Università degli Studi di Napoli Federico II

Dipartimento di Ingegneria Civile, Edile e Ambientale

CORSO DI LAUREA IN
INGEGNERIA PER L'AMBIENTE E IL TERRITORIO

TESI DI LAUREA IN
Sistemazioni idrauliche per la difesa del territorio

Nature Based Solutions for the reduction of hydrogeological risk. Definition and "weighting" of performance indices: the case study of Quindici (AV)

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Anno Accademico 2018/2019

Solutions for the Mitigation of Natural Risk

"T… nd
co… to
ad… nd
ad…
economic, social and environmental benefits".

(European Commission, 2015)

PHUSICOS

According to Nature

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776681.

Summary of Activities

PHASE I

Data Collection

- **Map**
- **Statistics**
- **ISTAT data in 1991 and 2001**
- **Hydrological data**
- **Geotechnical data**
- **Gis Software**
- **Others**

PHASE II

Calculation of Indicators for the current status (Baseline Scenario)

- **Hydraulic solvers (FLO-2D)**
- **Statistic models (Soil Conservation Service-SCS, limit equilibrium theory, ecc..)**
- **Others**

PHASE III

Definition of two alternative Design Scenarios

- **NBSs Scenario (*B1*)**
- **Hybrid Scenario (*B2*)**

PHASE IV

Calculation of Indicators for the Design Scenarios

PHASE V

Assessment Procedure

The Assessment Procedure of Phusicos

The Assessment Framework of Phusicos

The Framework Tool is based on the assessment of distinctive *Indicators PI*, making up a *Framework Tool Matrix*

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
AMBIT	CRITERION	CONCEPT	SUB - CRITERION	INDICATOR	METRIC	TIPOLOGY	DIRECTION	SOURCE	ASSESSMENT FACTOR
RISK REDUCTION	*Hazard*	Landslide Risk Resilience	Site response to Landslide phenomena based on susceptibility indicators: slope angle, pore water pressure, groundwater depth, soil properties, land use, land cover	Factor of Safety	-	QT	+	M	
				Percentage of Occurred Landslide Area/ Risk Area	%	QT	-	S	
				Velocity of Occurred Landslides	m/s	QT	-	S	
		Flooding Risk Resilience	Site response to Flooding phenomena based on susceptibility indicators: land use cover, run-off coefficient, rainfall intensity and frequency and duration	Peak Flow	m^3/s	QT	-	M/LL	
				Peak Volume	m^3	QT	-	M/LL	
				Flooded Area	km^2	QT	-	M/GIS	
		Snow Avalanche Risk Resilience	Site response to Snow avalanche phenomena based on susceptibility indicators: topography, wind, temperature, snow thickness and duration	Snow Cover Map, Digital Terrain Model (DEM), Land Relief [To be integrated according to Living Labs]	-	QT		GIS/M/ LL	
		Drought Risk Resilience	Site response to Drought phenomena based on susceptibility indicators: land use cover, temperature,	Standardized Precipitation Index (SPI)	-	QT		M	
				Effective Drought Index (EDI)	-	QT		M	
	Exposure			Homeless)					
				Elderly, children, disabled	$nr./km^2$	QT	-	M/S	
		Potential Species Involved	Potential Species Exposed to Risks	Domestic and wild fauna (livestock and protected species)	$nr./km^2$	QT	-	M/S	
		Potential Buildings Involved	Potential Buildings Exposed to Risks	Housing	$nr./km^2$	QT	-	M/S	
				Agricultural and Industrial buildings	$nr./km^2$	QT	-	M/S	
				Strategic buildings (hospitals, schools, wastetreatment plants,…)	$nr./km^2$	QT	-	M/S	
		Transportation Infrastructures	Potential Infrastructures Exposed to Risks	Roads	m/km^2	QT	-	M/S	
				Railways	m/km^2	QT	-	M/S	
				Lifelines (watermain, sewerage, pipeline,….)	m/km^2	QT	-	M/S	
	Vulnerability	Social - Population Density	Potential Population Vulnerable to Risks	Population	$nr./km^2$	QT	-	S	
		Economic	Potential Economic Effects due to Risks	Economic value of the productive activities vulnerable to risk (i.e. economic value of the fields, n.workers)	€/km^2	QT	-	S	
		Physical Housing Infrastructure Density	Potential Infrastructures Vulnerable to Risks	Buildings	$nr./km^2$	QT	-	S	
		Physical Transportation Infrastructure Density		Transportation Infrastructures and Lifelines	m/km^2	QT	-	S	
&		Financial Assessment	Cost-Benefit Analysis of the Intervention	Initial costs	€	QT	-	M/S	
				Maintenance costs	€	QT	-	M/S	

