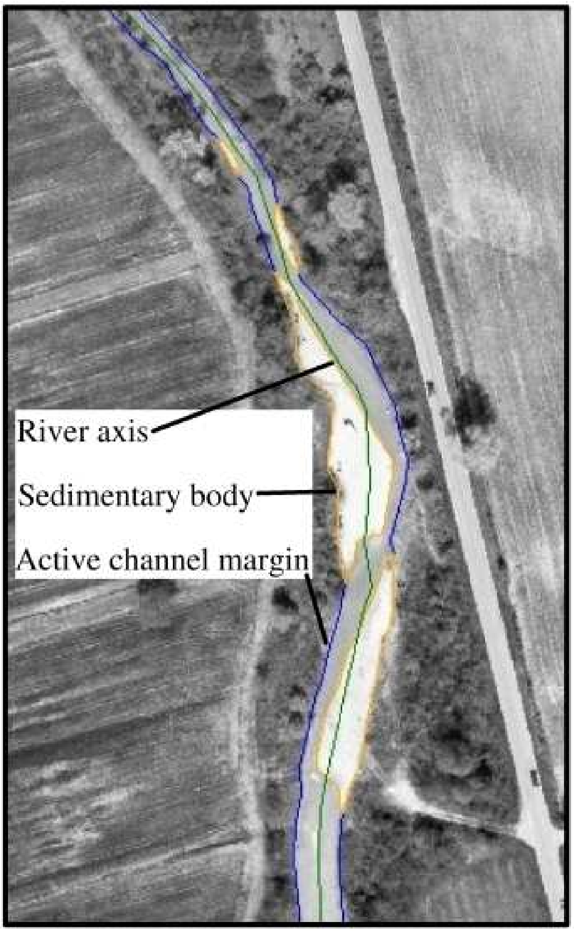
The indetermination errors we found in the rectification of aerial photographs are due to numerous factors, among them:

- distortion due to the projection (central for aerial photographs, orthogonal for the CTR);
- distortion due to the scanning effect.

Rigorously, the geocoding process of aerial photographs would have to be executed by the use of a high resolution plain scanner and through the orthorectification of the scanned images. The reasons we didn't follow this strict procedure are:

- we didn't know the Camera Parameters Calibration for the 1982 aerial photograph;
- the DEM of the study area was still not in our possession (only recently we obtained contour data from the Tuscan local government);
- the large number of aerial photographs to rectify implied the use of a quick and simple procedure;
- the landscape of the study area, uniform and without high reliefs, minimized errors due to the morphology;
- the cost of a plain high resolution scanning of all the aerial photographs is too high for a similar small research.

FIGURE 4.2. Morphological and sedimentological characters' digitized



4.2. **Morphological and sedimentological characters' digitalization.** To compare the water course characters we proceeded to digitize (v.digit module) the active area perimeters, the sedimentary bodies (bars) margin and the river axis (see figure 4.2). The photo-interpretation, in this phase, was used to enhance recognition, by stereoscopic vision, of some creek elements.

Different parameters value were evaluated:

- the average active river bed width;
- the river axis, defined as the joining of all the points equidistant from the active area margins;

- the valley axis, defined as a broken line traced arbitrarily following the direction of the valley and, for this reason, invariable during the time;
- the sinuosity, defined as the distance between two points, measured along river axis, and the same distance straight measured;
- the average braiding index (the number of canals along river axis in a defined reach);
- the lateral shift (the shift of the river axis during the time);

5. Results

All the parameters showed sensible variations during the time.

5.1. **Active river bed width.**

The average active river bed width was evaluated on the basis of a simple ratio between the polygon area representing river active area and the total length of the river axis:

$$average\ active\ river\ bed\ width\ = \frac{area\ poligon}{axis\ river\ length}$$

The value of this parameter passed from a value of 38.35 metres in 1930, throughout 11.51 metres in 1982, to 7.42 metres in the 2001 (see fig. 5.1).

