Mapping territorial fragility and viticultural suitability in inland Umbria: identifying place-based development opportunities

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Objectives

Develop an integrated spatial framework combining territorial fragility and climatic suitability analysis.

Identify rural municipalities in Umbria with both high fragility and potential for climate-adaptive viticulture.

Assess the availability of underutilized land suitable for new vineyard development.

Explore whether viticulture can support rural regeneration in marginal and fragile areas.

Provide a policy-oriented tool to support place-based development strategies under climate and demographic change.

Metodology

The study combines two complementary approaches:

1. Territorial Fragility Analysis

Construction of a **municipal-level composite fragility index**

Identification of municipalities characterized by structural socio-economic vulnerability

Focus on areas potentially benefiting from new vineyard development

2. Viticultural Suitability Analysis

Development of a **spatial suitability map** for grapevine cultivation

Assessment of climatic suitability and land availability

Consideration of underutilized land (pastures and permanent grasslands)

Territorial fragility index

Macro-indicator	*Variable*	*Definition*	*Positive/Negative effect on the fragility index*
Socio-economics	Population density	Number of inhabitants per km^2; used as a proxy for land-use and settlement pressure (higher values = greater pressure)	+
	Dependency ratio	Ratio of the population in non-working age (0-14 years and 65 years and older) to the population in working age (15-64 years), multiplied by 100	+
	Birth rate	Ratio of live births in the year to the average population size, multiplied by 1,000	-
	Internal migration rate	Ratio between the annual internal migration balance and the average resident population, multiplied by 1,000	+
	International migration rate	Ratio between the annual international migration balance and the average resident population, multiplied by 1,000	+
	Population with higher education	Percentage of the resident population with tertiary education at levels I and II, PhD, and advanced studies	-
	Activity rate	Ratio of individuals in the workforce to the corresponding reference population	-
	Unemployment rate	Ratio of individuals looking for employment to the corresponding workforce	+
	Per capita income	Annual average income per taxpayer	-
Agriculture	Average farm size	Ratio of the total agricultural surface to the number of farms (hectares)	-
	Area dedicated to PDO and/ or PGI vineyards	Percentage of PDO and/or PGI vineyards surface relative to UAA	-
	Number of producers of PDO and/or PGI products.	Number of producers of PDO/PGI quality products in the municipality	-
	Farm owners who have attended at least one agricultural training course	Percentage of farms owners who have attended at least one agricultural training courses out of the total number of farms owners	-
	Utilized agricultural area	Percentage of UAA out of the total area of the municipality	-
Tourism	Composite receptivity function rate	(Number of beds/resident population*area)*100	-
	Yearly stays	Number of nights spent by guests in lodging establishments	-
	Average duration stays	Ratio of overnight stays to the number of guests who arrived at the lodging facility	-
	Seasonality coefficient	Evenness of monthly arrivals across the year ($\omega \in [1/12, 1]$); $\omega = 1$ indicates an even distribution (no seasonality), $\omega = 1/12$ indicates full concentration in one month (maximum seasonality)	-
	Average restaurants rating	Average score of all restaurant reviews on Google Maps	-
	Restaurant density rate	(Number of restaurants/resident population)*100	-