5 Ambits 14 Criteria 37 Concepts

42 Sub-Criteria 91 Indicators

COLUMN C1: **AMBIT**

COLUMN C2: **CRITERION**

COLUMN C3: **CONCEPT**

COLUMN C4: **SUB-CRITERION**

COLUMN C5: **INDICATOR**

COLUMN C6: **METRIC**

COLUMN C7: **TIPOLOGY**

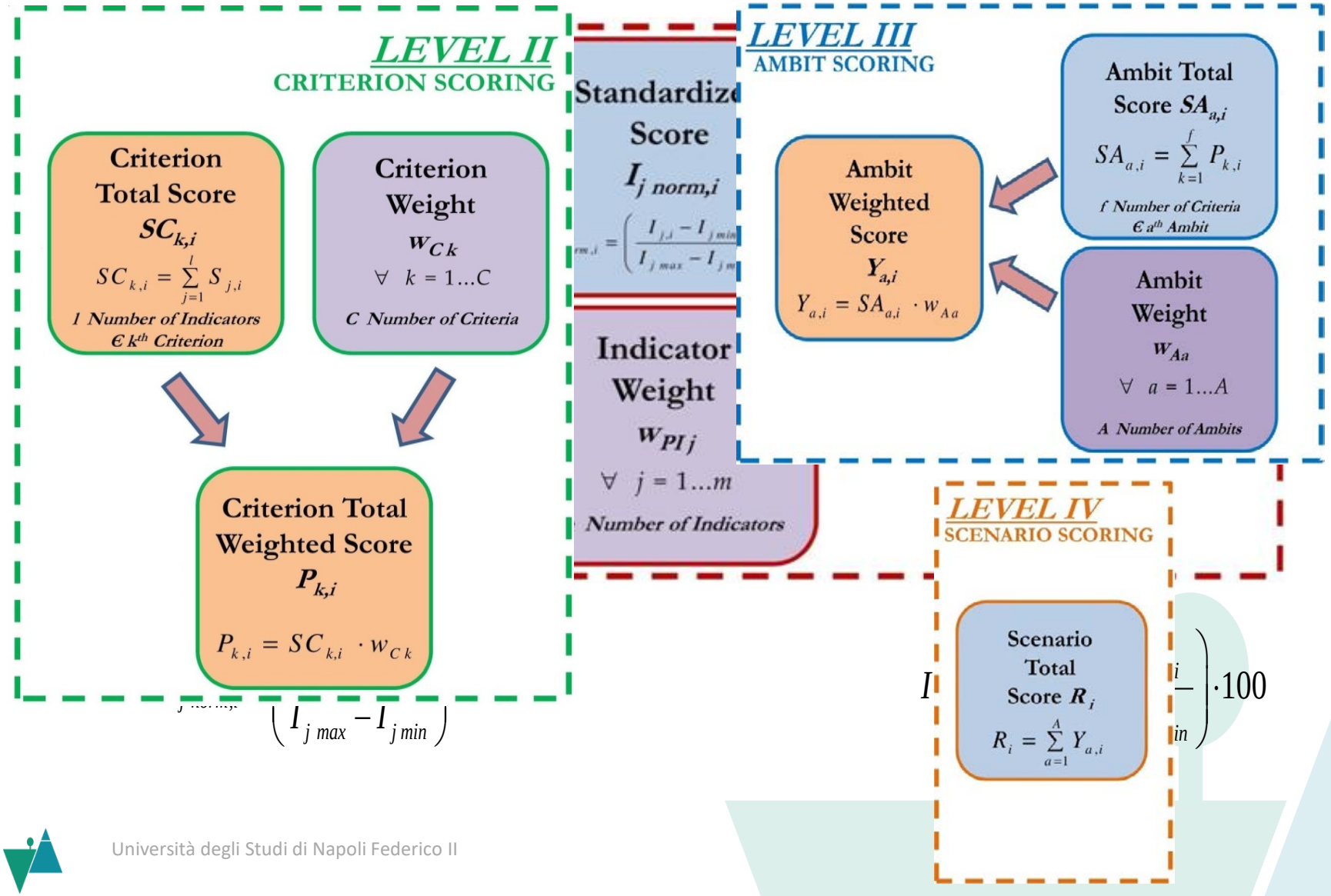
COLUMN C8: **DIRECTION**

COLUMN C9: **SOURCE**

COLUMN C10: **ASSESSMENT FACTORS**

The Assessment Framework of Phusicos

Aggregation and Weighting Methods

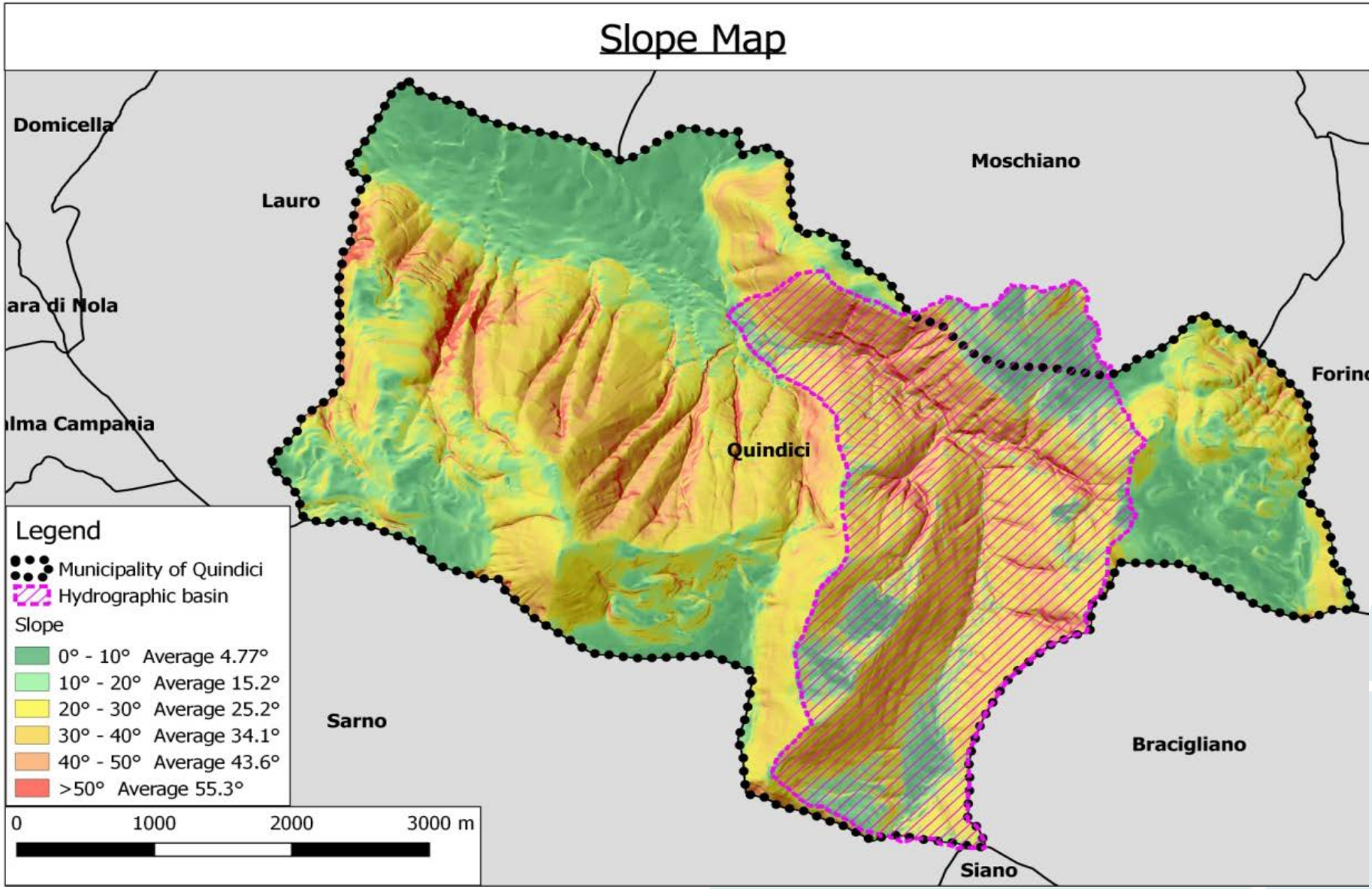


The Case Study of QUINDICI (AV)