We can see a dramatic variation of this parameter, which today is around 20% of the value at the beginning of the 20th century. The diagram in fig. 5.1 shows that the variation is rapid in the first phase and slower in the second. However, if we admit that the narrowing phenomenon started after 1930, we can imagine that the first phase was much more rapid we can see from the diagram.

5.2. **Sinuosity.**

The sinuosity was evaluated along the whole reach studied.

The average sinuosity of the creek increased, although not enormously, over time. The increase seems to have been quite constant (see fig. 5.2): the value passed from 1.11 in 1930, to 1,13 in 1982 until it reached 1.14 in 2001.

5.3. **Braiding index.**

The braiding index (BI) was compared only for 1982 and 2001. This is because the sedimentary bodies represented on the historical maps can sometimes be inaccurate.

Figure 5.1. Average active river bed width

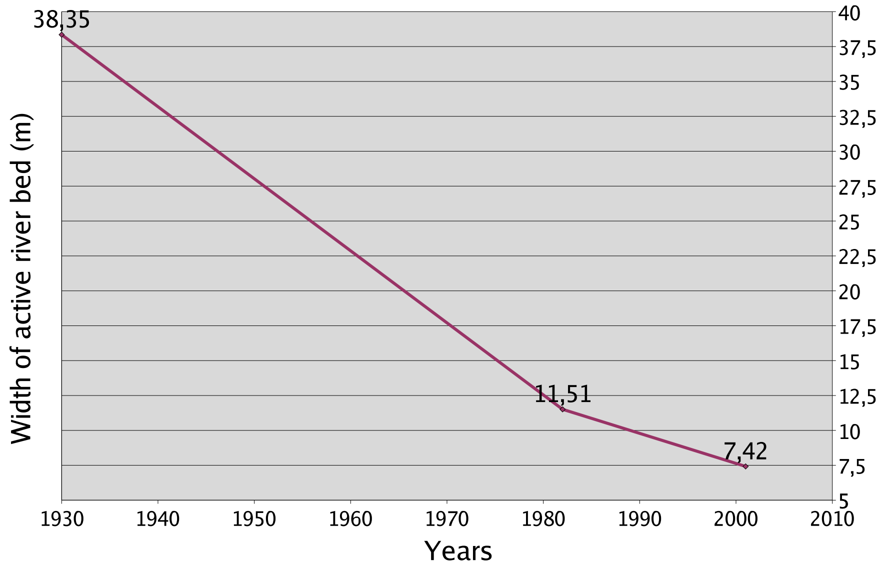
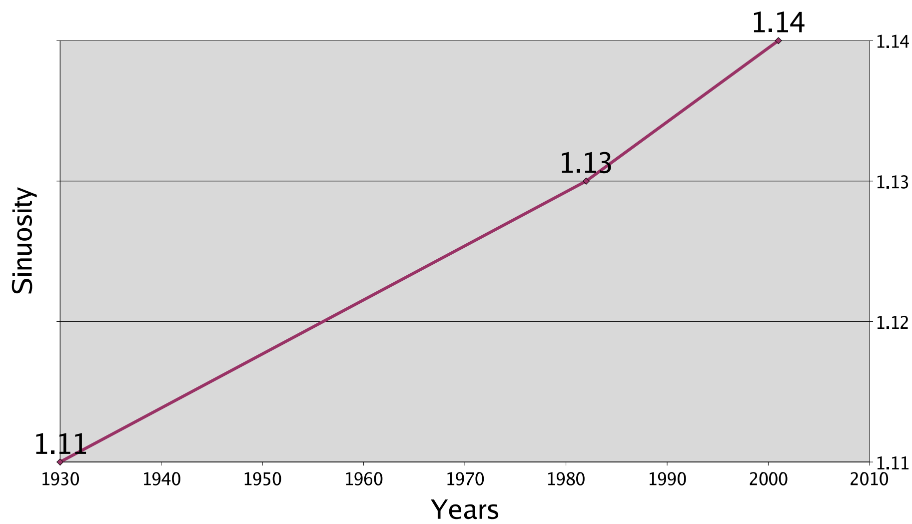
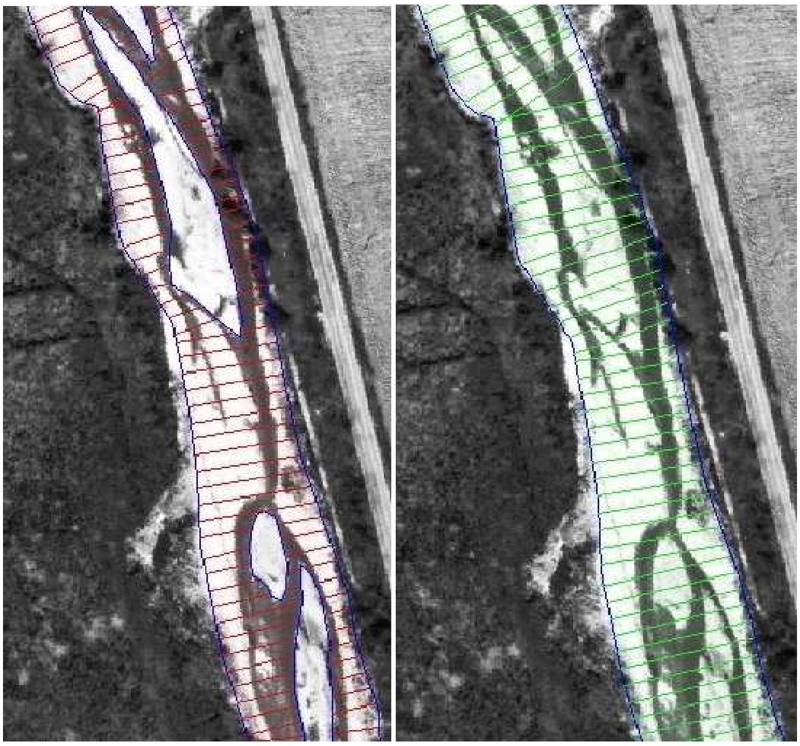


