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ORIGINAL ARTICLE

A Transdisciplinary Analysis of the 2009 Catastrophe in Giampilieri Superiore by Land Use Evolution Over Time

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Abstract
On October 1 2009 a deluge hit the Peloritani Mountains, in NE Sicily, Italy, where the rainfall data recorded 225 mm in 9 h. Giampilieri Superiore was the most affected townlet in terms of infrastructural damages and human losses (37 dead, 37 wounded, and more than 1000 evacuees). The debris flows, triggered by flash floods wreaked havoc of the urban structure. More than 200 mln € was granted to protection works for conveying water and debris flows to bypass the town. The disaster was numerically simulated by SCIDDICA (Digital Twin) with excellent approximation, and the effects of the safety installation were tested as well, proving to offer sufficient protection for the village. The Peloritani area overlooking the Ionian See flourished during the Saracen domination, whose legacy of systems of terraces, cisterns and wells guaranteed the finest water management in steep terrains, allowing a safe emplacement of watermills, around which Giampilieri and other villages developed. This hydraulic legacy has been undermined during the last decades due to lack of appropriate maintenance because of the progressive loss of the Saracen culture. It is unconceivable that subsidies on the scale granted to Giampilieri are sustainable when facing innumerable future climatic disasters. A cheaper and more viable solution is to be found, e.g., the settlement of immigrants in the area, promoting the labor-social inclusion of those persons who already possess such a Saracen culture or are willing to acquire it from the last local depositaries, according to a retro-innovation perspective and methodology.

Keywords Debris flow · Risk assessment · Numerical simulation · Digital twin · Inclusion of migrants · Retro-innovation

1 Introduction

Natural hazards and disasters, especially those causing great, painful human losses, command us careful analyses and profound reflections. The case of Giampilieri Superiore (hereon shortly Giampilieri) is sadly paradigmatic of events that will occur more and more frequently in the Mediterranean area due to the accelerating climate change and environmental degradation (Aronica et al. 2012).

Giampilieri's safety measures (Arena 2020; Navarra 2020; Ortolani and Spizuoco 2014) constituted an extremely expensive post-disaster solution, difficult to be adopted for many other similar situations, certainly not as a preventive action.

The 2009 Giampilieri disaster and the efficacy of the emplaced safety works have been simulated using the Urban Tissue version of the SCIDDICA-SS2 numerical model (Lupiano et al. 2017).

Yet, if we go beyond a mere techno-scientific analysis, it emerges from a transdisciplinary view point that environmental degradation is also due to an increasingly critical loss of "culture", a consequence of the pervasive growth of globalization. Giampilieri, the most important farmhouse in Messina at the beginning of the seventeenth century, grew into a townlet near one of the watermills then existing in

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the valley. The presence of the mill in such a strategic area implied a finest water management, a precious agricultural necessity. The system of terraces, dry-stone-walls, "gebbie", cisterns and wells, a cultural, hydraulic heritage since the Saracen domination (Di Gregorio 1904), is now almost completely lost due to the scarcity of local manpower and skills, aggravated by the ongoing globalization which leaves almost no market or economic opportunity whatsoever to the potential of its top agricultural quality.

The traditional culture lost in Sicily is however still thriving amongst human communities of the countries on the southern and eastern shores of the Mediterranean and Middle East. Migrations from these countries may represent a great resource and opportunity (Lanza and Fernandez 2024), since entrusting migrants with now degraded land that can nevertheless still be recovered, and endowing them with the necessary resources, could represent a sustainable preventive solution according to the retro-innovation approach (Stuiver 2006).

The next section summarizes the 2009 Giampilieri's catastrophe in its geological context. Section 3 reports the results of the disaster simulations applying the SCIDDICA-SS2 model.

In Sect. 4, we describe the recent protection works and their relevance in emergency situations of the like, as assessed by the SCIDDICA-SS2 simulations.

Section 5 consists of a transdisciplinary analysis of the territory and its land use evolution, that entailed a very fine control and management of the water in steep terrains still unsurpassed today; the historical conditions that led to the present-day degradation are also considered.

Section 6 explores the globalization effects that are potentially leading to similar disasters in many areas of Mediterranean, and proposes sustainable solutions based on the recovery and therefore the application of undermined agricultural techniques involving the assessment and assistance by migrants in a retro-innovation perspective (Salvati et al. 2010). Discussion and conclusions close the article.

2 The Giampilieri Territory and 2009 Catastrophe

Giampilieri village is located on the eastern slopes of the Peloritani Mountains, on the left bank of Giampilieri River. Lying on an alluvial fan crossed by various streams, tributaries of the Giampilieri River, these possess their own small catchments, ranging from 0.03 to 0.1 km^2, all of them exposed to peak torrential regimes.