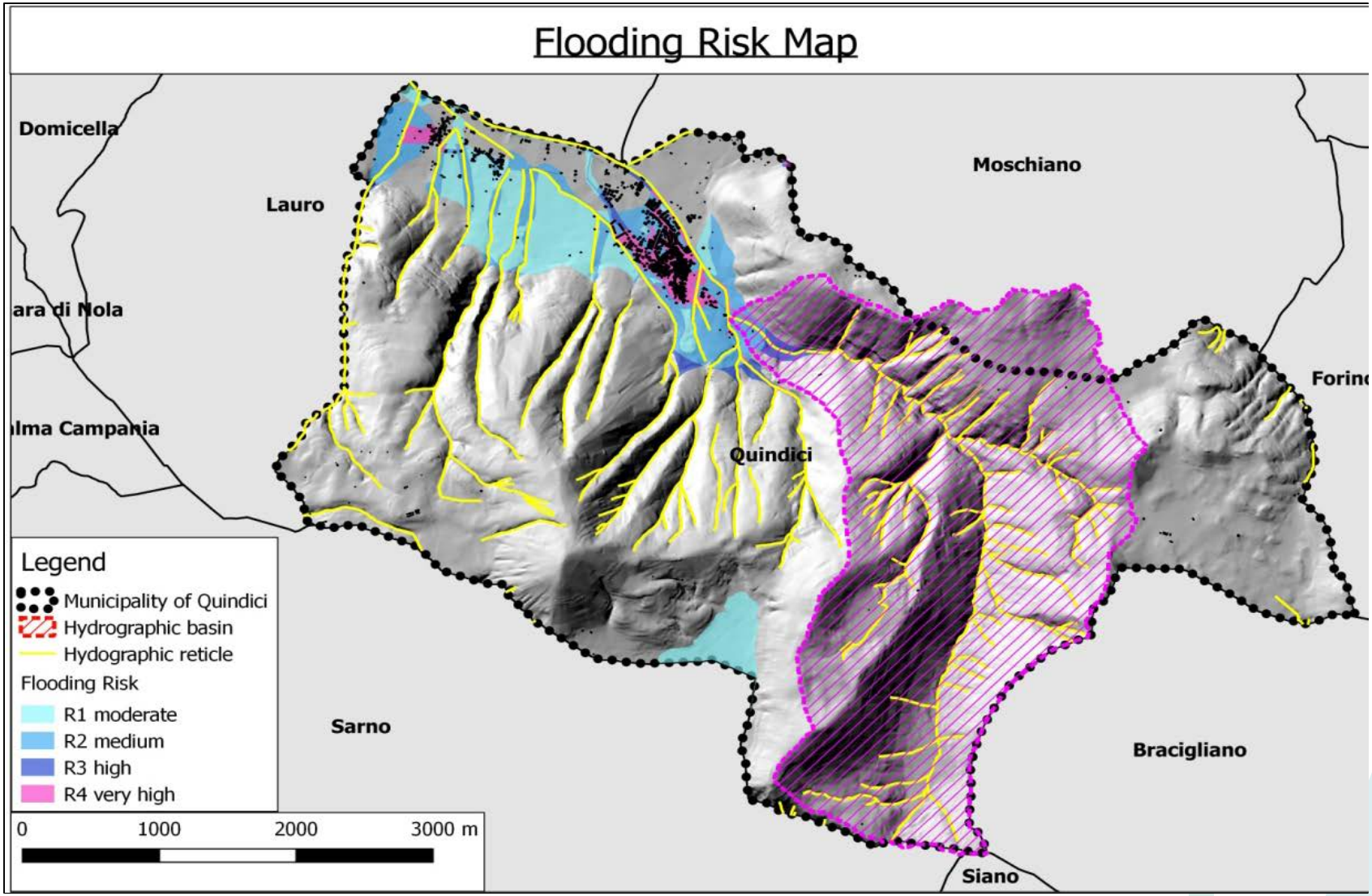
Why Quindici (AV) Case-Study?

The Case Study of QUINDICI (AV)