Figure 5.2. Sinuosity of the studied reach



This parameter was evaluated along a reach which in 1982 showed numerous lateral and longitudinal sedimentary bodies. Many definitions exist for this parameter [Thorne, 1997]; in this paper the BI is defined as the ratio

FIGURE 5.3. Measuring the BI in a short river bed reach. The left picture shows the lines representing canals widths, the right picture shows the lines representing active river bed widths.



between the number of segment digitized perpendicularly along the river axis (representing the width of canals) and the number of segments representing the active river bed width (both digitized regularly spaced along the river axis) (see fig. 5.3). As this parameter depends on the length of the sedimentary bodies, the digitized transects have to be very close regularly spaced to correctly represent the fluvial morphology.

The braiding index average value was 1.31 in 1982 and became 1.03 in 2001: many longitudinal, nude, sedimentary bodies have become lateral, inactive vegetated bars (see fig. 5.4) .

5.4. **Lateral shift.** The lateral shift was evaluated by a procedure already used [Leys & Werrity, 1999]: some segments were traced perpendicularly to the 2001 river axis to intersect with the 1982 river axis (see fig. 5.5); the segments, which represent the lateral shift, were distinguished on the basis of

FIGURE 5.4. River bed reach showing transformation from braided to single channel morphology.

the direction, respective to the valley axis, in which the lateral shift occurred. The lateral shift was evaluated for the period 1982-2001 and in the reaches where, from a first visual inspection, it was possible to note probable river path variations.

