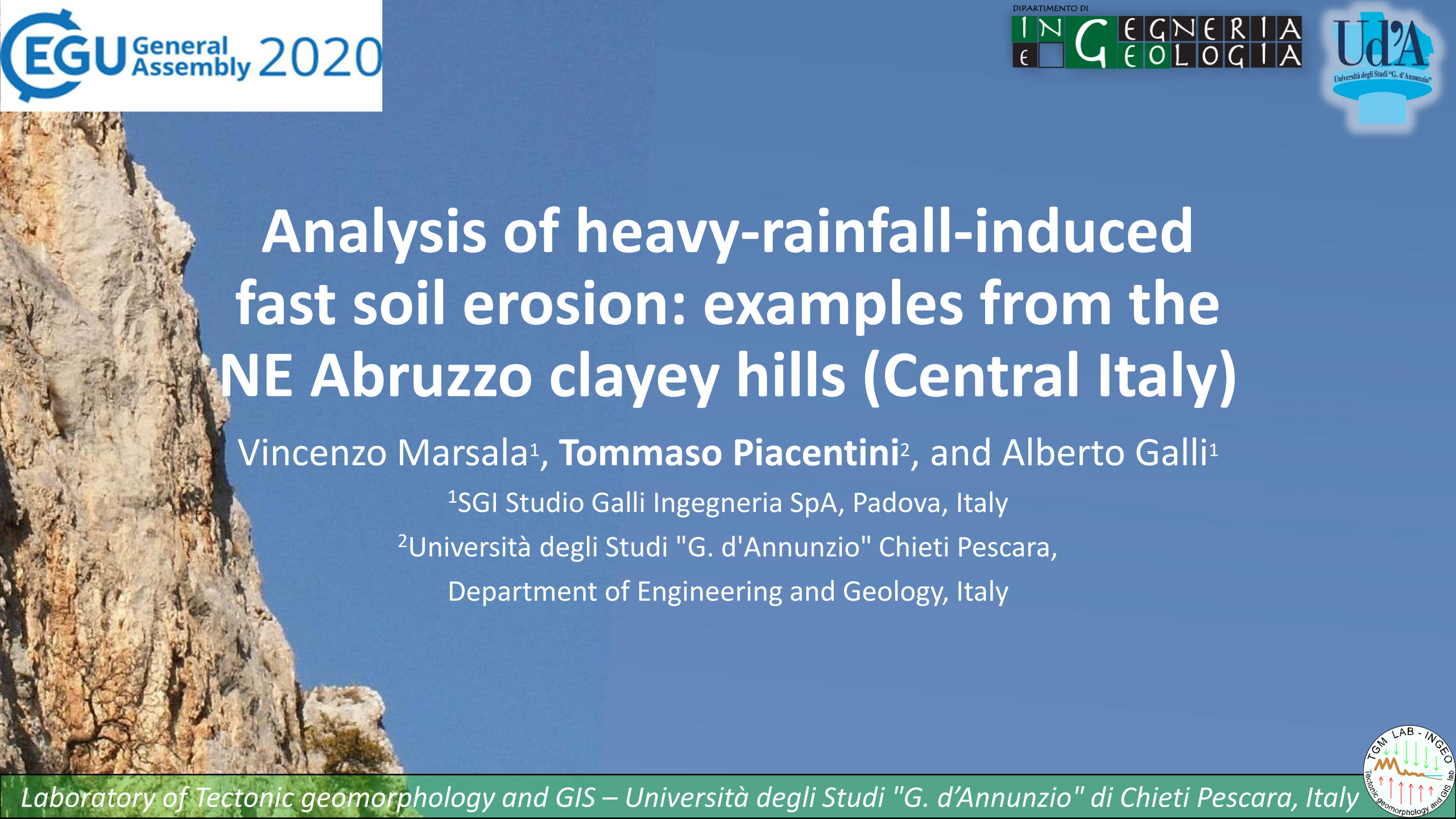

Analysis of heavy-rainfall-induced fast soil erosion: examples from the NE Abruzzo clayey hills (Central Italy)

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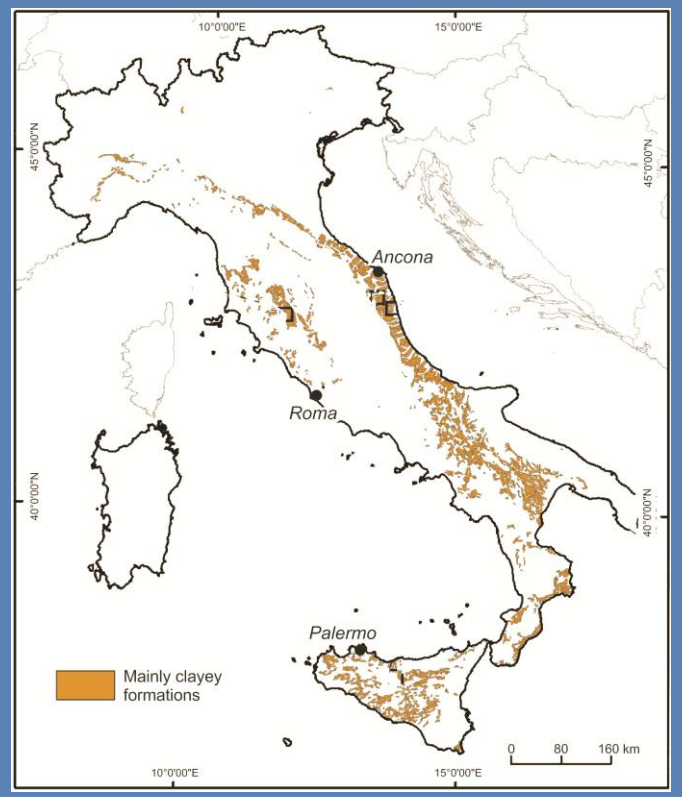
MOTIVATION

Widespread clay landscapes in Italy



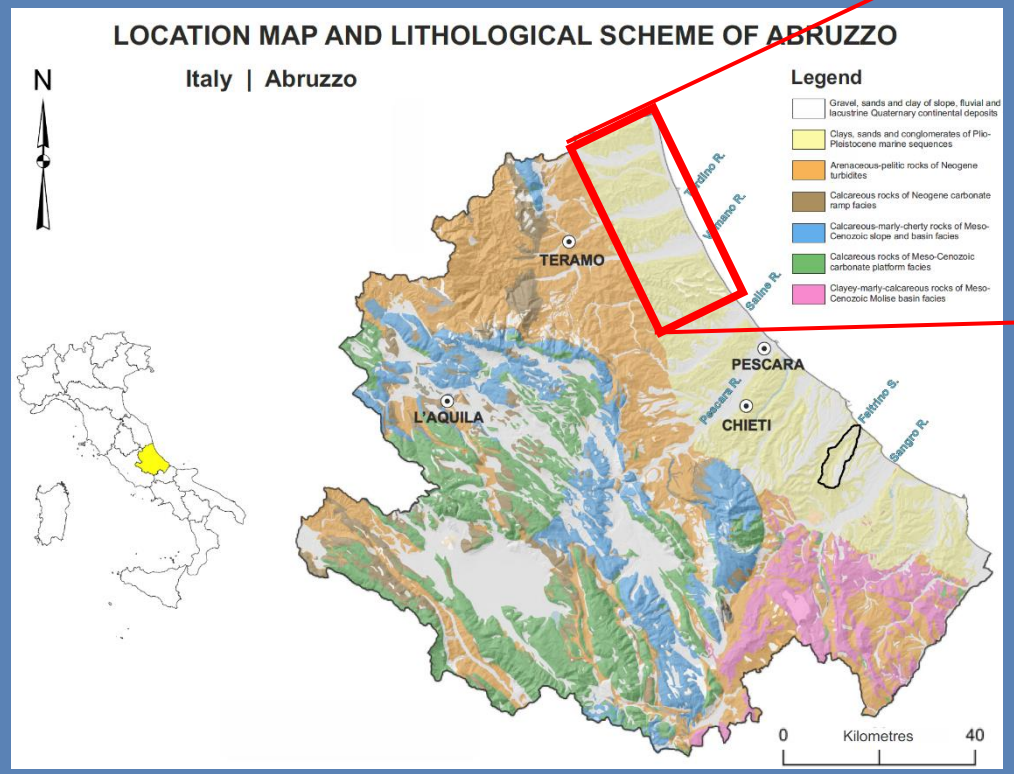
Affected by heavy rainfall events
(>40mm/h and >100 mm/d)
inducing fast soil erosion