Site Characterization – Baseline Scenario *B0*

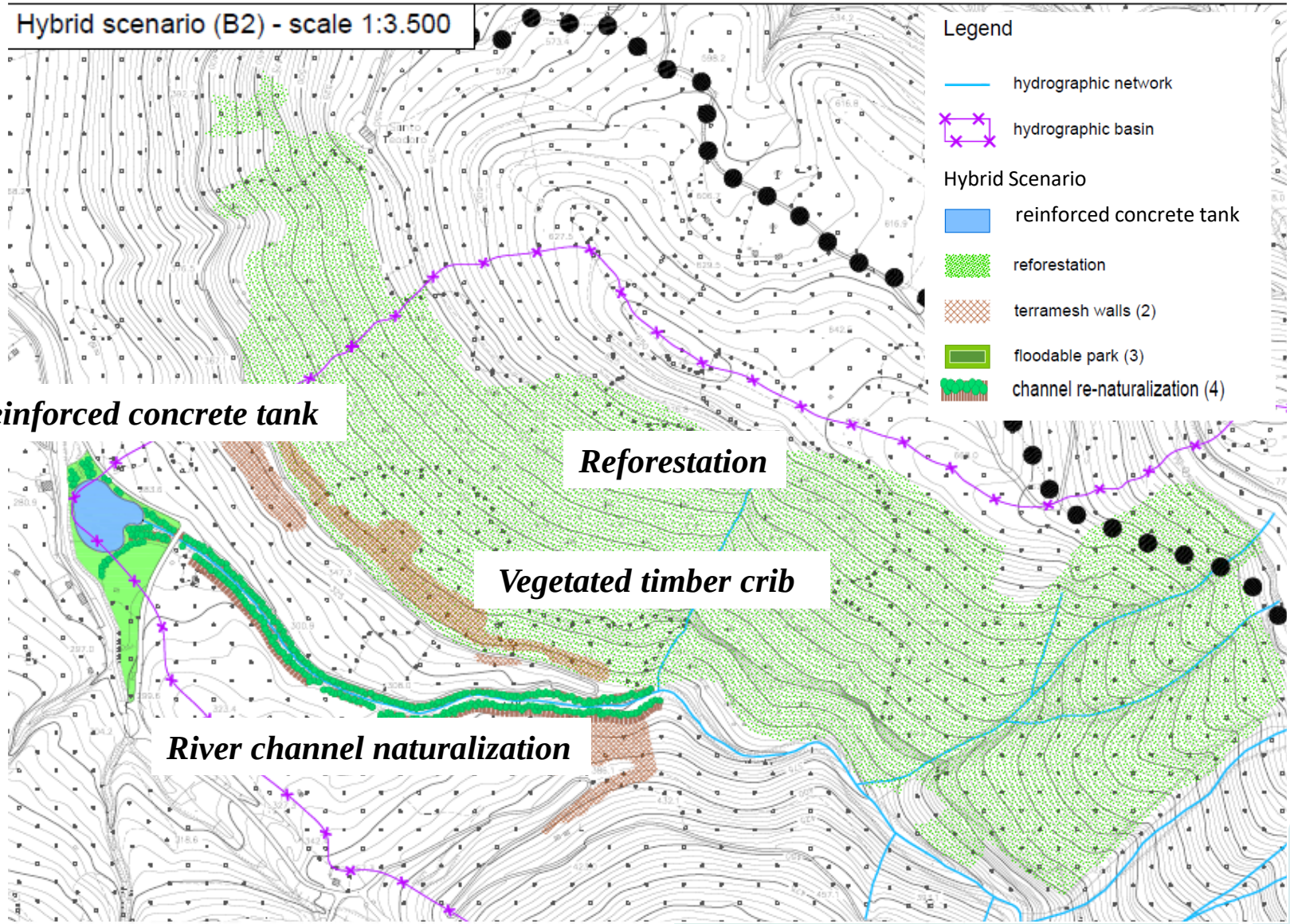


Site Characterization – Baseline Scenario *B0*

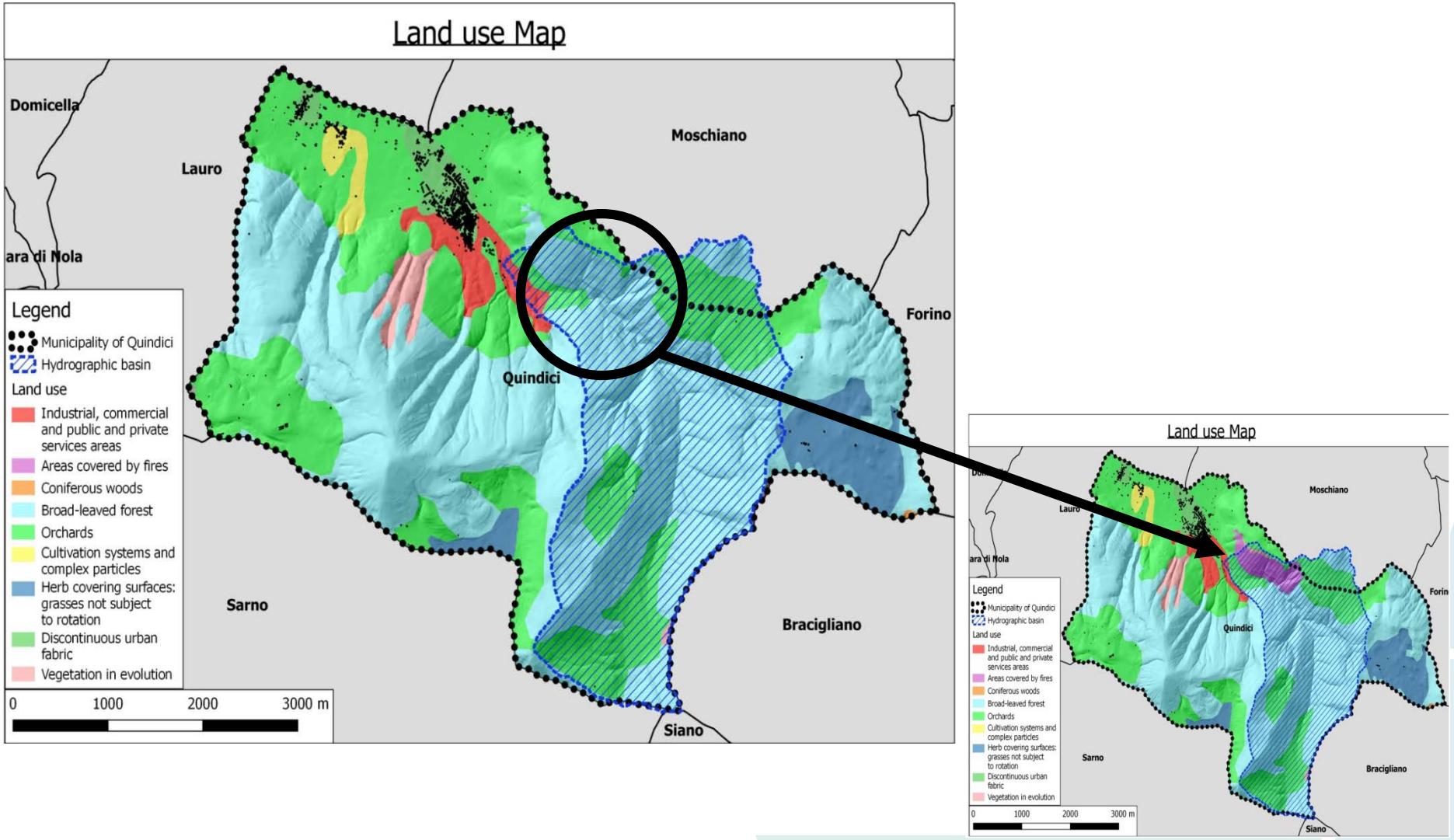


Design Scenarios: the NBSs Scenario *B1*

Design Scenarios: the Hybrid Scenario *B2*



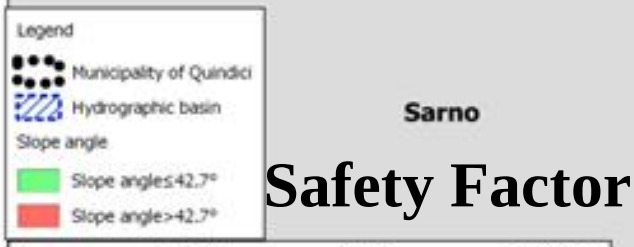
Design Scenarios: Land Use Map

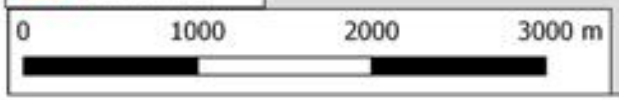


Calculation of Indicators

Slope Angle Map

Return Period T = 100 years (Medium Hazard)					
Scenario			***B0***	***B1***	***B2***
Landslides Risk Resilience	Site response to Landslide phenomena based on susceptibility indicators: slope angle, pore water pressure, groundwater depth, soil properties, land use, land cover	Area with Safety Factor *SF < 1* [km^2]	0.28	0.26	0.26
		Covered area by mobilizing landslide volume [km^2]	0.71	0.47	0.34
		Landslide velocity [m/s]	10.23	9.9	9.27





