FLOODING AREAS OF OFANTO RIVER USING ADVANCED TOPOGRAPHIC AND HYDRAULIC APPROACHES

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ABSTRACT:

Apulia Basin Authority (AdBP) is actually carrying out an advanced and complex study for evaluating flooding areas of downstream reach of Ofanto, one of the most important river in Southern Italy. The performed analysis is strictly related to a reliable definition of the hydraulic risk map in order to plan efficient hazard management actions. Due to the geo-morphological characteristics of the selected river branch – that presents a length of about 36 km from the Roman bridge, close to Canosa city, to the sea outfall –- this activity represents an interesting case study for the contextual use of modern technologies in topographic data management and hydraulic computation. The geometrical model used for the hydraulic simulation was created using input data coming from airborne laser scanning (LIDAR), which generates 1 m cell-size Digital Surface Model (DSM) and Digital Terrain Model (DTM), that were integrated with high-resolution digital orthophotos. The hydraulic simulation was developed adopting a mixed 1D/2D scheme, where one-dimensional model within the levees and two-dimensional model outside were used. Simplified model for estimating friction factor distribution within the floodplain area was adopted, too.

RESUMEN:

La Autoridad de Bacino de la Puglia está realizando un tema avanzado y complejo para establecer las áreas inundables de la parte terminal del rio Ofanto, uno de los rios más importantes del sur de Italia. El estudio desarollado está estrechamente ligado al mapeo real del riesgo hidráulico para planificar una actividad eficiente de gestión del riesgo. Examinadas las peculiaridades geològicas-morfológicas de la parte terminal del rio – con una longitud aproximada de 36 km desde el puente Romano, cerca de la ciudad de Canosa, hasta la desembocadura – dicha actividad representa un interesante motivo para utilizar modernas tecnologías sobre la gestión del elemento topográfico y sobre la utilización de códigos de cálculo hidráulico. El modelo geométrico utilizado para la simulacióne hidráulica está hecho empleando elementos de entrada obtenidos por el procedimiento *airborne laser scanning* (LIDAR), que permite generar modelos digitales del terreno y modelos digitales de superficie con celdas de 1 m de lado, integrados con ortofoto de alta resolución. La simulación hidráulica ha sido desarollada utilizando una esquematización mixta 1D/2D, con modelado monodimensional en el interior de los espigones y modelado bidimensional en el exterior. Se ha adoptado además un modelo simplificado para la estimación del factor de rugosidad en la llanuras aluviales.

1. INTRODUCTION

The Ofanto river is one of the most important in Southern Italy. It has a watershed area, involving Puglia, Basilicata and Campania, of about 2790 km^2 and a total length of about 170 km (Figure 1). The river presents a semi-perennial regime, with a monthly average discharge value less than 15 m^3/s. Even if water discharges near to zero are frequently observed during the dry season, large peak flows may occur. The National Group for Prevention of the Hydrological Hazards (*GNDCI - Gruppo Nazionale per la Difesa delle Catastrofi Idrogeologiche*) of the Italian National Research Council (*CNR - Consiglio Nazionale delle ricerche*) reports, in an electronic database (*SIVAPI - Sistema Informativo per la Valutazione delle Piene*), many flood data, from 1920 to 1970, related to the Ofanto river..

The investigated area is about 200 km^2 and is strictly connected to the downstream reach of the Ofanto river - which has a length of about 36 km from the Roman bridge to the sea outfall – covering lands of five cities, in which a complex agricultural and infrastructural system has determined, in the last decades, a considerable alteration of the original territorial settings. Indeed, the low valley of the Ofanto river was interested since the 19th century by several fluvial works for land reclamation, as the construction of Tittadegna diversion channel, that flows into the Ofanto river just 2 km far from the sea outfall and drains a watershed area of about 300 km^2. It is remarkable to note that, during the eighties, soil levees and concrete bank protections have been realized along the lower reach of the river.