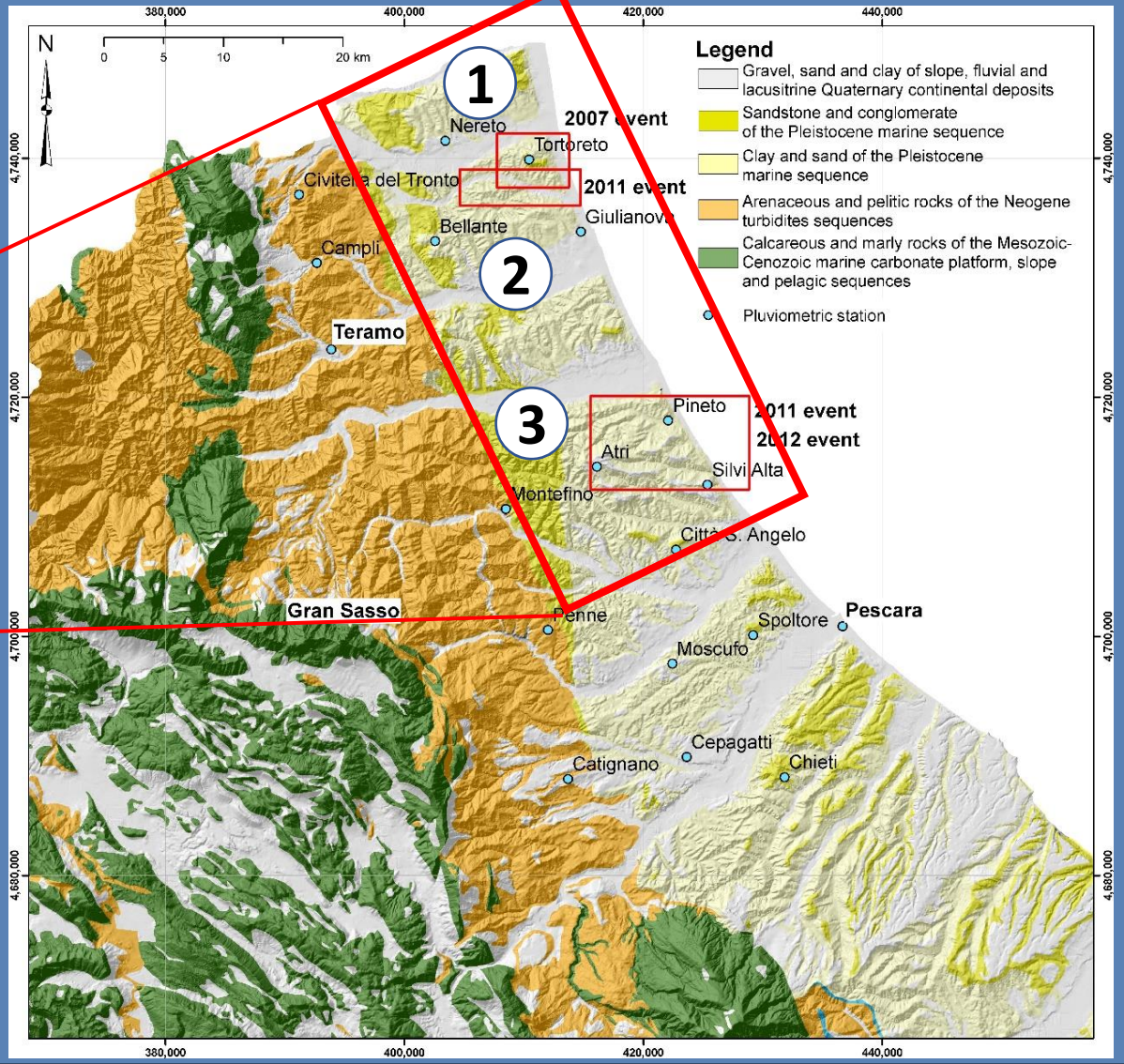
Questions: Erosion rates?
Rainfall threshold triggering fast soil erosion?

STUDY AREAS - Regional setting

3 sites and 3 rainfall events in the NE Apennines piedmont hilly area of Abruzzo

Clay-dominated bedrock (impermeable-erodible)