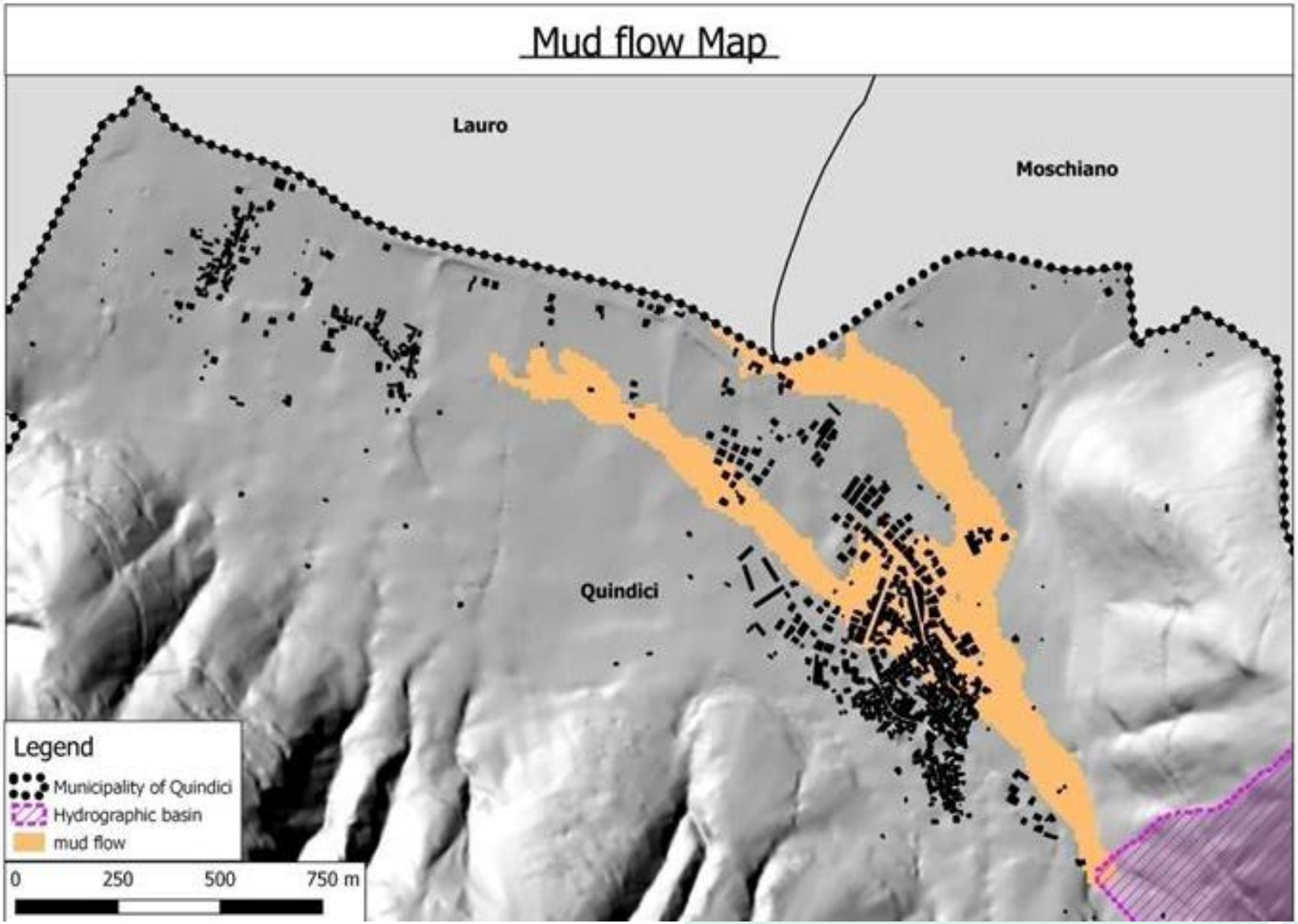
Sarno

Bracigliano

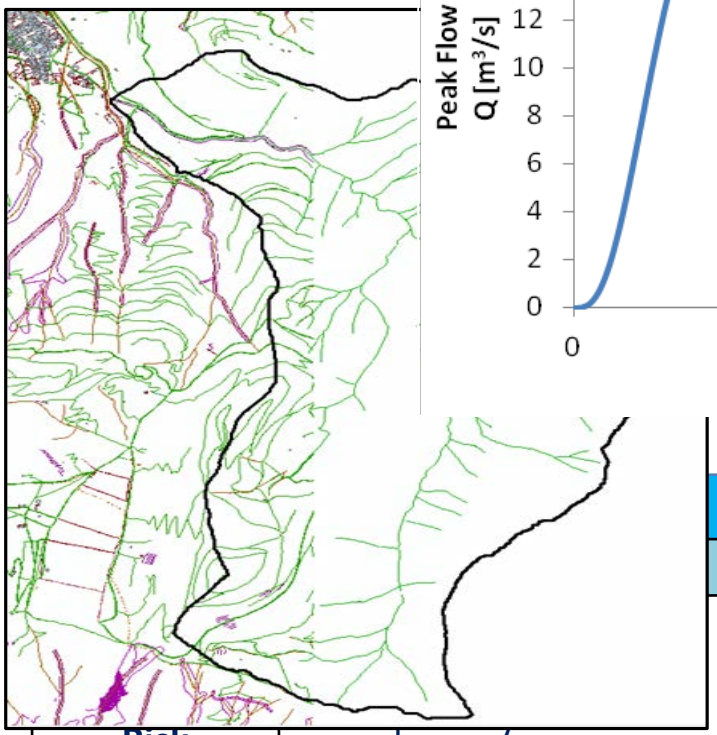
Siano

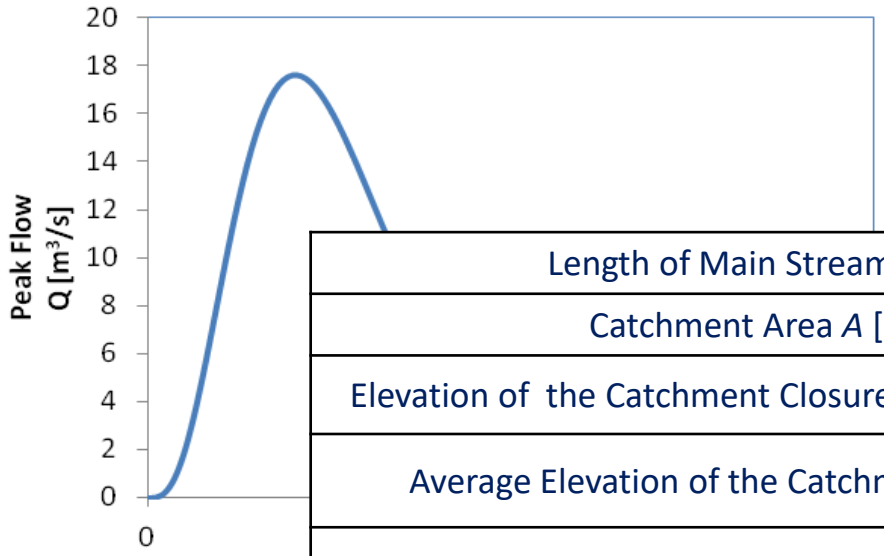
Safety Factor S*F* ≥ *1 for slope angle* $\beta \leq 42.7°$

