Areas prone to recent drought and heavy rainfall events: case studies in the Western Emilia-Romagna Apennines, Italy.

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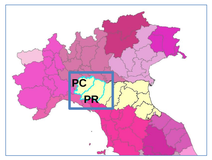

The study area, corresponding to the provinces of Piacenza (PC) and Parma (PR) in the western Emilia-Romagna region (yellow), Northern Italy

In the last five years, the study area has been interested by:
- two heavy rainfall events (2014, 2015)
- peak effects within the Emilia-Romagna region, during the 2017 severe drought

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EMILIA-ROMAGNA REGION
GEOLOGICAL, SEISMIC AND SOIL SURVEY

arpae emilia-romagna

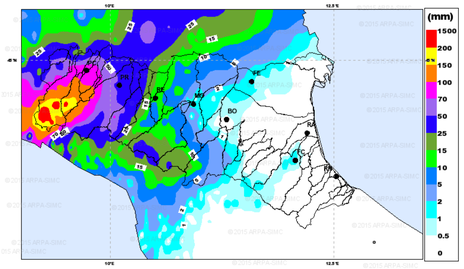
Heavy rainfall events: october 2014 and september 2015.

Very intense, several hours lasting rainfalls affected the moutain sector of the following catchment areas: **Parma and Baganza** (2014, Parma province), **Trebbia and Nure rivers** (2015, Piacenza province). According to climatology, each one of these events should have a very low propability of occurrence, less than one every 200 years. Both of them gave origin to impulsive floods, which caused debris-flow phenomena affecting minor river courses in mountain areas, and floodings in plain areas..

October, 13th, 2014, Parma province.
Heavy rainfall, 6 hours lasting and moving from mountain to plain areas, occurred;
peak intensities of 82 mm/h, 196 mm/3h e 257 mm/6h were recorded.
Among the effects, the crisis of small catchment areas in the mountains, where debris flow and erosive phenomena affected streams and minor river courses. Main river courses were interested by floods, among them the Po River which receives the Parma and Baganza tributaries within Parma province.
The city of Parma itself had some districts submerged, as in the photo on the right.

October 2014, flooding affecyed Parma city, neraby the confluence between Parma and Baganza rivers (In: http://www.parmaitaly.com/alluvione-parma.html)

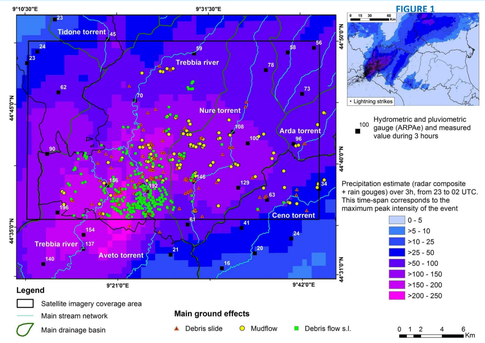
September, 13th-14th 2015, Piacenza province.
Heavy rainfall, lasting 6-7 hours, affected highly elevated mountain sectors of catchment areas. Among the effects: crisis of small, steep-slope catchment areas; widespread development of more than 300 debris flow accumulations, affecting small river courses (1st to 3rd order, according to Strahler's classification); floods with debris and scattered wood loading, in hilly and plain areas.
Intensity exceeding 100mm/h, the threshold of 30mm/h, considered as a benchmark for intense precipitations was overcome 47 times.



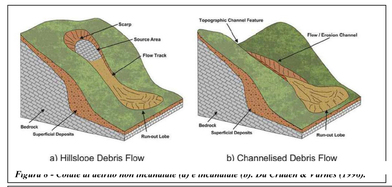
In the figure, cumulate rainfall (mm) within Emilia-Romagna region, from 23.00, September 13th to 5.00, September 14th . Peak values were recorded in the high Piacenza Apennines, where they exceeded both 100 (orange color) and 150 mm (yellow). In the Trebbia and Nure mountain catchment areas, nearby the boundary between Emilia-Romagna and Liguria region, the red area corresponds to a cumulate rainfall of 200 mm in 6 hours

2015 heavy rainfall, Trebbia and Nure Valleys, Piacenza Apennines,

after Grazzini *et alii,* 2016.



The 2015 event stroke the hilly and mountainous territory of Trebbia and Nure catchment areas. Distribution of major effects and field geomorphological evidences, matched with estimate precipitation intensity (mm/3h). More than 300 debris flow phenomena, shallow landslides, deposits due to flash floods and overbank flooding were mapped. Small catchment areas with slope inclination of 35° to 45° that underwent precipitation intensity of 125 to 175 mm/3h, show the highest density of debris-flow phenomena.