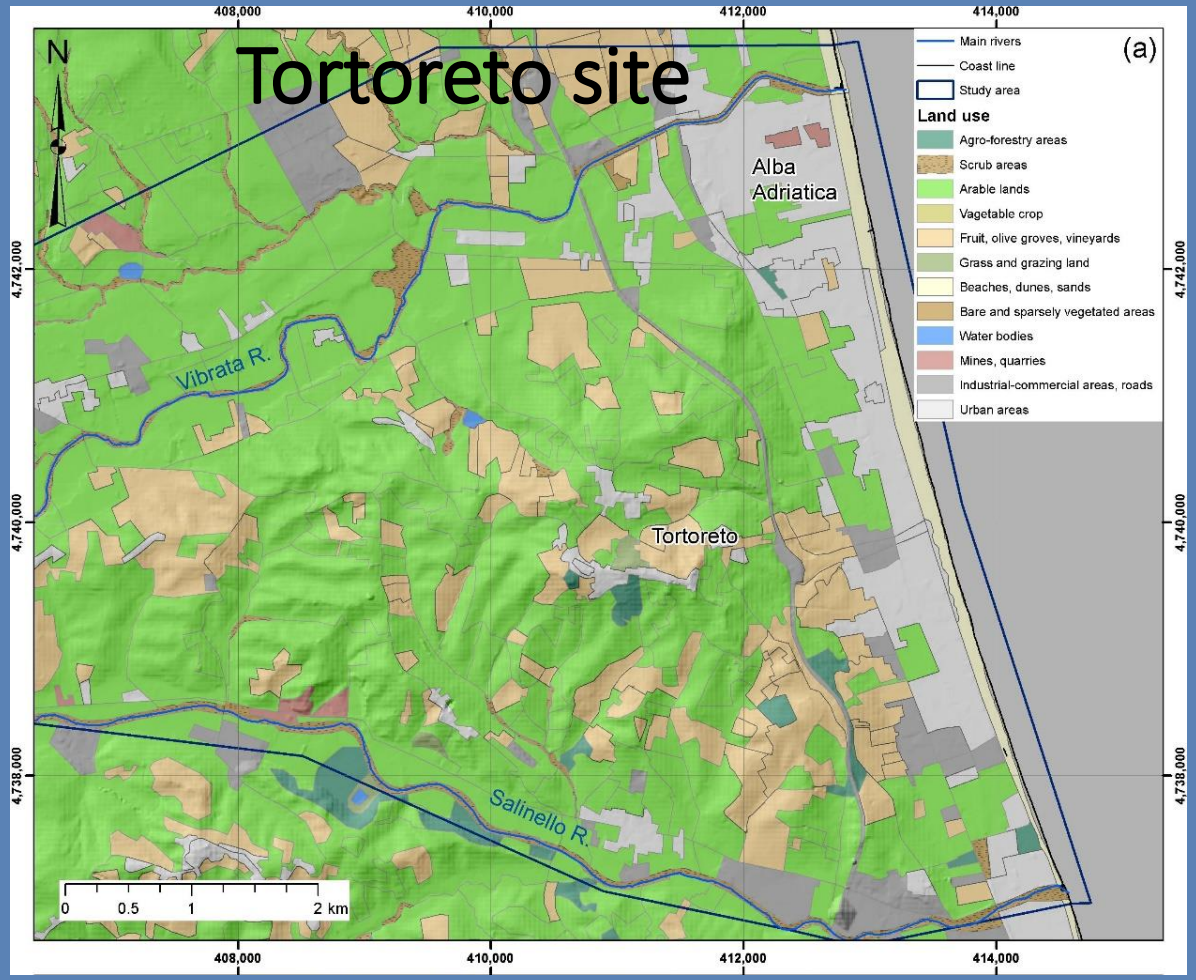




STUDY AREAS – SITE 1 2007 heavy rainfall event

Land use

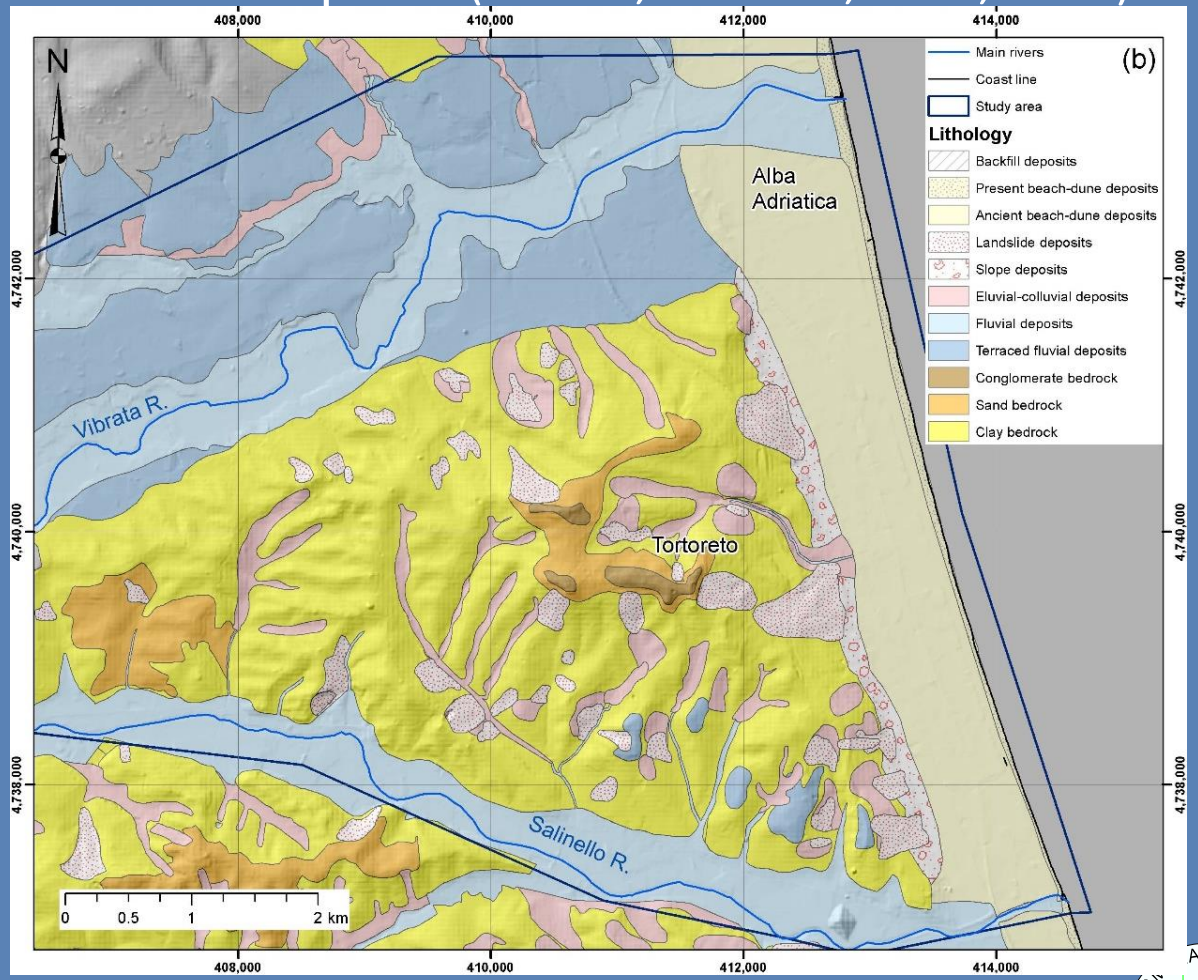
Arable land, olive groves, vineyards, urban areas



Lithology

Clay-sand bedrock

surficial deposits (colluvial, landslides, fluvial, beach)



STUDY AREAS – SITE 2 2011 heavy rainfall event

Land use

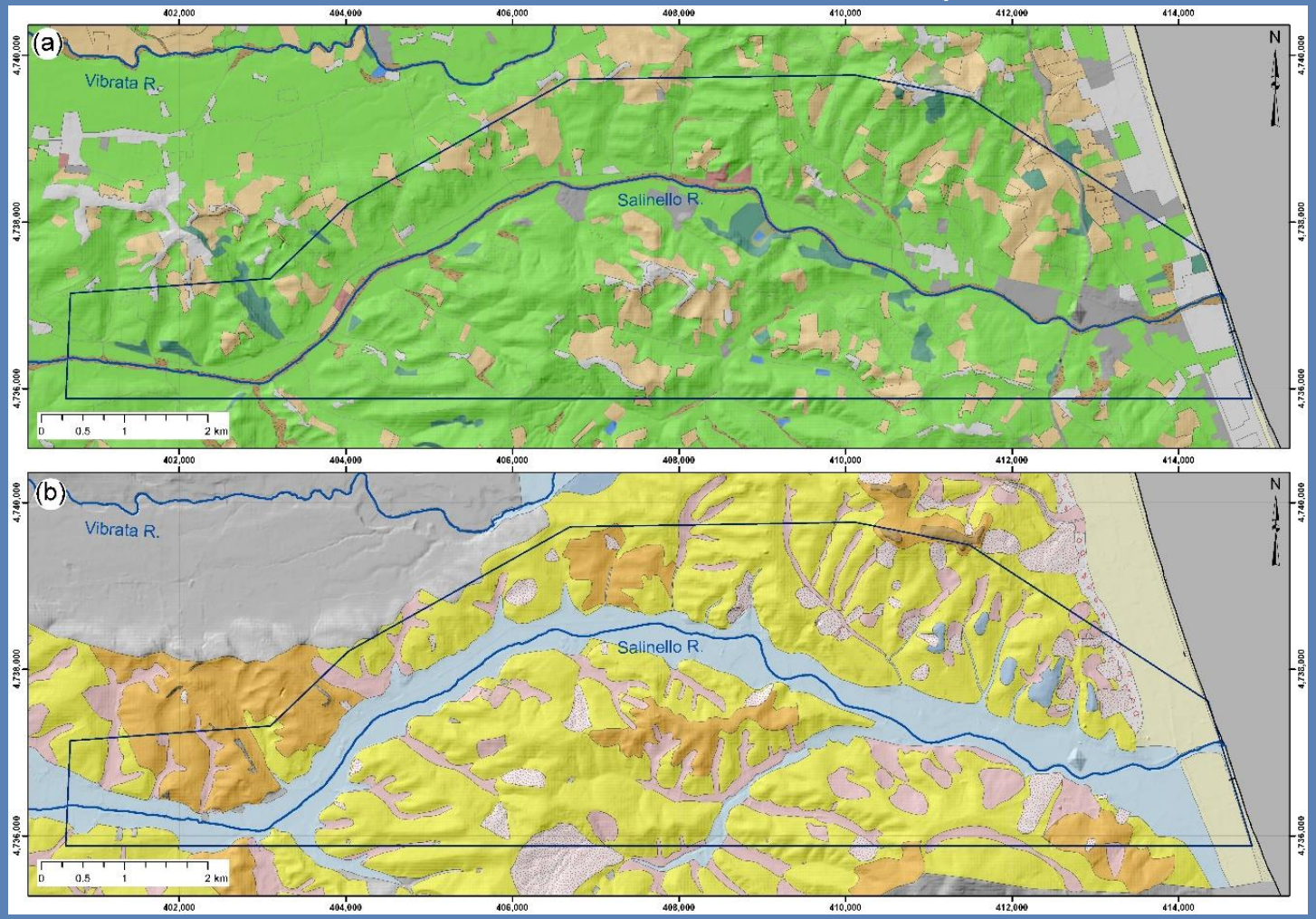
Arable land, olive groves, vineyards, urban areas

Lithology

Clay-sand bedrock

surficial deposits (colluvial, landslides, fluvial, beach)