Inside the urban area (Fig. 1), the streams' paths overlap to the streets, so Loco stream turns into Saccà Street, Sopra Urno stream into Chiesa Street and Puntale stream into Vallone Street (Ortolani and Spizuoco 2014).

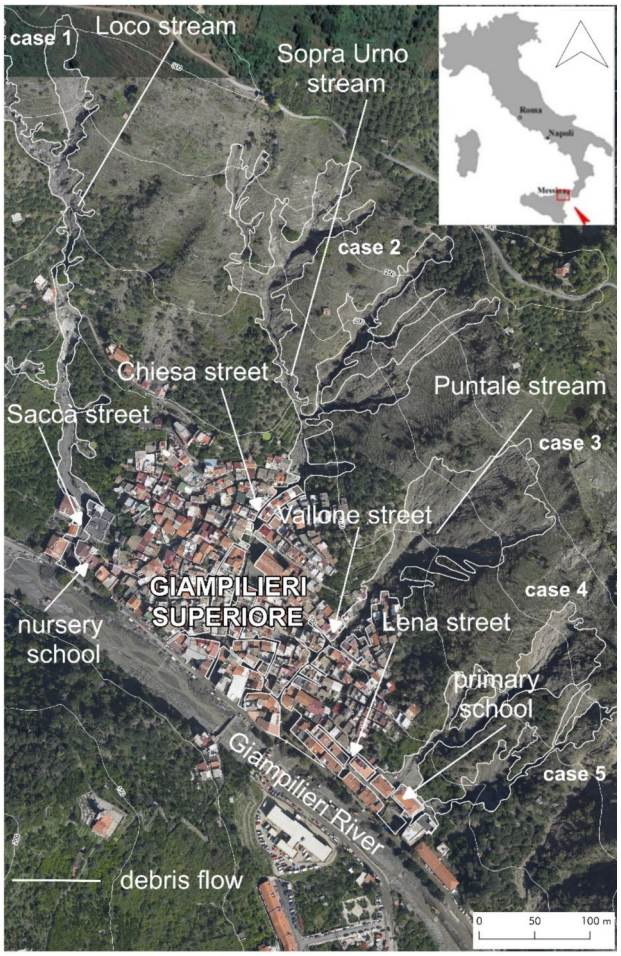

Fig. 1 October 2009 debris flows occurred in Giampilieri

On the October 1st 2009 a severe meteorological event hit the Peloritani Mountains (NE Sicily). The intense rainfall caused flash floods that triggered many debris and mud flows, and the consequent havoc resulted in 37 fatalities, dozens injured, hundreds of evacuees, devastating public and private infrastructures like buildings, railways, roads, electric and telephonic networks. The Department of Civil Protection of the Sicilian Region mapped more than 600 landslides in an area of approximately 50 km^2. The meteorological data recorded by the S. Stefano di Briga rain-gauge showed a cumulative rainfall depth of 225 mm in 9 h, with a peak of about 22 mm/min. The area is prone to debris flows due to the peculiar local lithology, a complex tectonic history, steep slopes (30–60 degree) and narrow gullies with torrential hydraulic regime (Arena 2020). The 2009 disaster occurred in an area of high hydrogeological risk, already hit by previous landslides and wildfires.

Three years earlier, in 2006, a serious fire spread across the bushland overhanging Giampilieri (Fig. 2), annihilating the whole vegetation cover. The following year, in October,

Fig. 2 Slope area burned in 2006 (Google Earth image)

a violent storm triggered mud flows running on the ashy, exposed ground eventually flooding Giampilieri and causing great material losses, fortunately without casualties (Ortolani and Spizuoco 2014). Thus, when on October 1 2009 the deluge hit the Peloritani, all the conditions were already set to convey catastrophic debris flow phenomena (Fig. 1) with the potential of wreaking havoc in Giampilieri and in many other townlets nearby.

During the paroxysmal pluvial event, debris flows were mobilized from the slope sprawling over the village (Fig. 1). Many of these were first channeled towards the natural drainage network and then inundated the riverbeds-street; when they finally reached the core of Giampilieri, they devastated urban infrastructures and caused human losses (Bagarello et al. 2012; Ortolani and Spizuoco 2014). The severity of the deluge was not the only forcer of the disaster, further causes rooted in a general lack of maintenance of the agricultural lands, as epitomized by abandoned terraces lacking the proper drainage, and the unmaintained dry walls, as Ardizzone et al. (2012) emphasized.

3 Simulations of the 2009 Catastrophic Event by SCIDDICA

Even in the aftermath of the disaster, it may be fundamental to develop a digital twin to test the safety of the vulnerable areas. The Cellular Automata SCIDDICA-SS2 model (Simulation through Computational Innovative methods for the Detection of Debris flow path using Interactive Cellular Automata for Subaerial and/or Subaqueous debris/mud/granular flows version 2) was applied to the 2009 Giampilieri case. The simulation results were in excellent agreement with the real event; hence the protection works may be assessed by this digital twin (Lupiano et al. 2017).