Calculation of Indicators



Calculation of Indicators

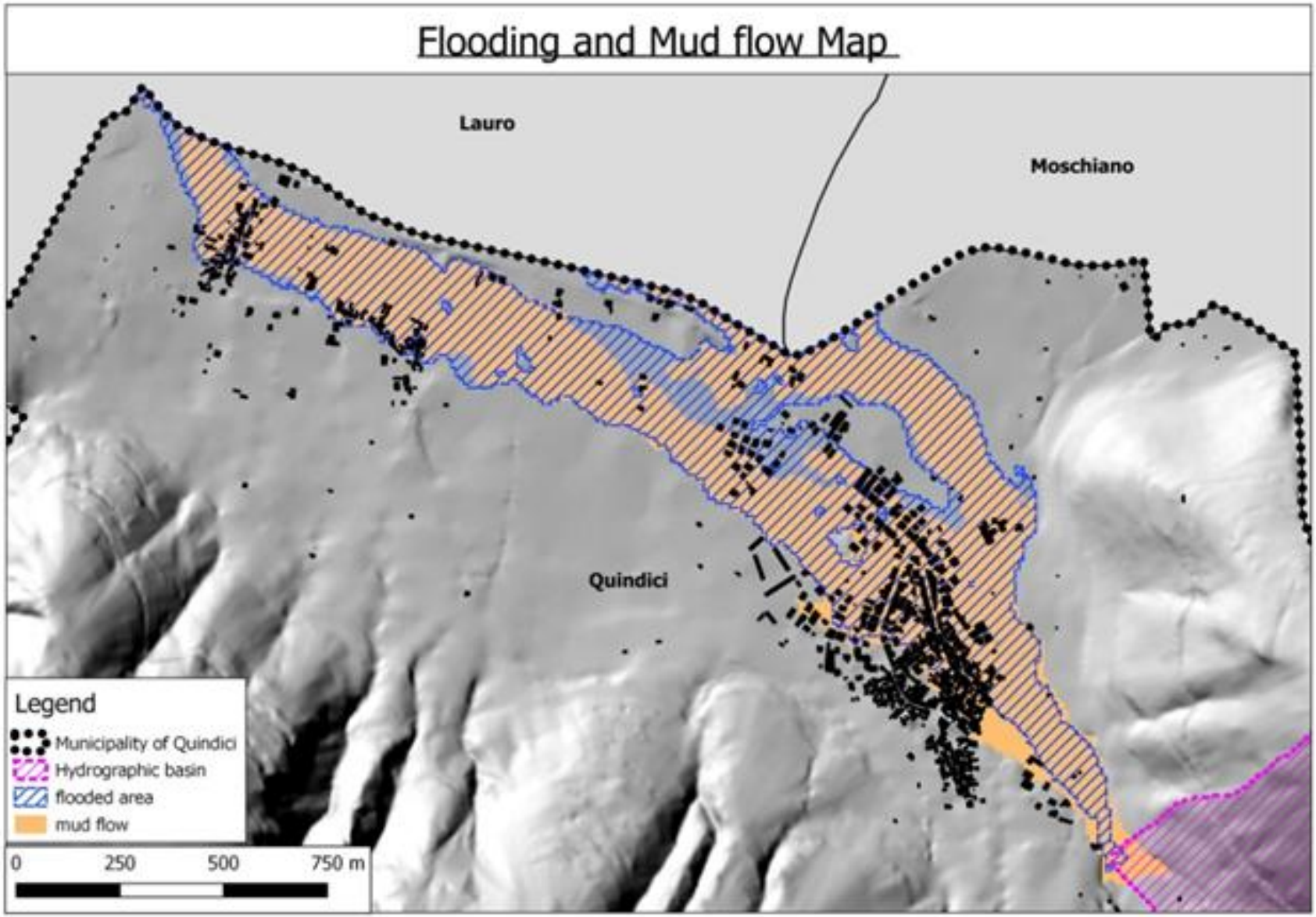




Length of Main Stream L [km]	**5.82**
Catchment Area A [km^2]	8.30
Elevation of the Catchment Closure Section z_0 [m a.s.l.]	280
Average Elevation of the Catchment z_m [m a.s.l.]	749
Maximum Elevation of the Catchment z_{max} [m a.s.l.]	1067
Average Slope of the Catchment s [%]	44.7
Concentration Time of the Catchment using the Giandotti's formula t_c [h]	1.17
Average Curve Number of the Catchment CN [-]	46.8

Risk Resilience	land use cover, run-off coefficient, rainfall intensity and duration	Peak Volume [m^3]	141647	104703	92238
		Flooded Area [ha]	75.1	72	71

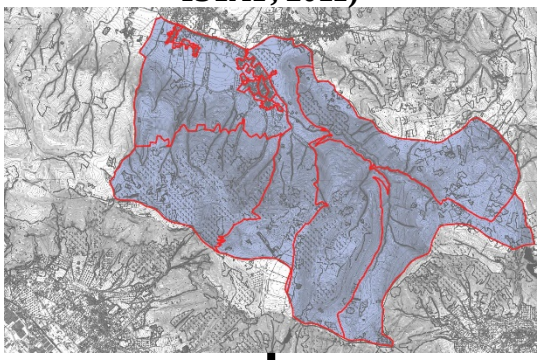
Calculation of Indicators



Calculation of Indicators

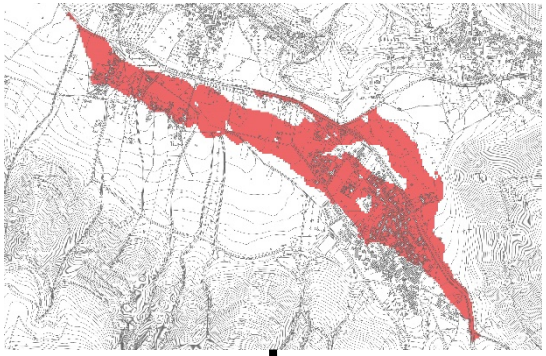
Potential Population exposed to Risks

Census Tracts (source: *Italian Institute of Statistics ISTAT*, 2011)