2. HYDRAULIC MODEL

2.1 Mixed 1D/2D scheme

According to the geometrical and environmental characteristics of the investigated Ofanto reach, the hydraulic model has been set up to represent the flow dynamics inside the banks and through the bridges, the junction of the Tittadegna channel, as well as the flood on surrounding areas, taking into account the interference with the road embankments and the presence of the reclamation channels. Due to the complexity of the river hydraulics and for computational optimization, the hydrodynamic simulation has been developed using a mixed 1D/2D scheme (Figure 2). One-dimensional solution was adopted inside the banks, whereas a two-dimensional scheme was used outside for correctly evaluating water flow paths on the overland area. The used calculation tool is the TUFLOW (Two-dimensional Unsteady Flow) code, distributed by the BMT WBM [*Syme*, 2001a].

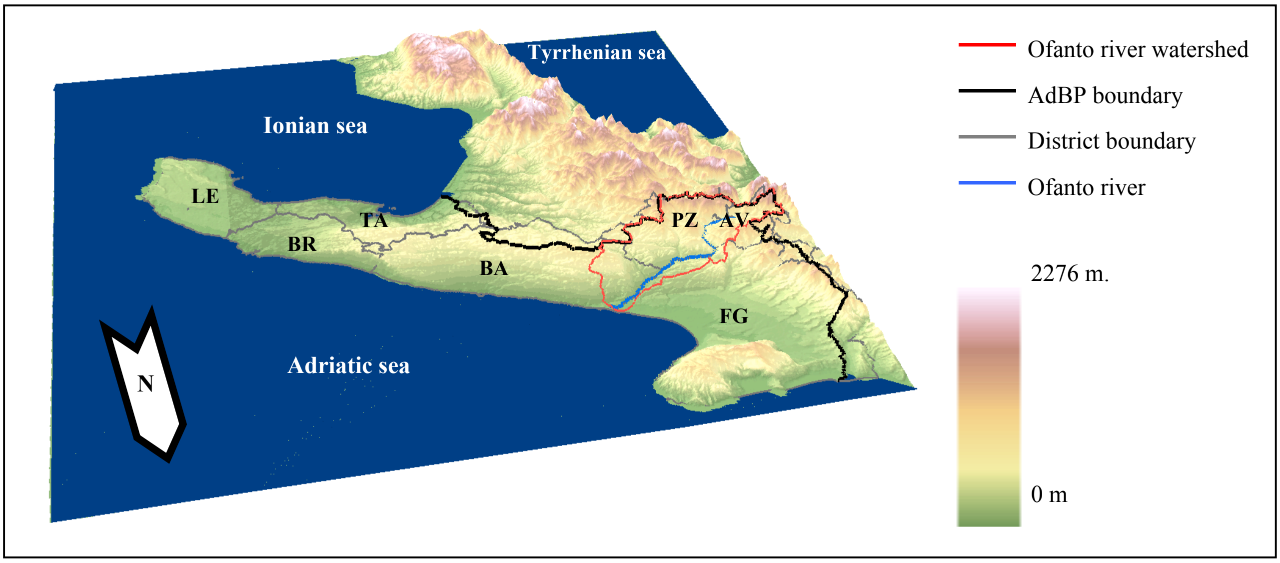

Figure 1. Geographical setting of Ofanto river watershed

2.2 Topographic information

Detailed topographic data is an essential element for a reliable and accurate hydraulic modelling, because elevation data drive free surface water flow [*French*, 2003]. In order to perform a correct detailed analysis, the Apulia Basin Authority (*AdBP - Autorità di Bacino della Puglia*) acquired an airborne LIDAR survey, carried out by *Compagnia Generale Ripreseaeree S.p.A.* (*CGR*) along the lower river reach; 1 meter cell-size Digital Surface Model (DSM) and Digital Terrain Model (DTM), joined with high-resolution digital orthophotos, were used for building the geometric model.
For computational requirements, the Lidar DTM was re-sampled to a 35 meters quadratic mesh on the two-dimensional domain, while levees and road embankments were reproduced by breaklines, whose elevations were interpolated by means of the 1 meter cell-size DTM. A specific field survey was necessary for locating the openings in the embankments, that were easily recognized in the investigation area by high-resolution DTM and digital orthophotos. These openings were schematized as one-dimensional elements, opportunely linked to two-dimensional domain [*Bradley*, 1978; *US Army Corps of Engineers*, 1995].