Salinello site



STUDY AREAS – SITE 3 2011-2012 heavy rainfall events

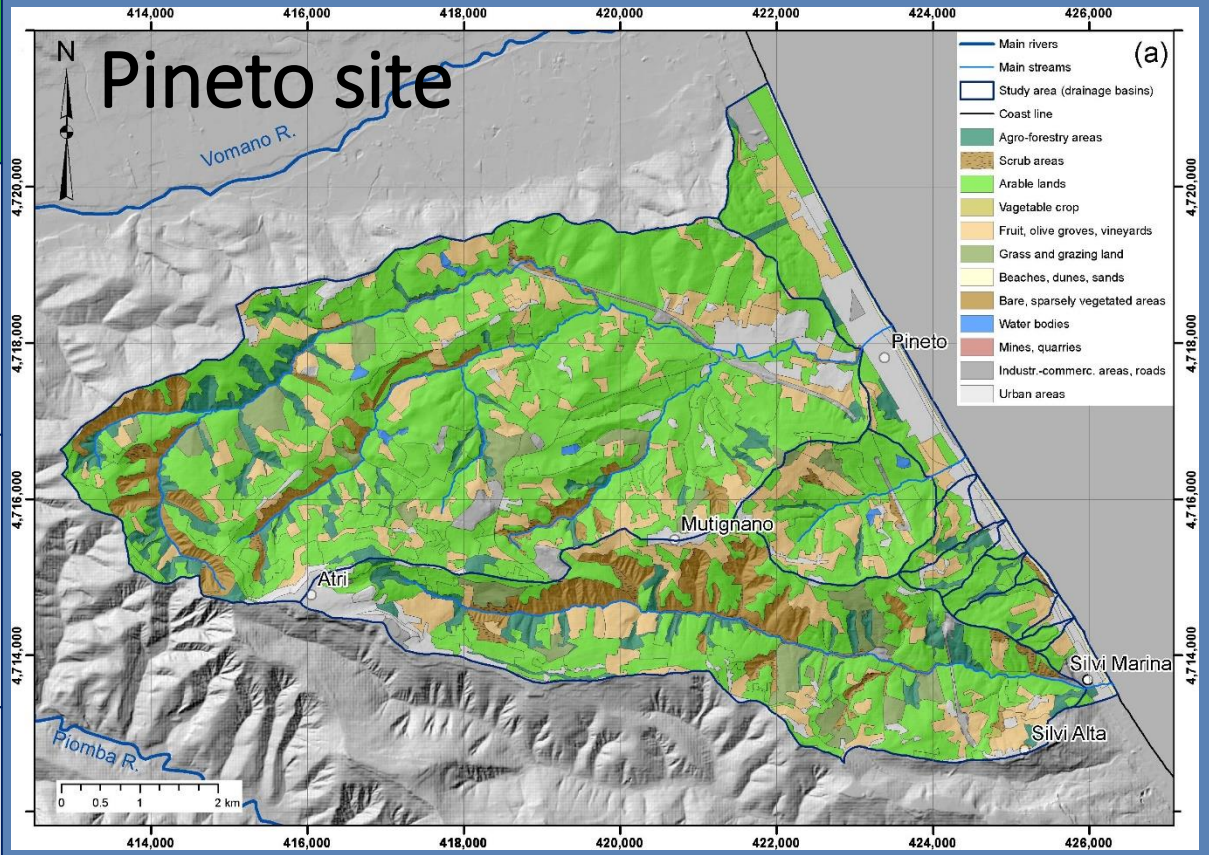
Land use

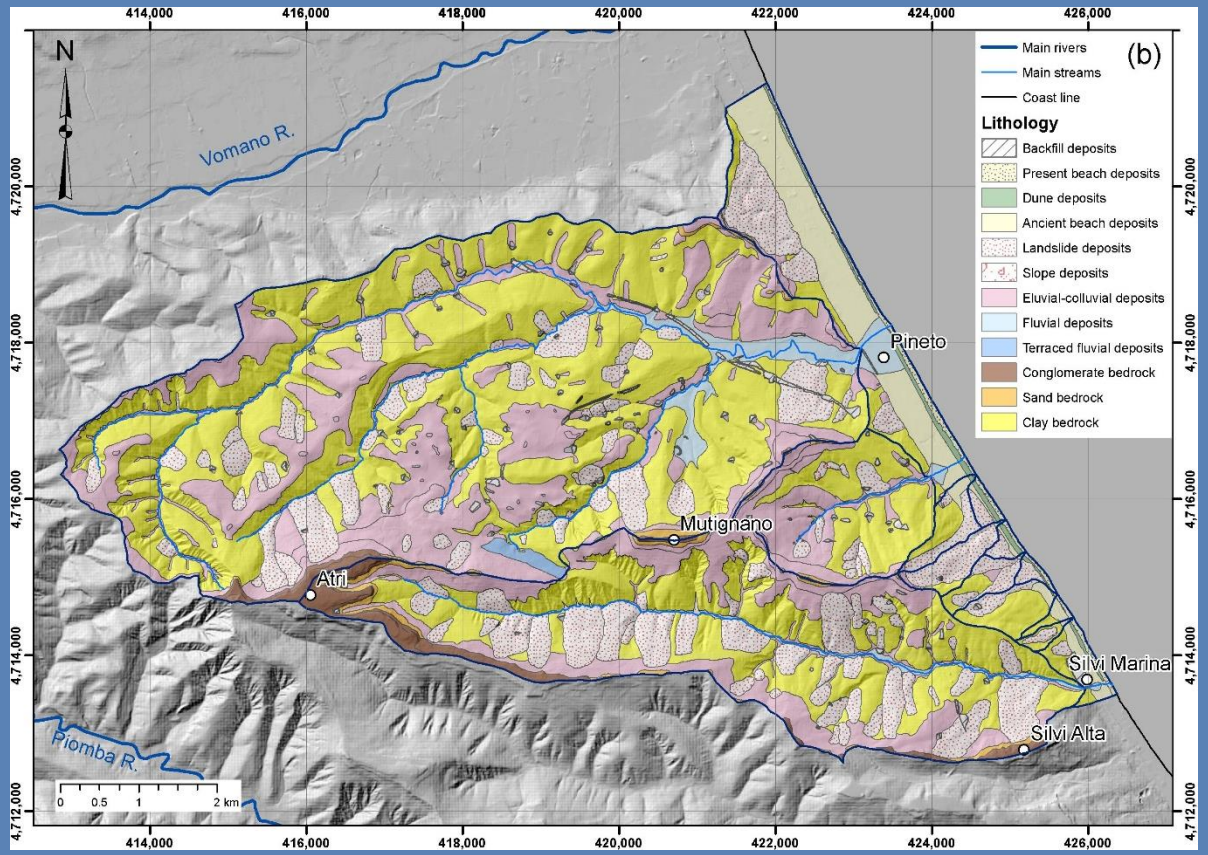
Arable land, olive groves, vineyards, urban areas

Lithology

Clay-sand bedrock

surficial deposits (colluvial, landslides, fluvial, beach)





AIMS AND METHODS

AIMs

(1) to outline the correlation between rainfall parameters and geomorphological effects in terms of soil erosion in NE Abruzzo;
(2) to assess the impact of soil erosion on the clayey landscape (which is largely characterized by high-quality plantations);
(3) to contribute to the empirical definition of rainfall threshold for the triggering of heavy soil erosion through local inventories

MATERIALs

- Rainfall analysis: 18 rain gauge data (decadal time series and raw 5-15 min datasets of heavy events
- Soil erosion analysis:
  a. 1–2-day post-event field surveys (1:5000; 2011 and 2012 events);
  b. analysis of 2-day post-event aerial photos (2007 event) combined with ground truthing through direct landform measurements;
  c. effects inventories and technical reports (all events).

AIMS AND METHODS

METHODs

Geomorphological mapping of soil erosion landforms induced by heavy rainfall based on direct field observation and remote air-photo analysis.
Comparison of geomorphological effects of heavy rainfall and related eroded volumes, with rain gauge data.

Soil erosion and sedimentation volume calculation

Considering the surface area (for areal landforms), length and width (for linear features), and the average erosion depth or accumulation thickness of the landforms, the eroded volume, as well as the sedimented volume, were estimated for each landform for the overall investigated areas and for each event as follows:

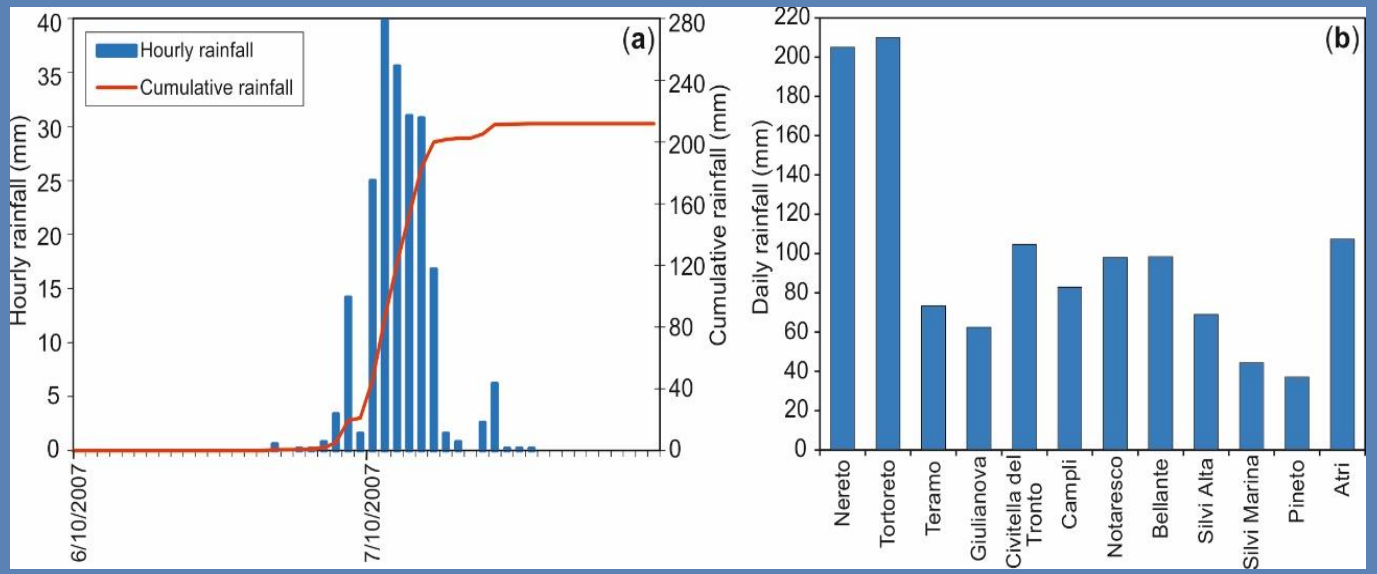
(1) areal landform erosion = $\sum_{i=1-n} avg.\,erosion\ depth_i \times landform\ area_i$
(2) linear landform erosion = $\sum_{i=1-n} avg.\,erosion\ depth_i \times landform\ length_i \times landform\ width_i$
(3) areal landform accumulation = $\sum_{i=1-n} avg.\ accumulation_i \times landform\ area_i$