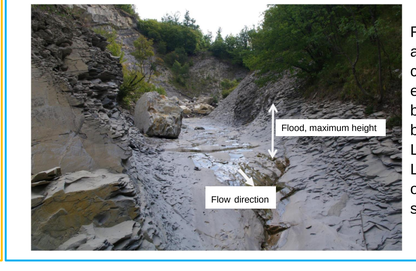


Landforms originated by debris flow occurrence were mapped both using satellite imagery and field geological surveying. A classification of debris-flow phenomena (Cruden, Varnes, 1996), was applied in the field, distinguishing between hillslope (a) and channelised accumulations (b).

Example of hillslope, non-channelised debris-flow (photo on the left); on the right, the same accumulation, made up by chaotic debris and mud admixed with scattered wood remains, flowed on-to the road-site.

Example of channelised debris-flow affecting a river course (photo on the left); on the right, the same chaotic accumulation, deposited downhill nearby the thalweg

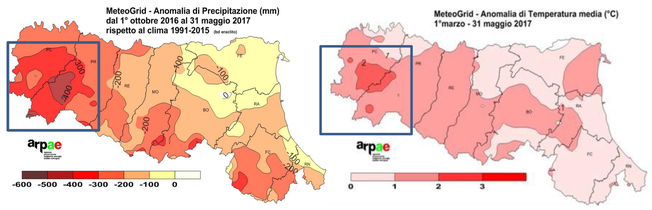
Flows or slides, caused by intense rainfall, affected pre-existing debris accumulations, along steep slopes in small catchment areas. In the photo, an example of «source area», outcropping as a consequence of the mobilization of a debris slide



River course in a small catchment area, with erosive landforms caused by the mobilization of the existing alluvial deposits, removed by debris-flow mass-transport. The bedrock, made up of marlstones of Late Cretaceous Flysch of the Ligurian Domain, is now outcropping and impressively smoothed.

Severe drought in 2017

In June 2017 drought emergency was officially declared in the Piacenza and Parma provinces, due to the scarcity of precipitations recorded from the autumn of 2016 to the spring of 2017, coupled with high temperatures values that characterized the spring and early summer in the same year.



On the left, difference (anomaly, in mm) between precipitations recorded in the period October 2016- May 2017 and the mean value referred to the period 1991-2015: on the right, anomalies of temperature values, in the period March- May 2017. The area in the box corresponds to Parma and Piacenza Apennines (from: ARPAE-SIMC, 2017b).

Interdisciplinary studies, for regional policies on climate change adaption

Alternations of intense rainfalls and droughts characterize nowadays climate evolution. To study the climate setting and the effects of these hydrological extremes, interdisciplinary collaboration based on Climate and Earth Sciences was carried out by ARPAE- SIMC and the Geological, Seismic and Soli Survey of the Emilia-Romagna Region. Studies are in progress:

- Individuation of a **preliminary, quantitative relationship** between heavy rainfall events and widespread debris-flow phenomena, in small catchment areas or "microbasins" (Grazzini *et alii,* 2016) The Autors analised the 2015 event in the Piacenza province and documented a linear increase of debris flow frequency for an intensity of 100-150 mm/3h of precipitations, in "microbasins" with slope inclination higher than 25°, the latter being a critical threshold for their activation.

- A multidisciplinary project launched in 2017, searching for **past precipitation-related events**, starting from geological record and beyond the short instrumental history (Segadelli *et alii*, 2018). Stratigraphy of peat-bog deposits in the high Parma and Piacenza Apennines were studied, as natural archives of the geological effects of hyperconcentrated flood deposits triggered by high intensity precipitation events in the past

- Classification of aquifers in the Emilia-Romagna Apennines (De Nardo, 2018), according to variations in the average annual precipitation values recorded in the periods 1961-1990 and 1991-2015 (ARPAE-SIMC, 2017a); studies on the use of **springs as regional, early warning drought indicators**, coupled with meteorological and hydrological data of existing monitoring networks