Figure 2. Mixed 1d/2d scheme on Lidar DTM

◆ 0,27 - 0,46 ◆ 0,46 - 1,37 ◆ 1,37 - 2,38
◆ 2,38 - 3,47 ◆ 3,47 - 5,51 m

Figure 3. CHM obtained by subtracting DTM from DSM

2.3 Roughness evaluation

About the subject, a fundamental issue is related to the roughness determination, playing this parameter a key rule for hydrodynamics simulation, because it represents the flow resistance – as related to the presence of obstructions, surface irregularities and vegetation - and thereby produces effects on water depth and flow velocity. Due to the impracticability of field measurements for cost and time savings and being in absence of calibration data, a scientifically based methodology, that uses LIDAR data for mapping roughness, was applied [*Smith*, 2004]. Because airborne laser scanning is able to penetrate a forest canopy, local vegetation data (Figures 3 and 4) can be estimated by means of the Canopy Height Model (CHM) (Figure 3), as generated by subtracting the ground surface altitude (DTM) from the canopy surface altitude (DSM) [*Zhao*, 2007].

(a)

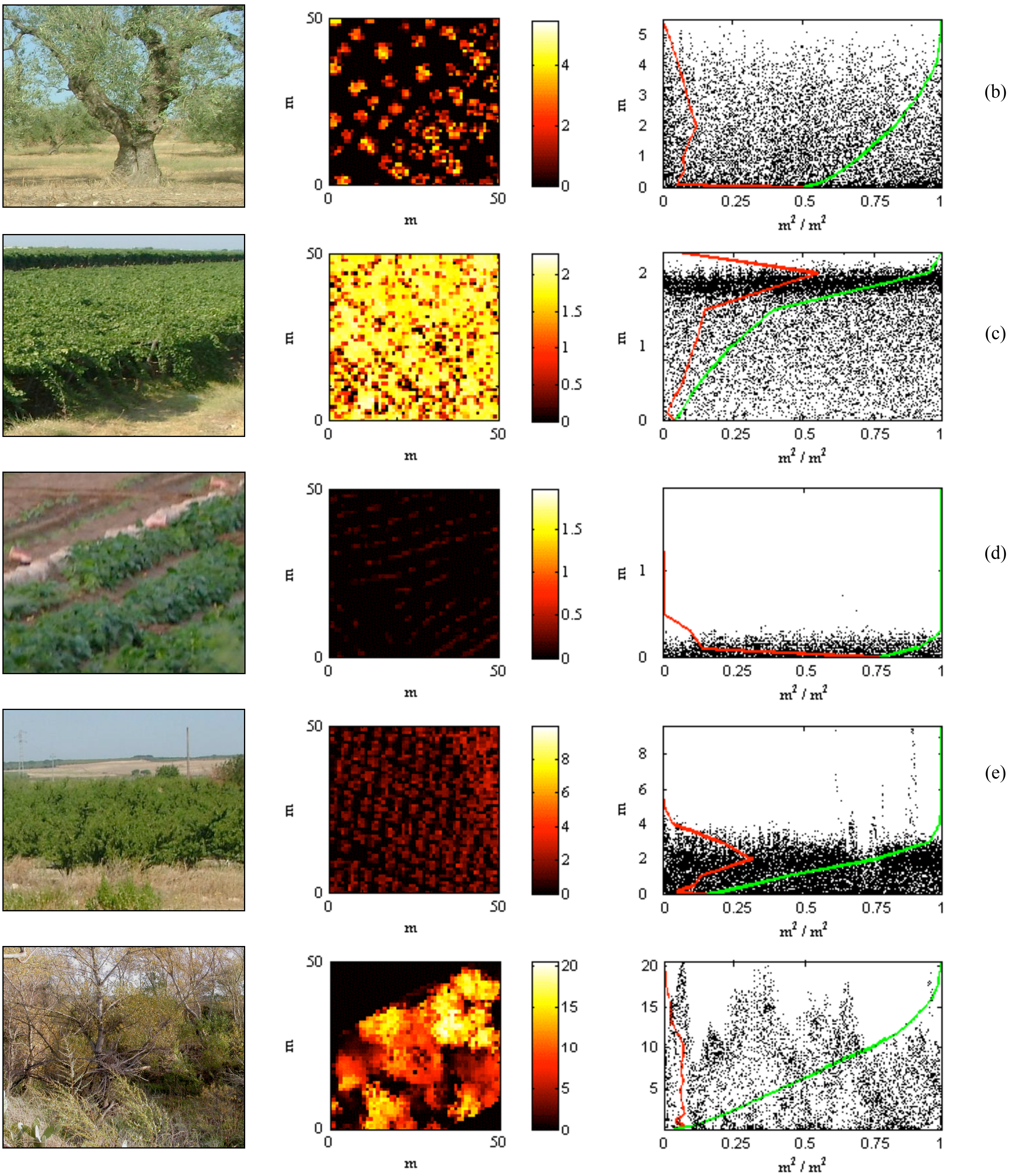

Figure 4. CHM maps for vegetation- analysis on (a) olive trees, (b) vineyard, (c) arable, (d) orchard, (e) trees and shrubs

Land use		Mean vegetation height [m]	Max vegetation height [m]	Min vegetation height [m]	Std dev.
(a)	olive trees	0.78	5.51	0.00	1.18
(b)	vineyard	1.40	2.29	0.00	0.62
(c)	arable	0.02	1.97	0.00	0.05
(d)	orchard	1.24	9.96	0.00	1.02
(e)	trees and shrubs	6.61	20.62	0.00	4.81

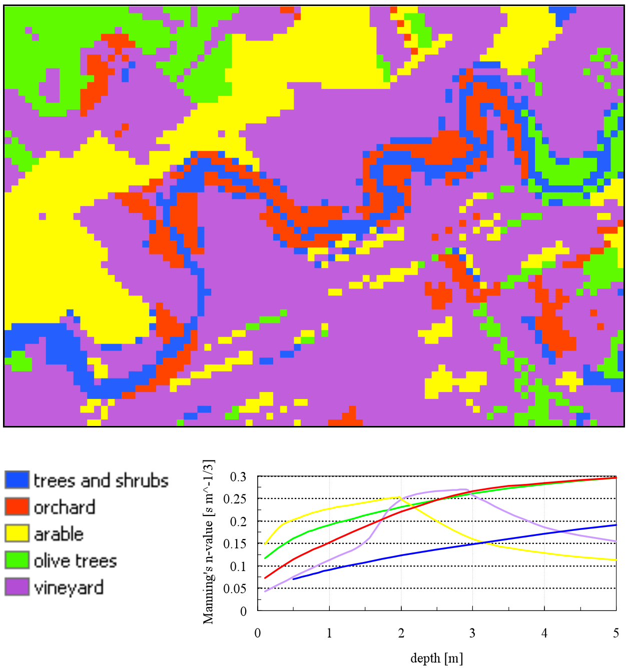

Figure 5. Roughness map

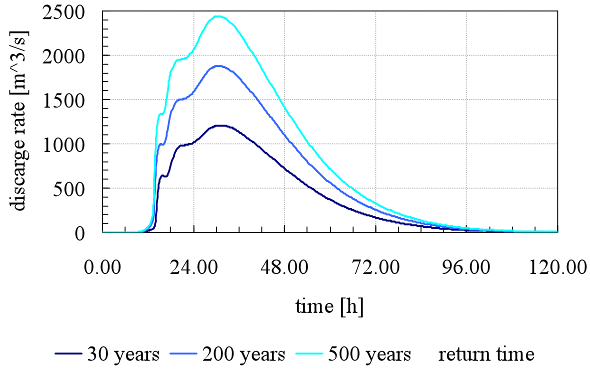

Figure 6. Flood hydrographs of Ofanto river

Once defined the vegetation data, that were validated using a recent land use map, the Chezy roughness coefficient was estimated using the following equation [*Baptist,* 2005] :