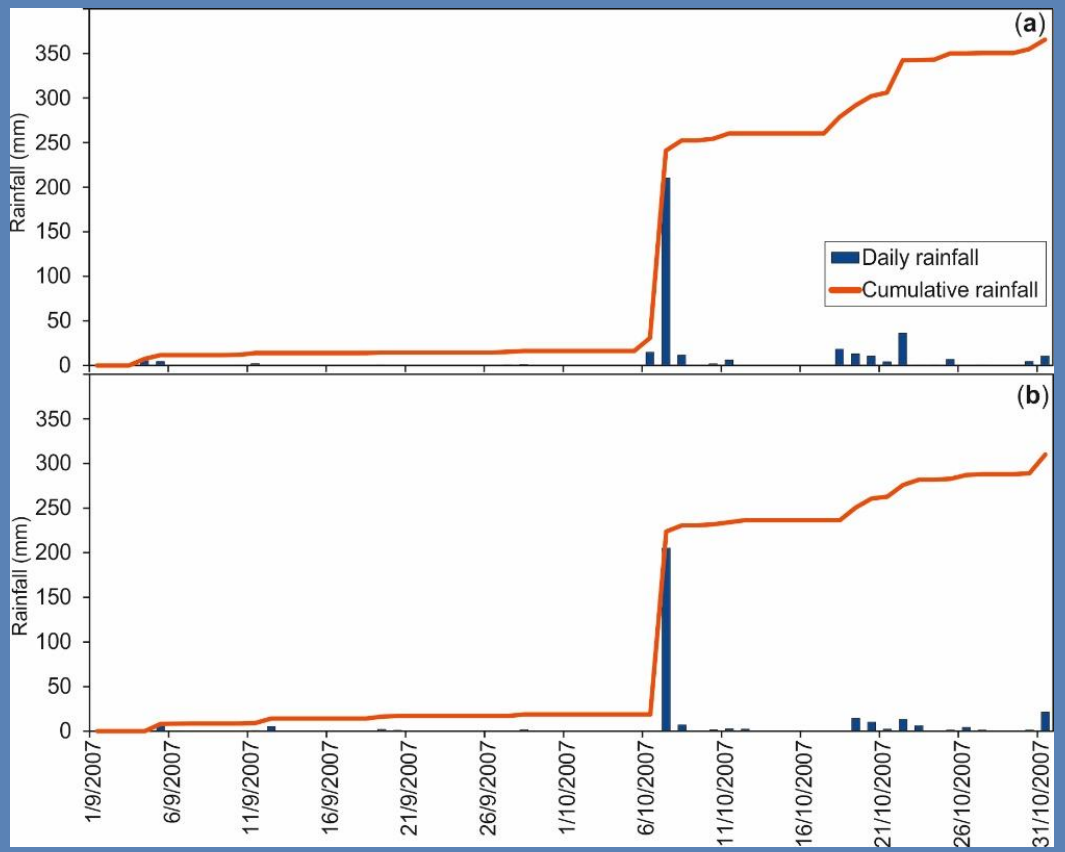
The total eroded volume was calculated from (1) and (2), and the total accumulated sediment from (3).

RESULTS –2007 heavy rainfall event - Site 1

The Tortoreto 2007 event had

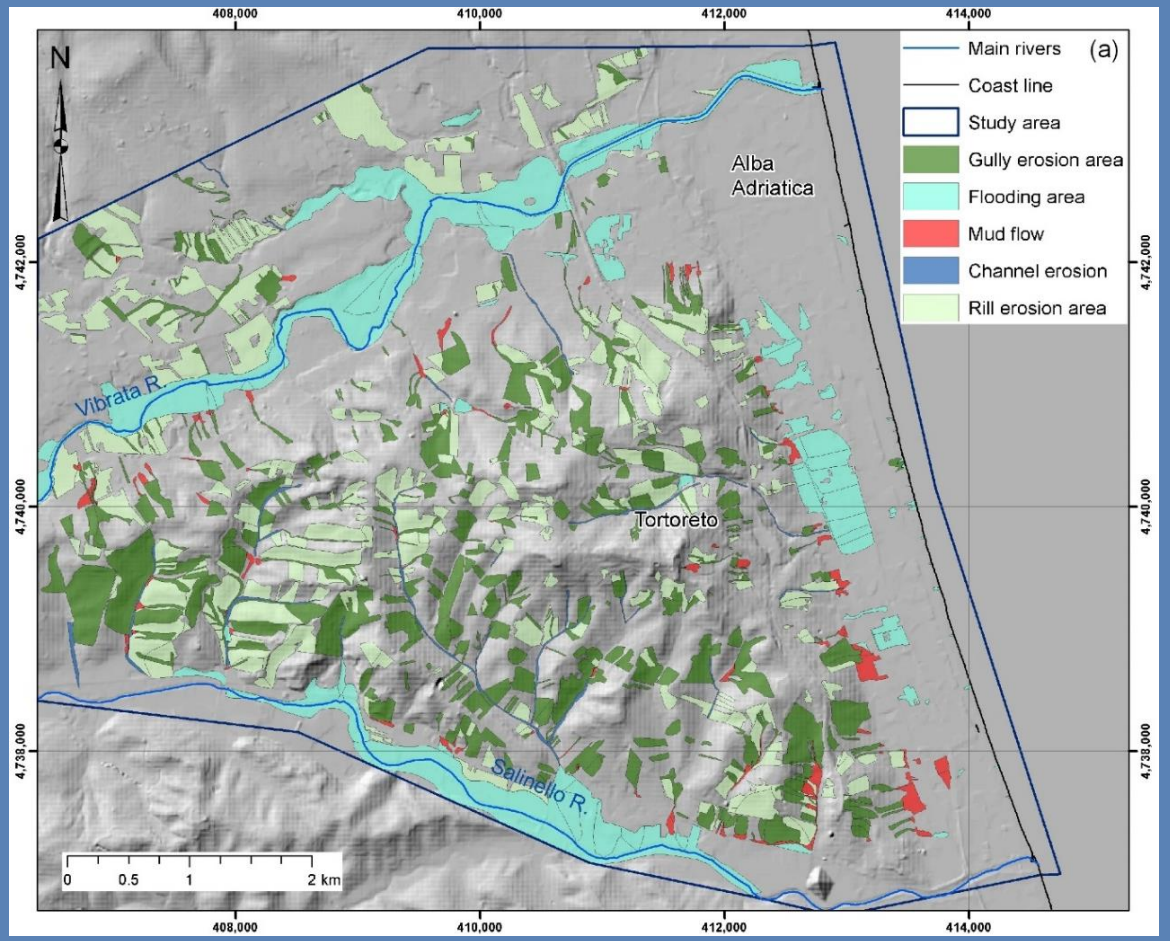
- 14-16 h duration
- high intensity (10–40 mm/h, up to >200 mm/day)
- high cumulative rainfall (up to 210 mm)
- occurred after >1 month of very low rainfall