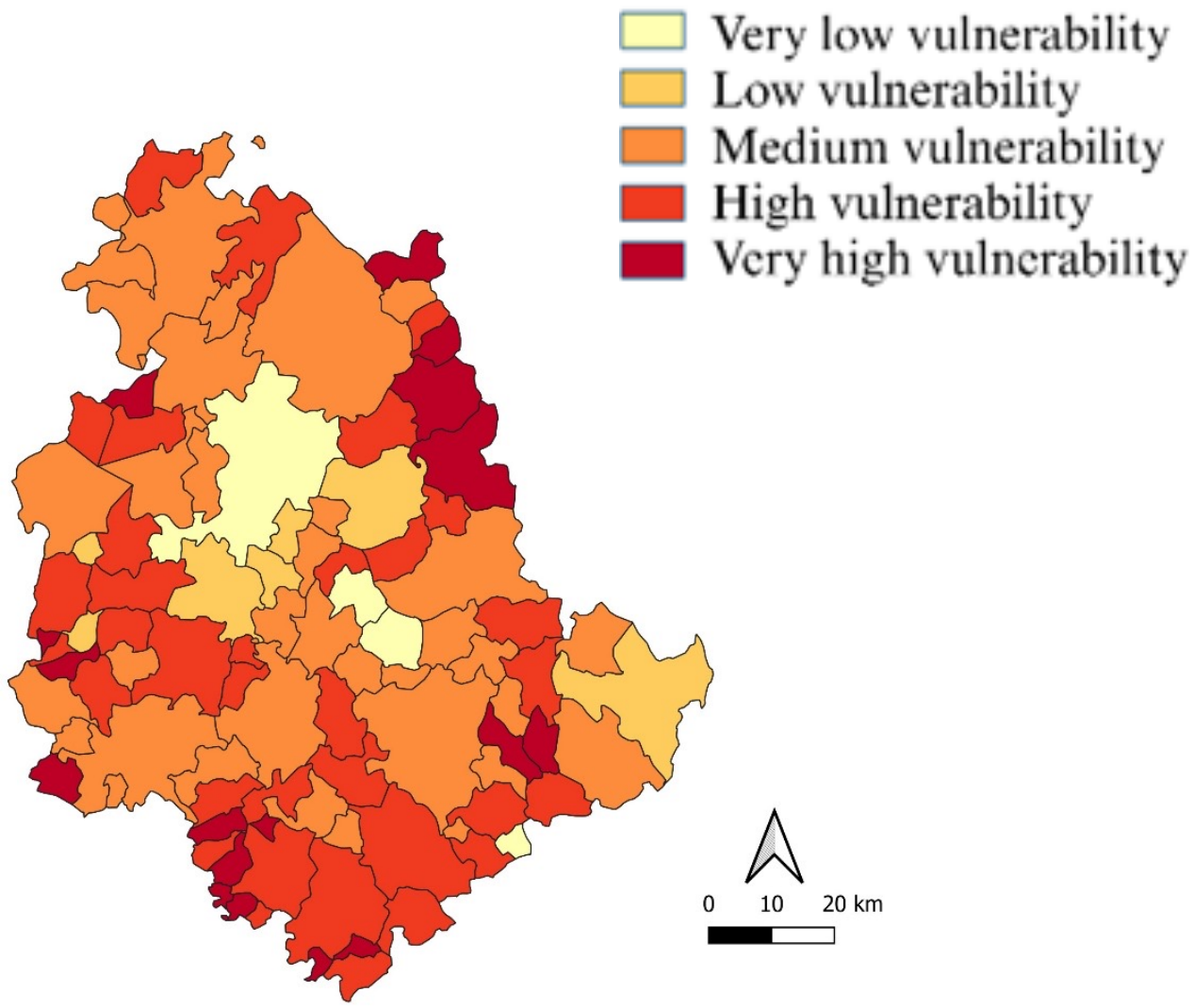
Territorial fragility index

Variables were then aggregated within each macro-indicator using equal weights (OECD, 2008) within the same domain.

Specifically, the socio-economic macro-indicator includes 9 variables (weight $1/9$ each), the agriculture macro-indicator includes 5 variables (weight $1/5$ each), and the tourism macro-indicator includes 6 variables (weight $1/6$ each). For municipality i,

macro-indicator scores were computed as weighted arithmetic sums:

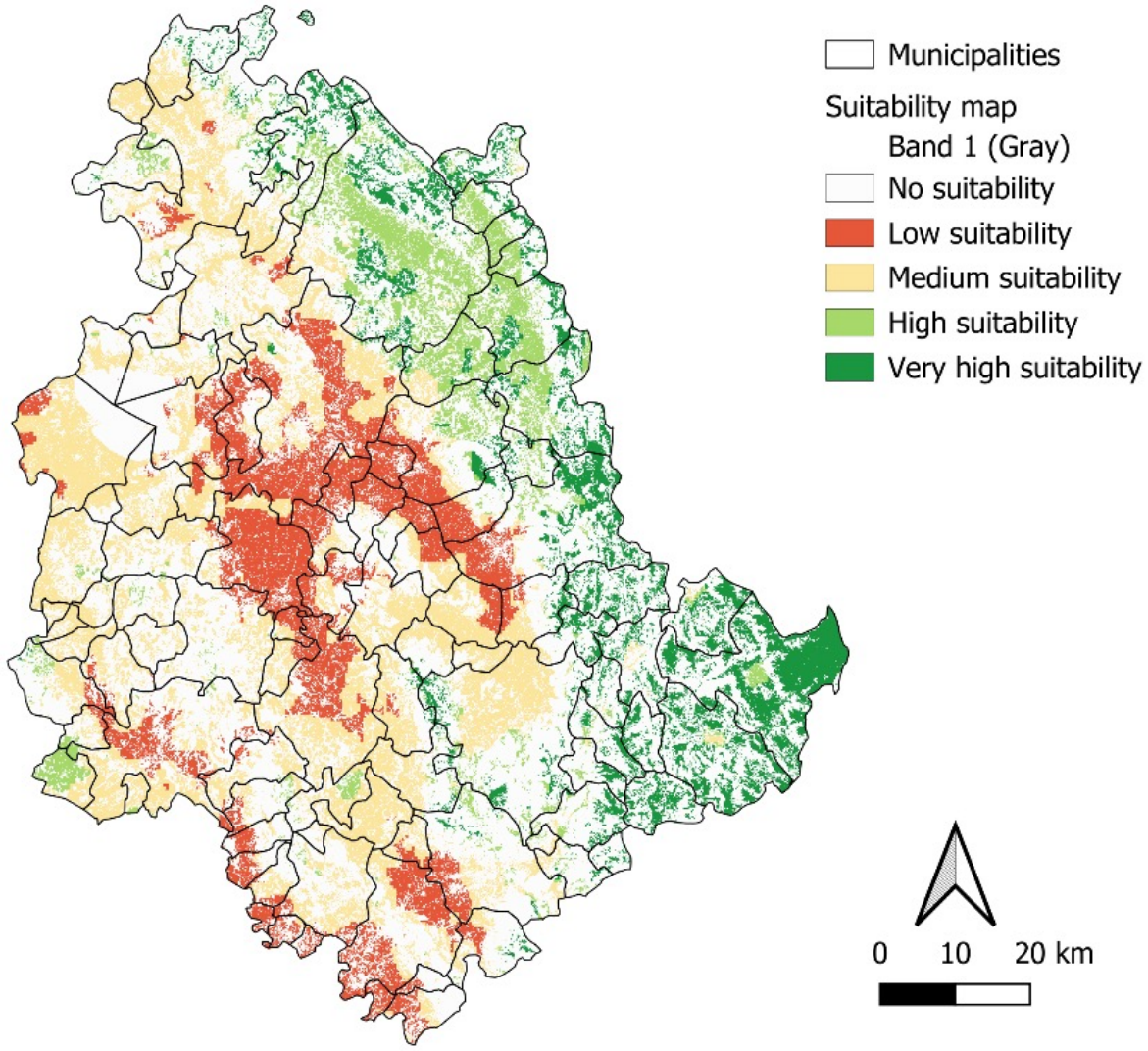
$$SE_i = \sum_{k=1}^{9} \left(\frac{1}{9} z_{i,k}\right), AG_i = \sum_{k=1}^{5} \left(\frac{1}{5} z_{i,k}\right), TO_i = \sum_{k=1}^{6} \left(\frac{1}{6} z_{i,k}\right)$$