$$C_r = \sqrt{\frac{1}{C_b^{-2} + (2g)^{-1} C_d D_v H_v}} + \sqrt{\frac{g}{k}} \ln \frac{h}{H_v} \quad (1)$$

where Cr = Chezy coefficient representing roughness of bare soil plus vegetation ($m^{1/2}.s^{-1}$)
Cb = Chezy coefficient for the bare soil ($m^{1/2}.s^{-1}$)
g = acceleration of gravity (9.81; m s^{-2})
Cd = drag coefficient (-)
Dv = vegetation density (m^{-1})
Hv = vegetation height (m)
k = Von Karman constant that is equal to 0.4 (-)
h = water depth (m).

By means of the equation (1) a friction factor value was assigned to any cell of the computational domain, as a function of the depth water (Figure5). The calculated values, although they need calibration, appear to be in agreement with other data coming from the scientific literature [*Arcment*, 1984; *Chow*, 1959]. In detail, high roughness values are inside the levees due to the presence of orchards and high and dense shrubs adjacent to the stream, while the vineyards located in the surrounding areas are characterized by roughness coefficient – as expressed by Manning index, n - that increases when the water depth increaseas, until the water level reaches the top of the crop height, where the leaf density is the greatest.

3. FLOODING SIMULATION

The unsteady flow simulation has been carried out using flood hydrographs corresponding to 30, 200 and 500 years return times (Figure 6) as defined by means of HEC-HMS (Hydrologic Engineering Center, Hydrologic Modelling System) software distributed by U.S. Army Corps of Engineers