RESULTS –2007 heavy rainfall event - Site 1

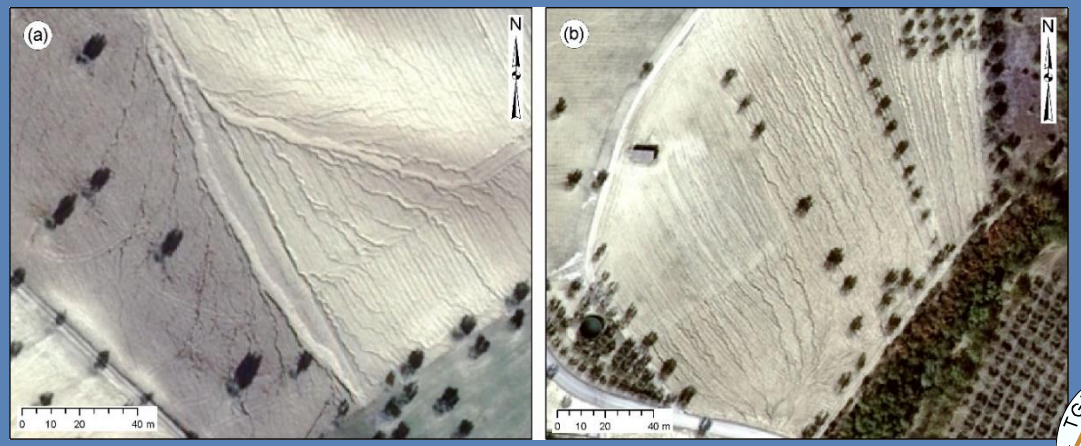
Soil erosion map



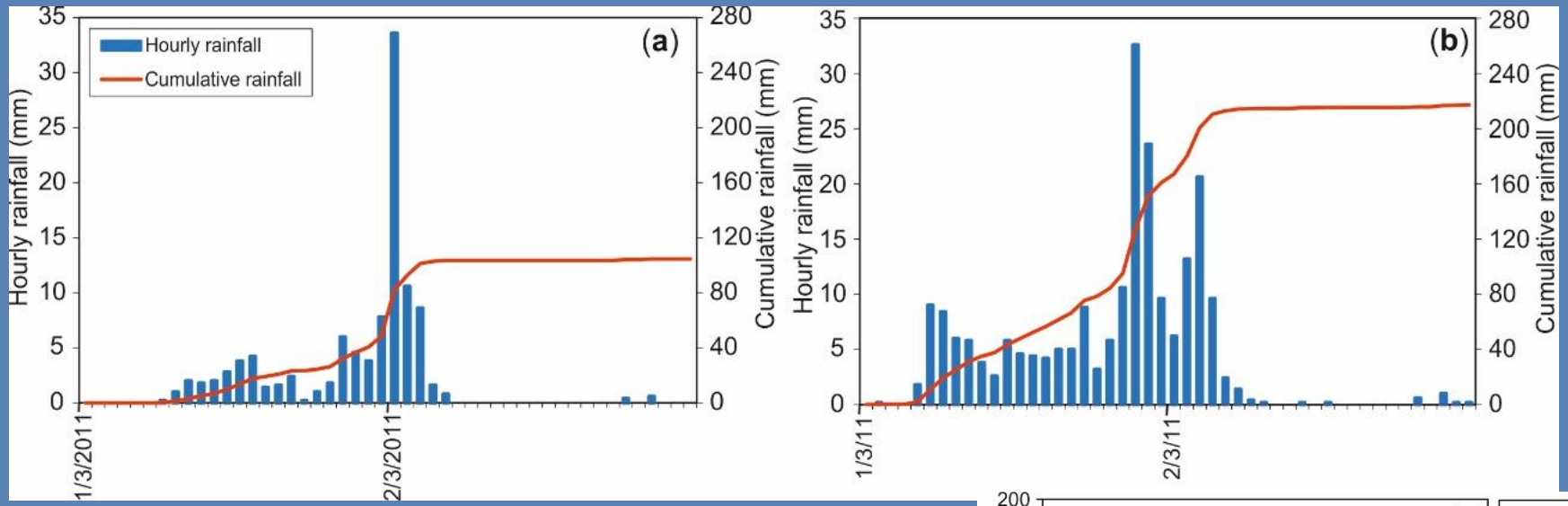
Volumes calculations

	Sheet–Rill Erosion	Gully Erosion	Channel Incision	Mud Flows	Flooding Areas	TOTAL
Number of features	389	506	45	128	124	**1192**
Depth/thickness (cm)	1–5	20–100	100–200	50–150	0–10	
Spacing (m)	1–10	4–8				
Area (km²)	4.36	4.84	0.23	0.37	3.97	**13.77**
% of total area	10.0	11.1		0.9	9.1	**31.00**
Eroded volume (m³)	48,400	610,900	228,400			**887,700**
Sedimented volume (m³)				250,900	153,000	**403,900**

Landforms

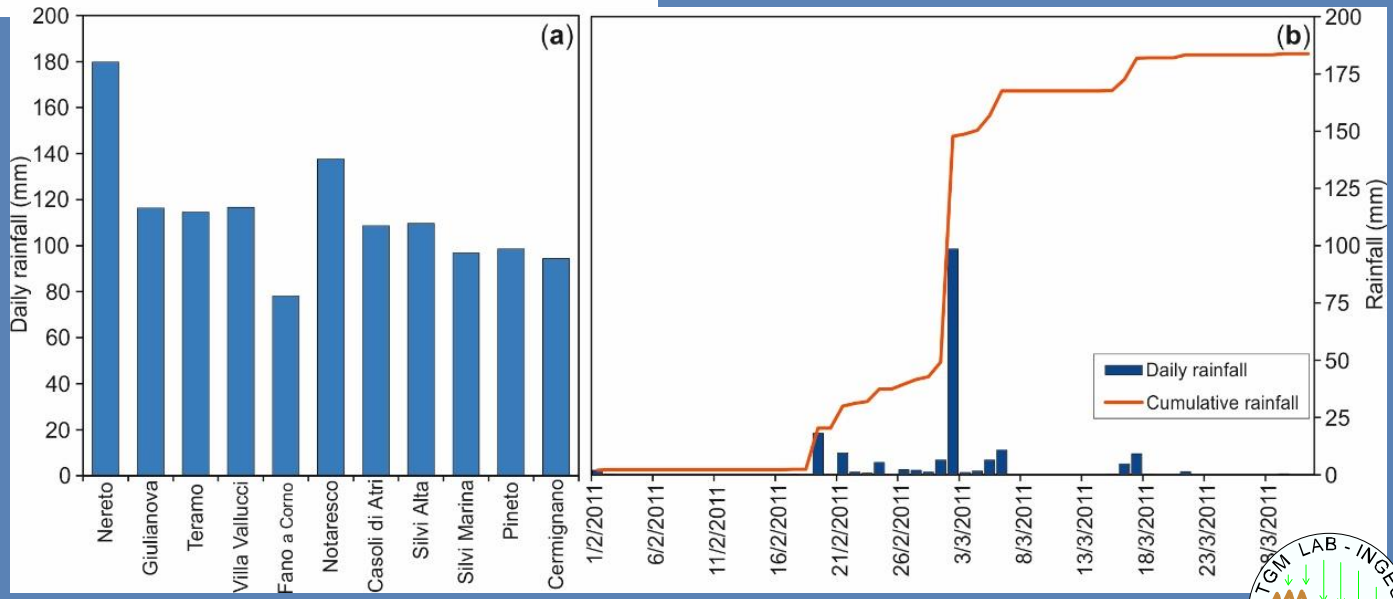


STUDY AREAS –2011 heavy rainfall event - Sites 2 3



The 2011 event affected a regional area (Pineto 2011 and Salinello 2011) for a moderately short duration (22–26 h)

with high intensity (15–35 mm/h, up to >180 mm/d) and high cumulative rainfall (up to 211 mm) and after ~10 days of moderate antecedent rainfall.