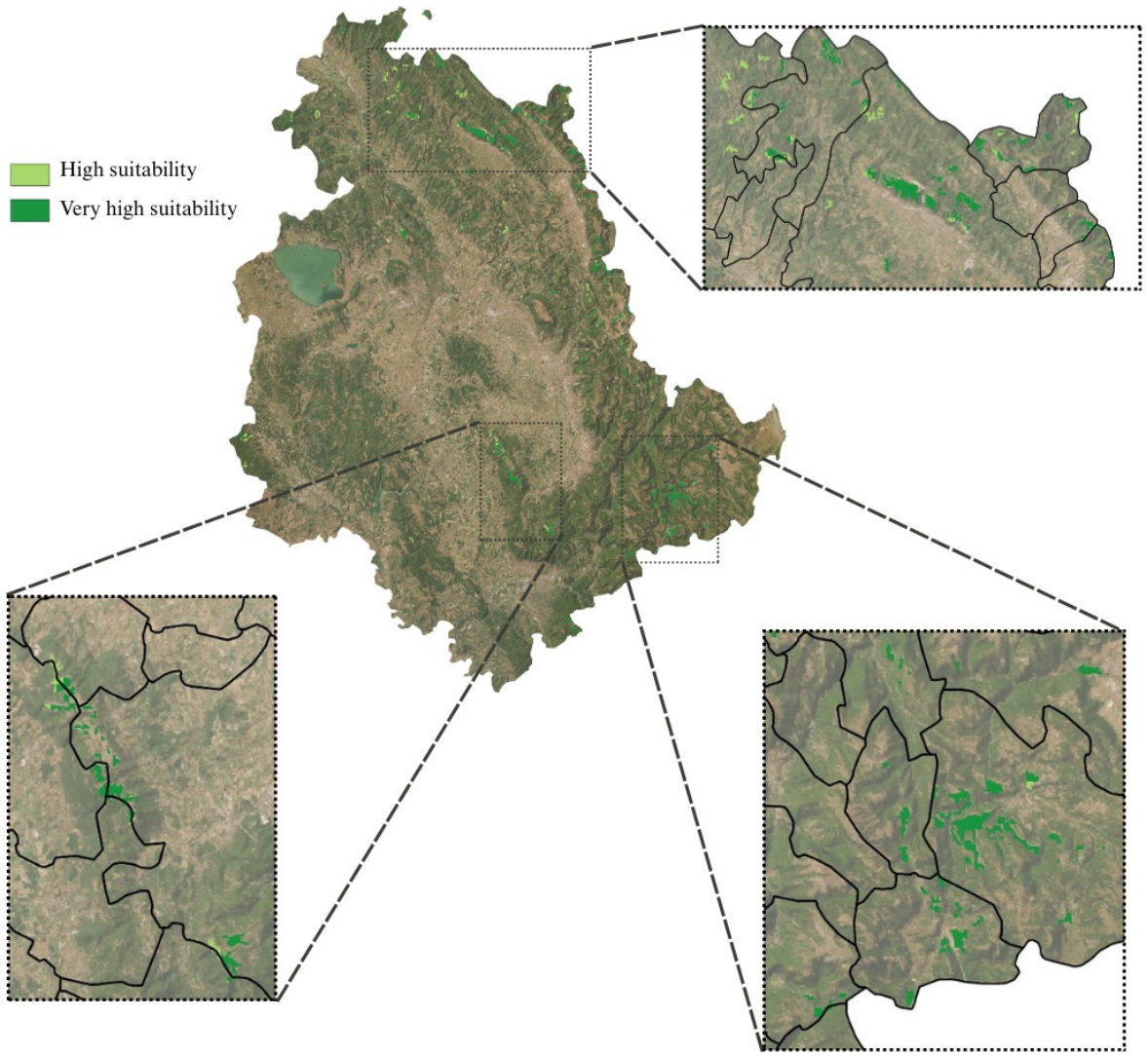
Territorial fragility index

Suitability map

- Heat stress: number of days with temperatures harmful to grapevines;
- Evapotranspiration: the difference between potential and actual evapotranspiration, indicating water stress;
- Late frost events: days with sub-zero temperatures between April 1 and May 15;
- Winkler Index: this index is a key indicator of heat accumulation essential for vine growth and development. It quantifies the cumulative Growing Degree Days (GDDs)—a measure of thermal energy—during the typical grapevine growing season, from April 1 to October 31 (Northern Hemisphere). The index is calculated using the formula:
- Winkler Index (WI) = Σ (Tmean − 10°C),