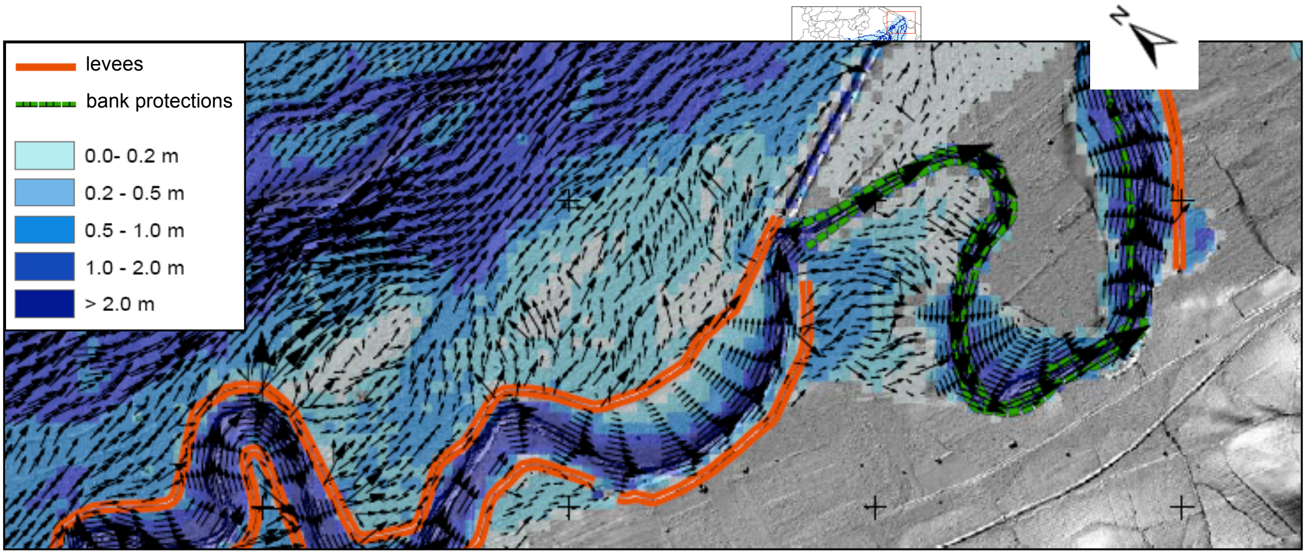

Figure 5. Vector and raster representation of flooding simulation on Lidar DTM

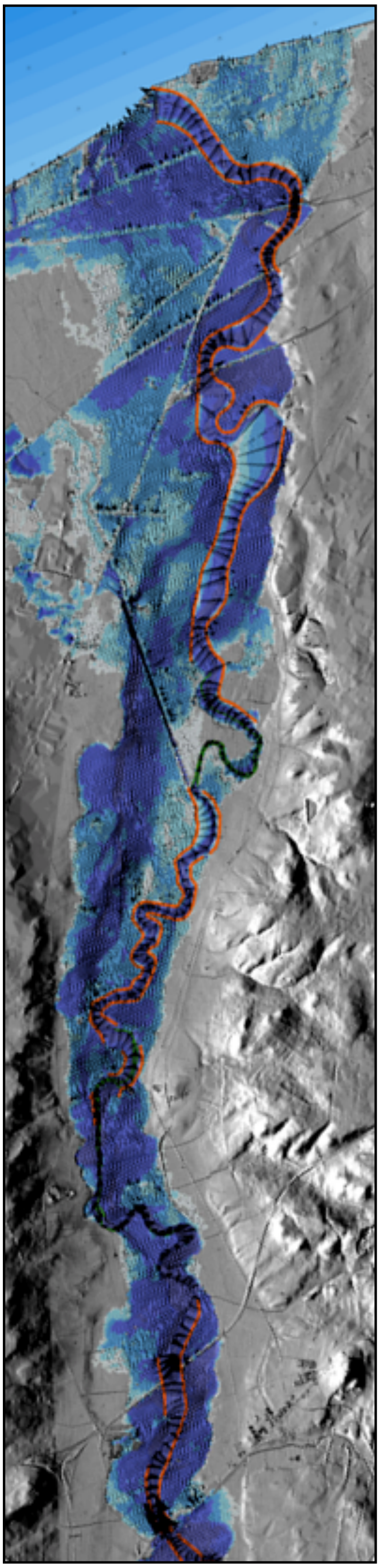

Figure 8. Flood-prone area of downstream reach of Ofanto river

[Maion‹ reas the rainfall data has been estimated according to the VAPI procedure proposed by GNDCI – CNR, that determines the rainfall-depth-duration curves using a two component extreme value probability distribution (TCEV) [Copertino, 1994].

The simulation results (Figures 7 and 8) show as the fluvial works are not adequate for containing peak flows characterized by return time equal or greater than 30 years. Moreover, the presence of un-authorized orchards insides the levees, increasing vegetation roughness, determines a strong reduction of the river flow capacity. In general, while on the hydraulic right the flood water generally remains confined by the natural lands slope of fluvial terrace, the relevant overflows occur on hydraulic left with propagation toward the downstream valley, involving large agricultural and urban areas and important transport infrastructures,. with water depth even higher than 1 meter and flow velocity greater than 2 m/s.

It's also relevant to note the activation of the derivation channel on the hydraulic left of the main stream, used in the past for reclamation and now disused and covered by crop.

4. CONCLUSION

The model set up properly reproduces the dynamic of the flooding - this is the propagation of the peak flow inside the banks and the inundation of surrounding area induced by stream overflow - thanks to the detailed topographic data, a suitable hydraulic 1D/2D scheme and an innovative model for estimating roughness distribution. The proposed approach, that appear to be consistent with the field data, allows to obtain very important and strategic information useful for correctly defining an hydraulic risk map and evaluating efficient hazard management actions.

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