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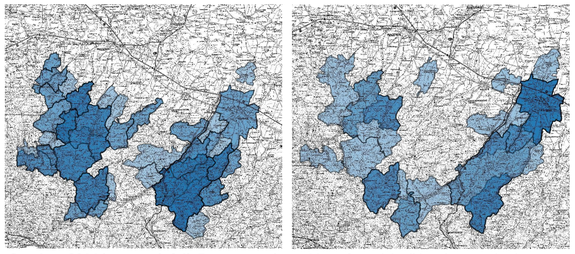
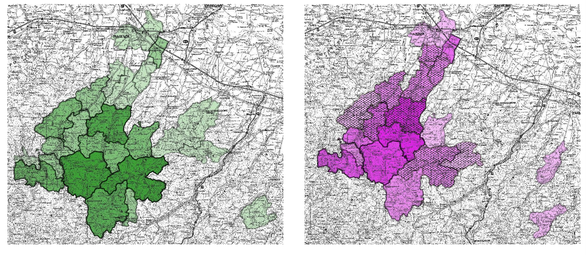
Regulatory Mesures: Decreto del Presidente della Regione Emilia-Romagna n. 149 del 4 agosto 2017; Decreto del Presidente della Regione Emilia-Romagna n. 178 del 13 novembre 2017; Decreto del Presidente della Regione Emilia-Romagna n. 32 del 29 marzo 2018; Regione Emilia-Romagna, Agenzia Regionale Protezione Civile, Piani dei primi interventi urgenti, eventi 13-14 ottobre 2014 e 13-14 settembre 2015.

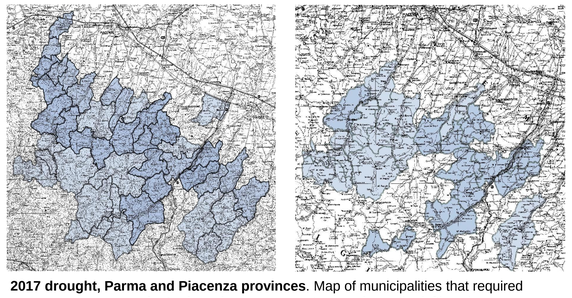
Extent, damages and early intervention national and regional financial support



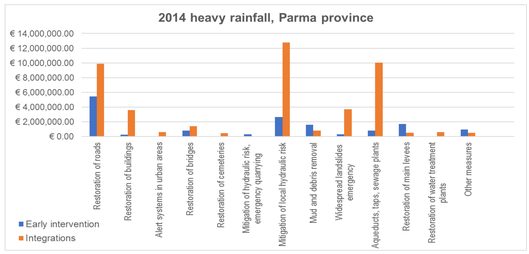
October, 2014 heavy rainfall, Parma province. Map of municipalities that required emergency measures for the **restoration of roads** (on the left) and the **mitigation of local hydraulic risk** (on the right). The intensity of colors is proportional to multiple interventions

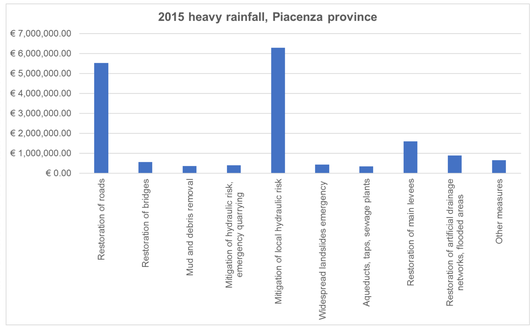


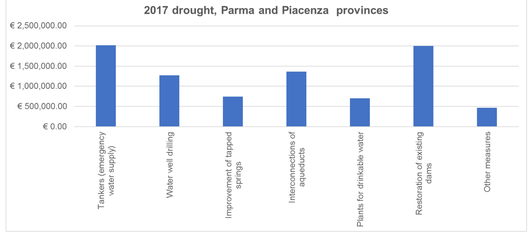
September, 2015 heavy rainfall, Piacenza province. Map of municipalities that required emergency measures for the **restoration of roads** (on the left) and the **mitigation of local hydraulic risk** (on the right), somewhere with quarrying of flooded, debris alluvial deposits (dotted ares). The intensity of colors is proportional to multiple interventions



2017 drought, Parma and Piacenza provinces. Map of municipalities that required emergency measures for **tankers** (emergency water supply, on the left) and **improvement of tapped springs** (on the right) . The intensity of colors is proportional to multiple interventions







Each chart refers to an extreme event, damages and measures are classified and plotted *versus* documented financial support, provided by national and regional emergency funding (cited in "References"). The total amount is almost 40 million Euros, referred to the very early phase of emergency, and almost double if we consider further intervention, especially required by the 2014 and 2015 events