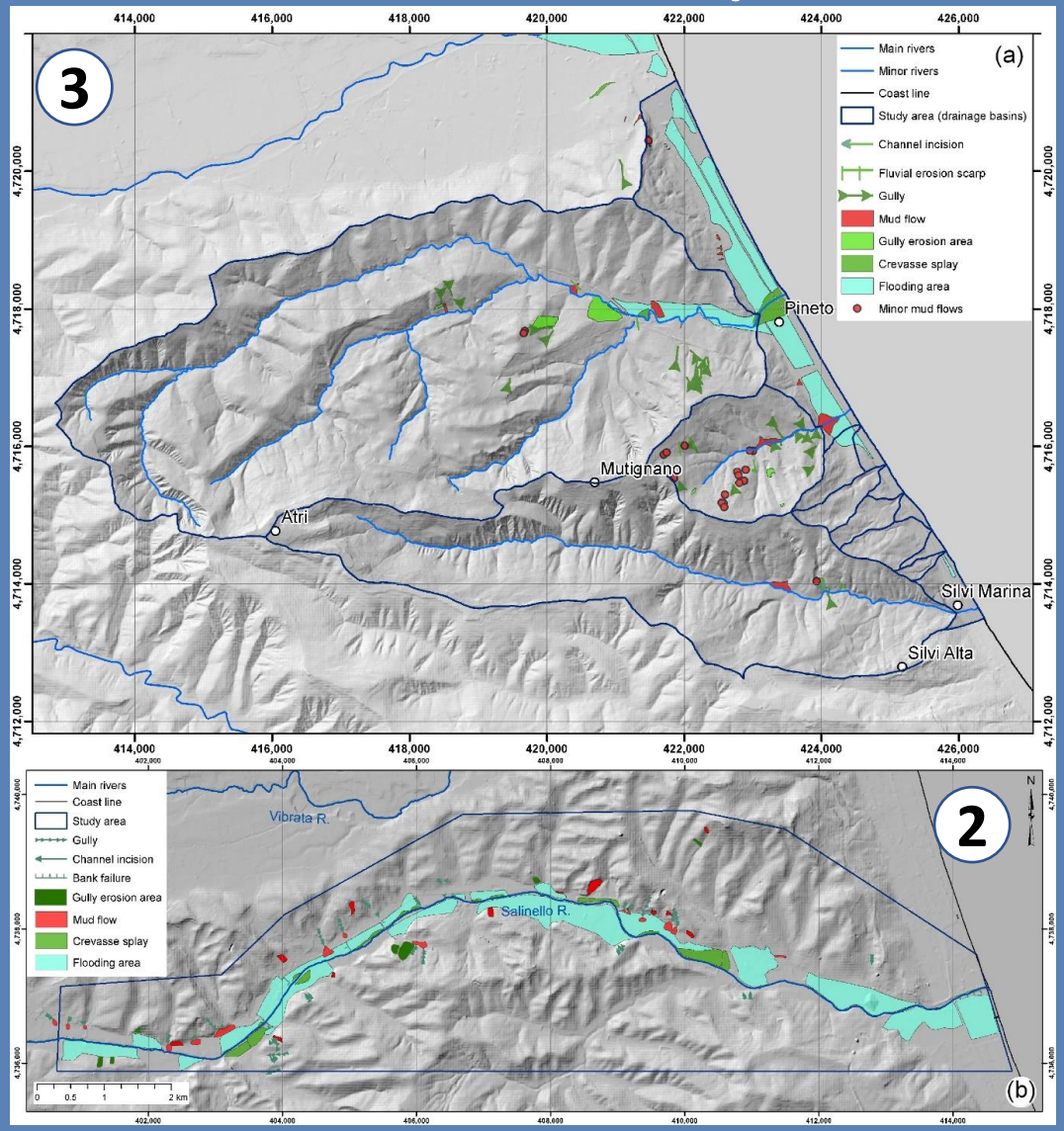


STUDY AREAS –2011 heavy rainfall event - Sites 2 3

Landforms

STUDY AREAS –2011 heavy rainfall event - Sites 2 3

Soil erosion map



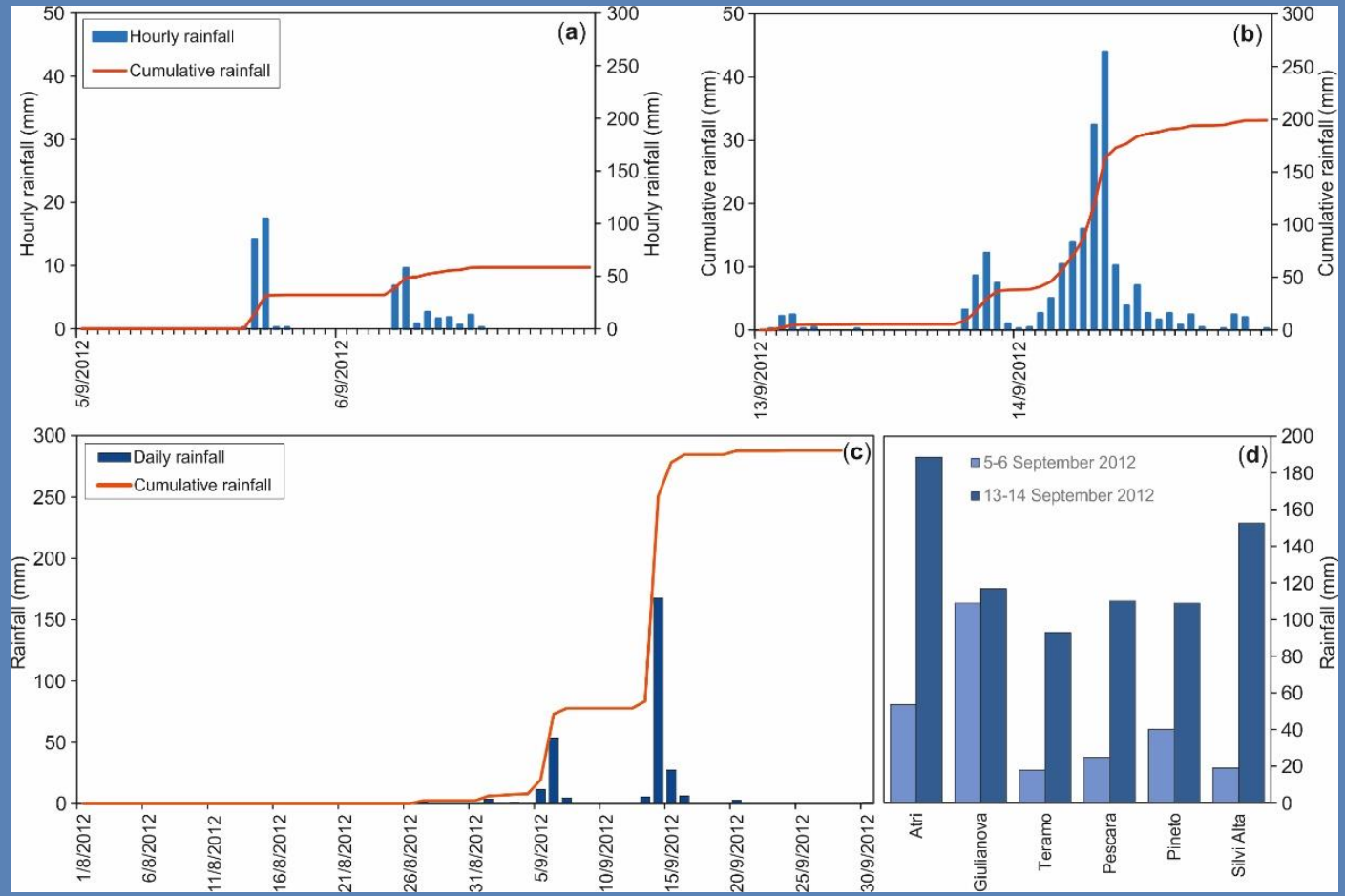
Volumes calculations

(a)	Gully Erosion	Major Gullies	Mud Flows	Flooding Areas	Crevasse Splays	TOTAL
Number of features	8	26	38	13	5	**90**
Depth/thickness (cm)	20–50	50–100	20–150	0–5	10–50	
Spacing (m)	3–20					
Area (km²)	1.13	10.20	0.26	2.01	0.16	**13.76**
% of total area	1.9		0.4	3.3	0.3	**5.9**
Eroded volume (m³)	133,000	8900				**141,900**
Sedimented volume (m³)			60,400	26,100	20,000	**86,500**

(b)	Sheet-rill Erosion	Major Gullies	Bank Failure	Mud Flows	Flooding Areas	Crevasse Splays	TOTAL
Number of features	27	84	15	31	32	20	**209**
Depth/thickness (cm)	5–10	20–100	100–200	50–200	0–5	20–40	
Spacing (m)	1–2						
Area (km²)/Length (km)	0.10	4.50	2.00	0.50	3.62	0.32	
% of total area	0.2			0.3	8.3	0.7	**9.5**
Eroded volume (m³)	5700	4400	2000				**12,100**
Sedimented volume (m³)				65,500	46,700	83,700	**195,900**

STUDY AREAS –2012 heavy rainfall event - Site 3

the Pineto 2012 event was a double event, 18 and 24 h long, and affected coastal hilly area within a 1-week interval, with high intensity (15–65 mm/h, up to >190 mm/d) and combined cumulative rainfall up to 280 mm, after a >1-month completely dry period