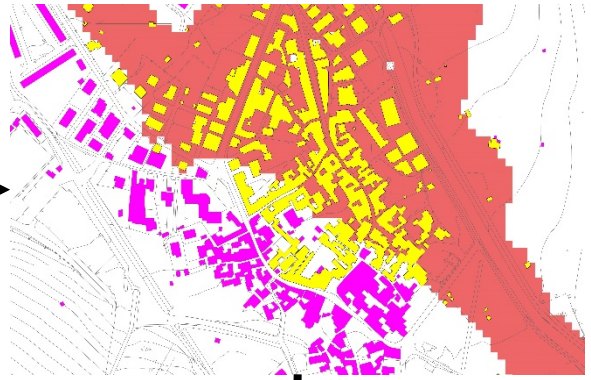


AVAILABLE DATA

Hazard Map (source: *Flo2D* simulation)



RESULTS



Census Variables (CVs)

- **Inhabitants**
- **Age class structure**
- **Commuters**

GIS tool — SPATIAL JOIN

GIS tool — SPATIAL QUERY

$$\delta_i^{CTV} = \frac{CTV_i}{B_i}$$

where:

- δ_i^{CTV} is the average value of the Census Variable of each building falling within the *i*-th Census Tract;
- CTV_i is the value if the Census Variable in the *i*-th Census Tract;
- B_i is the number of buildings falling within the *i*-th Census Tract.

GIS tool — COUNT

Population exposed to Risks

Buildings (source: Campania Region Map, 2011)

Calculation of Indicators

AMBIT	CRITERION	CONCEPT	SUB - CRITERION	INDICATOR	METRIC	SOURCE	PI-BASELINE SCENARIO	PI-BNBSs SCENARIO	PI-Hybrid SCENARIO
RISK REDUCTION	*Vulnerability*	Social - Population Density	Potential Areas Exposed to RisksPotential Population Vulnerable to Risks	Urban / Residential Areas	Population	S	743*	480*	385*
RISK REDUCTION	*Exposure*	Population Involved	Population Exposed to Risks	Commuters	nr	M/S	292	229	213
				Elderly, children, disabled	nr	M/S	421	373	360
		Potential Buildings Involved	Potential Buildings Exposed to Risks	Housing	nr	M/S	264	241	236
		Transportation Infrastructures	Potential Infrastructures Exposed to Risks	Roads	km	M/S	8.05	7.29	6.77

*The number of inhabitants has been calculated by adding different rates:

- 50% of people in the "*dangerous for a few*" area;
- Total people in the "*dangerous for many*" area;
- Total people in the "*dangerous for all*" area.

Economic Analysis

AMBIT	CRITERION	CONCEPT	SUB - CRITERION	INDICATOR	METRIC	SOURCE	PI-BASELINE SCENARIO	PI-NBSs SCENARIO	PI-Hybrid SCENARIO
TECHNICAL & FEASIBILITY ASPECTS	*Technical Feasibility (Affordability)*	Financial Assessment	Cost-Benefit Analysis of the Intervention	Initial costs	mln €	M/S	**0**	**9.24**	**7.51**
				Maintenance costs	mln €	M/S	**0**	**0.74**	**0.60**
				Avoided costs	mln €	M/S	**0**	**15.26**	**18.32**
		Landscape Coherence and Sustainable Use of Materials and Approaches	Application of Suitable Materials and Technologies	Material and techniques used coherence	0/1	LL	**0**	**1**	**0**

Hard drainage pavements	17.5	24200 m^2	0.42	8	0.03	0.46
Vegetated Timber Cribs	163.7	8019 m	1.31	8	0.10	1.42

Calculation of Indicators

AMBIT	CRITERION	CONCEPT	SUB - CRITERION	INDICATOR	METRIC	SOURCE	PI-BASELINE SCENARIO	PI-NBSs SCENARIO	PI-Hybrid SCENARIO
SOCIETY	*Quality of life*	Leisure and Connections Increasing	Recreational Opportunity	New Areas for recreational use and cultural events	m^2	GIS	**0**	**9050**	**0**
				Different activities allowed in new recreational areas	nr.	S	**0**	**4**	**0**
				Average distance of natural resources from urban centers	km	GIS	**2.3**	**1,25**	**2,3**
			Sustainable Mobility	New pedestrian and cycling paths	m	GIS	**0**	**1350**	**0**
				Sustainable transportation modes allowed	nr.	S	**0**	**2**	**0**
	Landscape and Heritage	Local Perception and Sense of Belonging	Identity	Traditional events organized in the new areas	nr.	S	**0**	**1**	**0**
		Heritage	Heritage Accessibility	Natural and cultural sites, made available	nr. Site	GIS	**0**	**3**	**0**
		Landscape Safeguard and Promotion	Landscape Perception	Scenic sites and Landmark created	nr.	GIS	**0**	**1**	**0**
				Scenic paths created	km	GIS	**0**	**4,34**	**0**
LOCAL ECONOMY	*Local Economy Reinforcement including New Job Opportunities*	Enhancement of Local Socio-Economic Activities	New Areas for Traditional Resources	New areas made available for traditional activities (agriculture, livestock, fishing,….)	ha	GIS	**0**	**-7,425**	**-7,425**
				Forest area planted	km^2	GIS	**0**	**0,5628**	**0,5628**

Scenarios Comparative Analysis and Weighting Procedure

LEVEL I

Performance Indicators →
- **Uniform weights**
- **Different weights**

LEVEL II

Criteria →
- **Likert Scale**

LEVEL III

Ambits →
- **Likert Scale**

→
- **Neutral Stakeholder**
- **Technical Stakeholder**
- **Political Stakeholder**

Each standardized performance indicator is properly as:

$$W_{PI} = I_{norm} \cdot w_{PI,s} \cdot w_{A,s} \cdot w_{C,s}$$

Different weighting options for Ambit and Criterion

AMBIT **CRITERION** **AMBIT + CRITERION**

Scenarios Comparative Analysis and Weighting Procedure Observations

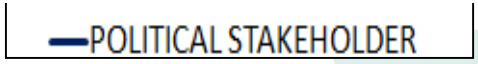
- Analyzing the **AMBIT scoring**, higher relevance of the Society Ambit was observed for *Neutral* and *Political Stakeholders*, whereas for the *Technical Stakeholder*, the **Risk Reduction Ambit** played a dominant role, except for the **CRITERION** weighting case;

- The evaluation procedure used is divided into **3 levels**. The latter starts from a broader point of view (the **Ambits**), and then goes down specifically from the **CRITERIA** to the **Indicators**;