The standard deviations of the positioning errors can be used as the indetermination parameters and to obtain the indetermination in the lateral shift measure:

$$\sigma_x = \sqrt{(\sigma_{2001})_x^2 + (\sigma_{1982})_x^2} = 4.02\ m$$

$$\sigma_y = \sqrt{(\sigma_{2001})_y^2 + (\sigma_{1982})_y^2} = 5.12\ m$$

On the basis of this result we decided to consider only lateral shifts larger than 10 metres.

The results of this measure show river reaches where lateral shifts were of the order of 1.3 - 1.2 metres/years (see fig. 5.6).

FIGURE 5.5. Evaluation scheme of the lateral shift

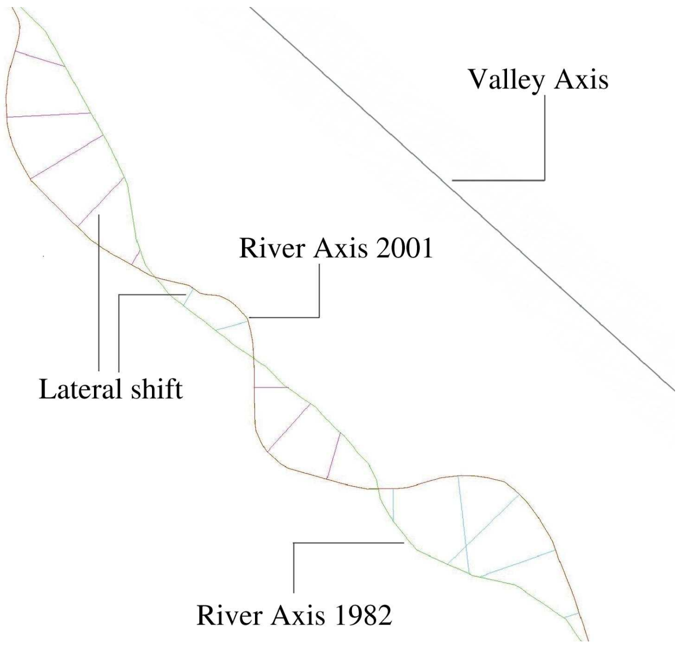


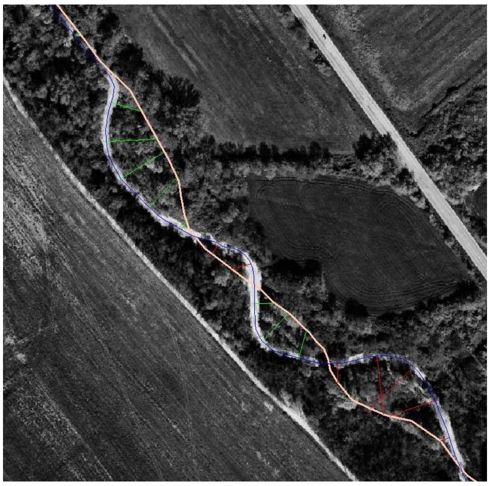
FIGURE 5.6. Bank erosion and damaging of agricultural land property: in rose the 1982 river axis path, in blue the 2001.

The lateral shift shows frequently the tendency of the river to increase its sinuosity (see fig. 5.7) .

6. Conclusion

The results obtained show the creek's transformation, which, over the years, has diminished the average active river width and the number of canals, but has simultaneously increased its sinuosity. This data seems to

FIGURE 5.7. River bed lateral shift: pink line represents the path of the 1982 river bed axis; blue line represents the path of the present river bed axis.



confirm that the Virginio Creek is changing its morphology, towards a planimetric path similar to that the Rosgen (1994) method previews.

The results match the field observations and represent a quantitative estimation of fluvial processes in action.

The reasons for this behaviour have to be researched in the construction of numerous hydraulic works (also represented on the 1930 historical map). These works could have determined the river bed incision and channellization, causing the overcoming of a "geomorphologic threshold" between the braided and the sinuous river [Schumm, 1973].

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