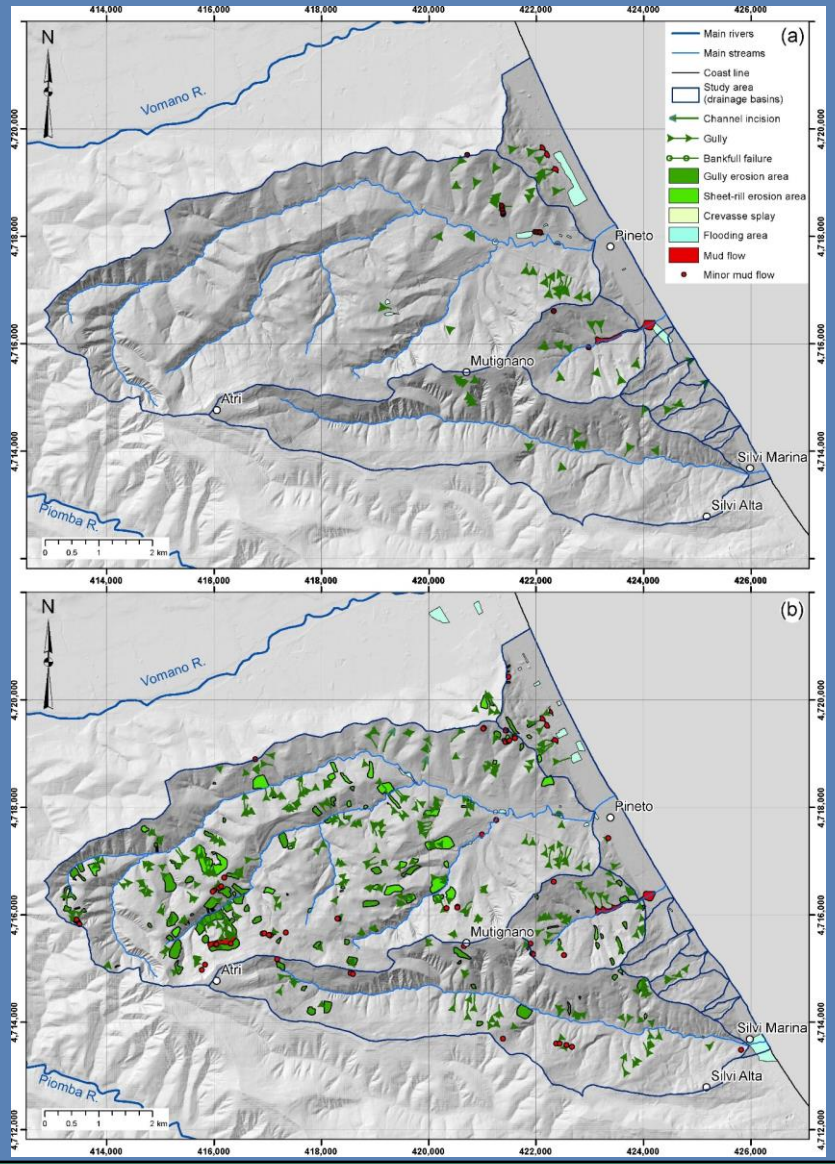


STUDY AREAS –2012 heavy rainfall event - Site 3

Landforms

STUDY AREAS –2012 heavy rainfall event - Site 3

Soil erosion map



Volumes calculations

(a)	Gully Erosion	Major Gullies	Mud Flows	Flooding Areas	Crevasse Splays	TOTAL
Number of features	23	66	4	13	1	**106**
Depth/thickness (cm)	10–30	20–40	50–200	0–3	30	
Spacing (m)	4–6					
Area (km²)	0.23	8.3	0.10	0.30	> 0.001	**8.93**
% of total area	0.4		0.2	0.5		**1.1**
Eroded volume (m³)	33,900	2700				**36,600**
Sedimented volume (m³)			30,900	6300	300	**37,500**

(b)	Sheet–rill Erosion	Gully Erosion	Major Gullies	Channel Incision	Mud Flows	Flooding Areas	Crevasse Splays	TOTAL
Number of features	52	76	321	4	23	24	8	**508**
Depth/thickness (cm)	2–5	20–40	20–70	30–60	50–200	0–3	10–30	
Spacing (m)	1–4	4–8						
Area (km²)	0.92	1.18	48.80	0.90	0.18	0.36	0.03	**52.37**
% of total area	1.5	2.0			0.3	0.6	0.1	**4.5**
Eroded volume (m³)	27,600	236,500	23,300	2500				**289,900**
Sedimented volume (m³)					88,000	5000	5900	**98,900**

CONCLUSION

Soil erosion landforms and soil loss calculation

Geomorphological effects and landform distributions for the investigated events, soil erosion-sedimentation, and soil loss estimation.

	Tortoreto 2007		Salinello 2011		Pineto 2011		Pineto 2012-1		Pineto 2012-2	
Erosion	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
Sheet–rill erosion	48,400	5	5700	56	0		0	0	27,600	10
Gully erosion	610,900	69	0		133,000	94	33,900	93	236,500	82
Major gullies	0	0	4400	44	8900	6	2700	7	23,300	8
Bank failure	0	0	2000	20	0	0	0	0	100	0
Channel incision	228,400	26	0		0		0	0	2500	1
Total eroded	**887,800**		**12,100**		**141,900**		**36,600**		**289,900**	
Sedimentation	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
Mud flows	250,900	62	65,500	33	60,400	57	30,900	82	88,000	89
Flooding areas	153,000	38	46,700	24	26,100	25	6300	17	5000	5
Crevasse splays	0	0	83,700	43	20,000	19	300	1	5900	6
Total sedimented	**403,800**		**195,900**		**106,500**		**37,500**		**98,900**	
Soil loss	**−484,000**	**−55**	**183,800**	**+1519**	**−35,400**	**−25**	**+900**	**+2**	**−191,000**	**−66**

CONCLUSION

Soil erosion landforms and soil loss calculation

Summary of rainfall and soil erosion–sedimentation in the investigated rainfall events.

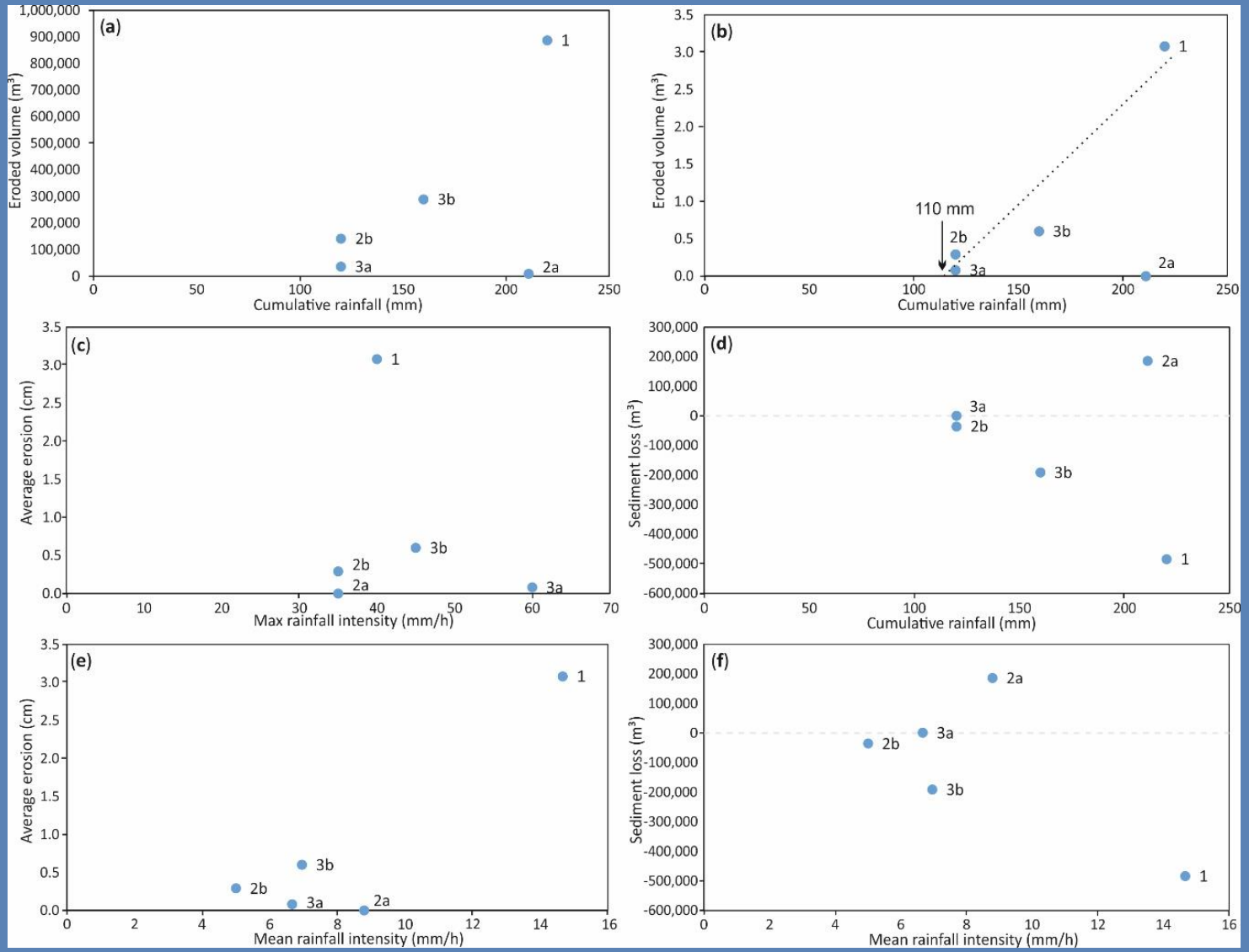
	Event	Cumulative Rainfall (mm)	Hourly Rainfall Intensity Max (mm/h)	Hourly Rainfall Intensity Mean (mm/h)	Rainfall Duration (h)	Eroded Volume (m^3)	Average Erosion (cm)	Sedimented Volume (m^3)	Soil Loss (m^3)
1	Tortoreto 2007	210	40	14.7	14–16	887,700	3.08	403,800	−483,900
2a	Salinello 2011	211	35	8.8	22–26	10,100	< 0.01	196,000	185,900
2b	Pineto 2011	120	35	5.0	22–26	141,900	0.29	106,500	−35,400
3a	Pineto 2012-1	120	60	6.7	18	36,600	0.08	37,500	900
3b	Pineto 2012-2	~160	45	7.0	22–24	289,900	0.60	98,900	−191,000

Question: Erosion rates?

Answer: 0.08-3.08 cm in a single event (occurring 1 time /2-4 years)
Values vary according to the season and to previous rainfall

CONCLUSION

Soil erosion parameters vs. rainfall parameters



Questions:
Rainfall threshold triggering fast soil erosion?

Answer:
Expected values 110 mm/d in this landscape type i.e. clayey hilly landscape surrounding the Apennines chain.

References

Piacentini, T.; Galli, A.; Marsala, V.; Miccadei, E. (2018) Analysis of Soil Erosion Induced by Heavy Rainfall: A Case Study from the NE Abruzzo Hills Area in Central Italy. Water, 10, 1314. https://doi.org/10.3390/w10101314