- The standardization makes the instrument **applicable to any indicator**, whatever its metric, which can reach a global information, that concerns the entire Design Scenario;

- Each indicator assumes a certain value with respect to the Baseline Scenario: the whole procedure is based on the **comparison of different Design Solutions** compared to the non-intervention case (Scenario *B0*);

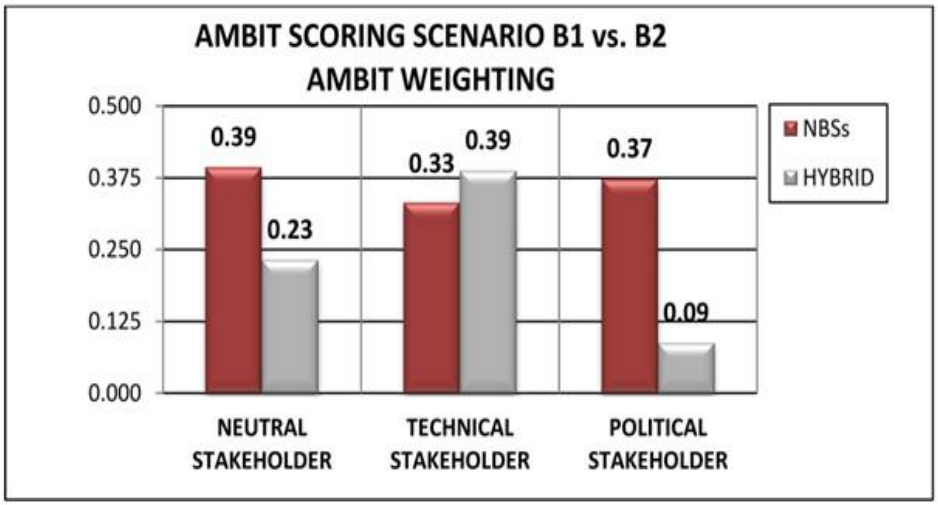
- Different weighting options were examined for Criteria and Ambits to underline how a solution could be preferable over others, **depending on the preferences of the Stakeholders** (*Neutral*, *Technical* or *Political*).

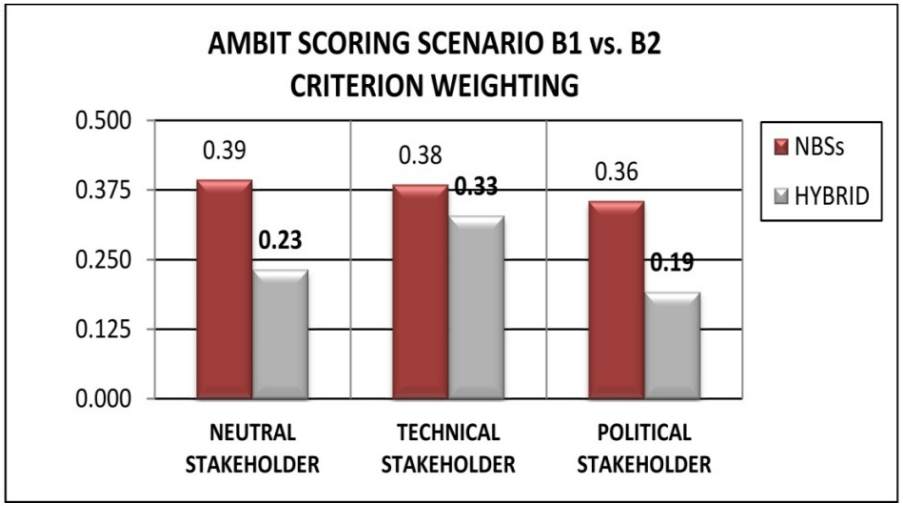


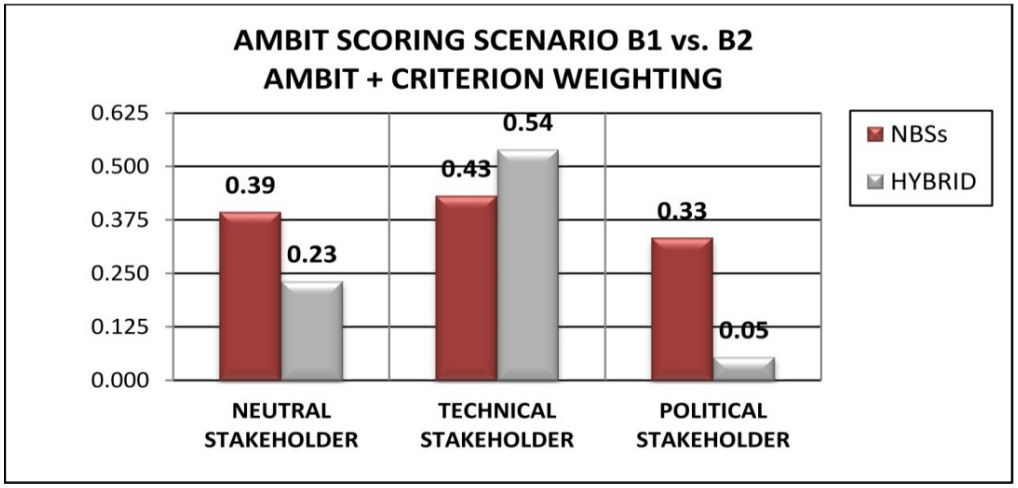
Scenarios Comparative Analysis and Weighting Procedure Observations

- **The procedure can be simplified** by choosing to **weight only either the Ambits or the Criteria or both of them**, regardless of the weighing of the indicators. Therefore, the proposed procedure could be simplified by considering a **lower number of Indicators** I_j;
- Considering 3 stakeholders with different backgrounds, the **participatory process** has been simulated, reproducing the process to be implemented within the Living Labs, in which each stakeholder pays attention to the objectives he considers most important;
- **The weighing of the Ambits and the Criteria is more relevant than that of the Indicators**. Indeed, the weighing of the Indicators, especially for a significant number of them, appears to affect less the final result;
- It should also be worth noted that in the Long-Term Scenario, the abovementioned Indicators could be re-calculated and monitored, through direct survey, in order to check whether the real use corresponds to the purposed one;
- It should be emphasized that this approach should be considered as a **FLEXIBLE and INNOVATIVE tool, to be customized and tailored for each case study.**

Scenarios Comparative Analysis and Weighting Procedure







The NBSs are among the interventions of Naturalistic Engineering that, on one hand, **reduce the Natural Hazards** induced by extreme weather events and, on the other hand, **are harmonized with the natural** environment, associating social factors such as human **Well-Being**, **Poverty Reduction** and **Socio-Economic Development**.

Thank you!