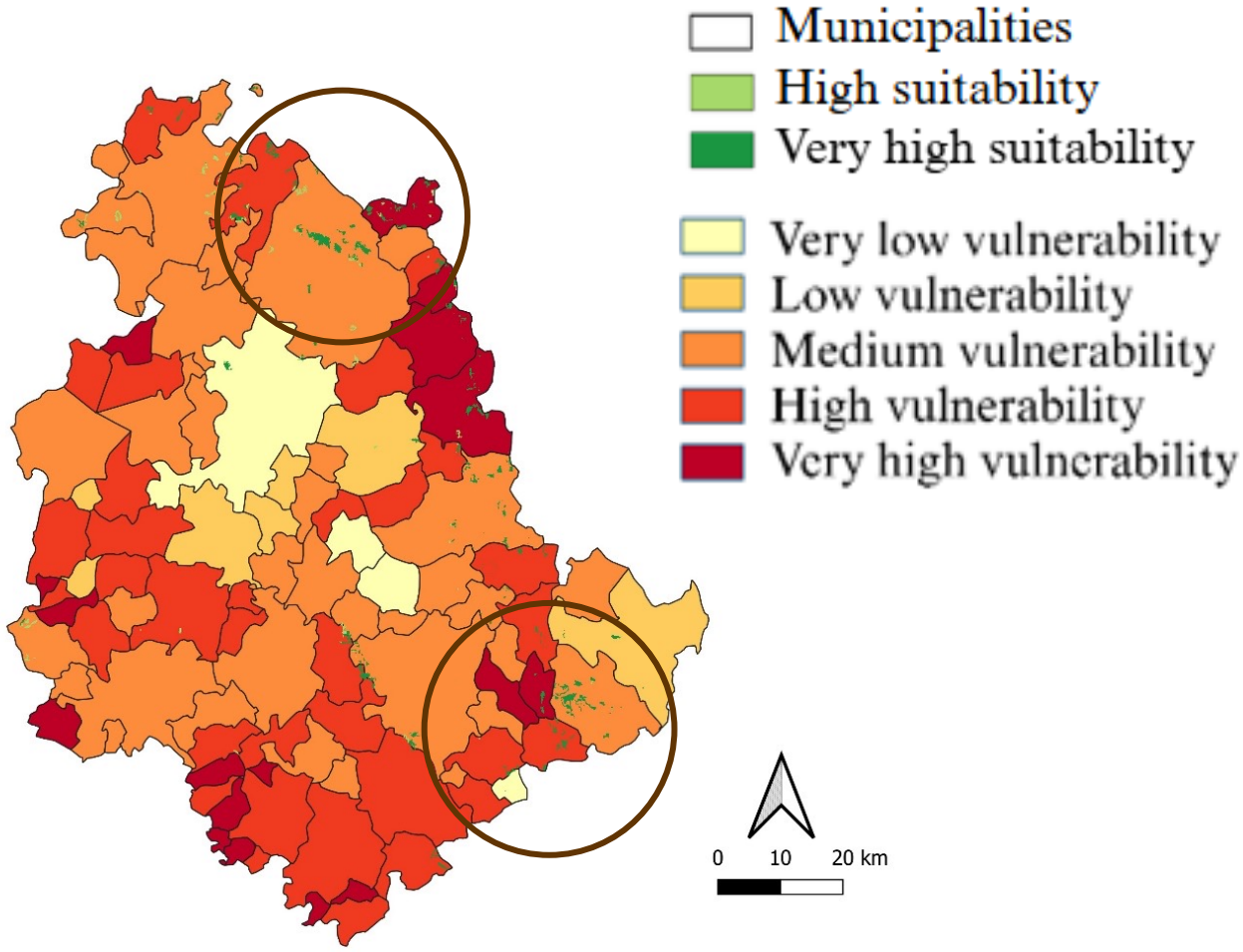


Suitability map



Map of land availability for vine cultivation

- High suitability: 1636.02 ha
- Very high suitability: 5914.90 ha



Intersection of territorial fragility and viticultural potential

Pietralunga (580 ha), Scheggia e Pascelupo (454 ha), Sigillo (118 ha), Fossato di Vico (90 ha), Gualdo Tadino (96 ha), Nocera Umbra (329 ha), Massa Martana (227 ha), Sellano (110 ha), Cerreto di Spoleto (54 ha), Poggiodomo (128 ha), Monteleone di Spoleto (278 ha), and Ferentillo (78 ha).

Conclusions

The study develops an **integrated spatial framework** combining: territorial fragility analysis climatic suitability for viticulture.

Results show that several fragile municipalities in Umbria also contain: climatically suitable areas, and available land for new vineyards.

Climate-adaptive viticulture may therefore represent: a tool for rural regeneration, a strategy against land abandonment, and an opportunity for economic diversification in marginal areas.

The main contribution of the paper is the identification of the **spatial overlap between vulnerability and opportunity**, supporting more targeted and place-based regional policies. The framework can support regional planners and local administrations in identifying priority areas for sustainable rural development under climate change.

Next steps: proposals

Il consumatore che ne pensa?

La profittabilità aziendale della spumantistica umbra: una nuova sfida per un nuovo vino

La sfida delle reti di impresa e del distretto spumantistico regionale