3.1 SCIDDICA a Cellular Automata Model for Simulating Granular/Debris/Mud Flows

Cellular Automata (CA) are a computational paradigm for modelling and simulating complex systems evolving on the base of the local interactions of their elementary components. They represent an alternative to the classic numerical methods of Partial Differential Equations.

A CA can intuitively be seen as a regular tessellation, i.e. a space, partitioned in equal cells, each one embedding an identical input/output computing unit. Each cell is characterized by its state. Input for each cell is local and is given by the states of the neighboring cells, where the neighborhood conditions are given by a pattern invariant in time and space. At time 0, cells are in arbitrary states (initial conditions) and the CA evolves changing simultaneously the state at discrete times (steps), according to local rules (the so-called transition function), that are invariant in time and space (Di Gregorio and Serra 1999).

The CA approach is based on the definition of "simple", fundamental local rules, that have to comply with the physics conservation laws in the context of space and time discretization. Such rules have to capture the significant interacting processes. The phenomenon evolution "emerges" by local interactions: simple rules can generate very complex realistic behaviors.

CA modelling and simulation of real complex "macroscopic" systems implies that some correspondence must be explicitly established between the model and the real world in order to compare phenomenon's development with simulation progress. The Macroscopic or Multicomponent CA (MCA) extension of CA is devised for such purposes (Avolio et al. 2012; Di Gregorio and Serra 1999). SCIDDICA-SS2 (Avolio et al. 2012; Lupiano et al. 2015) "Urban Tissue" version (Lupiano et al. 2017) was used for simulating the Giampilieri's past and possible future debris flows.

The model SCIDDICA-SS2-UT is a two-dimensional MCA, with hexagonal tessellation. The cell neighborhood is given by adjacent cells, and the cell state is represented by sub-states. Some sub-states specify all the features related to the third dimension. Sub-states are listed below:

- Altitude specification (the area of a single cell, falling within the urban tissue, can include a percentage belonging to road beds, which eventually fosters the runoff of the debris flow, and a percentage relating to buildings that can constitute a barrier to the flow. It is therefore necessary to specify in these cells the aforementioned percentages together with their corresponding altitudes. Average values of altitude are assigned to the other cells),
- Erodible soil depth,
- Matter (debris) inside the cell:
    - Thickness,
    - Co-ordinates X and Y of the barycenter of debris inside the cell,
    - Kinetic Head
- Flows from the cell toward the center of the neighboring cells:
    - Quantity normalized to a thickness,
    - Co-ordinates X and Y of the barycenter of the possible flows toward the neighboring cells,
    - Kinetic Head

The transition function is divided in parts, the so called "elementary processes":

- Computation of outflows and their shift
- Energy loss by turbulence
- Soil erosion

Each step involves the execution of the transition function, i.e. the sequential execution of elementary processes and updating of the states.

This version enables the simulation of the entire landslides' evolution, from the detachment areas to the deposition zone after invading the urban tissue, a powerful predictive tool in inhabited areas exposed to hazard natural disasters like those caused by shallow flows.

3.2 Simulation of Giampilieri Disaster by SCIDDICA-SS2-UT

The simulations have been performed on a DEM (Digital Elevation Model) with a cell size of 2 m, corresponding to an apothem of 1 m in the hexagonal tessellation. SCIDDICA-SS2-UT step corresponds to 0.065 s.

Initial conditions of the simulation are specified by the smallest detachment areas at the beginning of the debris flows as per field data, then in the simulation, erosion swells the initial debris flows, reproducing their path from the hills to the streams crossing the village.

For the simulation purposes, the Giampilieri's territory was divided into five main areas. The debris flows occurring in one area do not interact with the others (Fig. 1), so that single simulations may be considered for each of them (cases 1–5, Figs. 3, 4 and 5).

Case 1 (Fig. 1) corresponds to the zones flooded by debris flows originating in the hills above Saccà street (Loco stream). Case 2 (Fig. 1) corresponds to the zones flooded by debris flows originating in the hills above Chiesa street (Sopra Urno stream). Case 3 (Fig. 1) corresponds to the zones flooded by debris flows originating in the hills above Vallone street (Vallone stream). Case 4 (Fig. 1) corresponds to the zones flooded by debris flows originating in the hills above Lena street. Case 5 (Fig. 1) corresponds to the zones flooded by debris flows originating in the hills above the Primary School.

Debris flows of cases 2 and 3 converge respectively to Chiesa Street and Vallone Street, hitting the townlet core where most of the damage and casualties occurred; instead, the debris flows of cases 1, 4 and 5 impacted the outskirts of Giampilieri (Fig. 1).

Figure 3 shows the simulation of case 2, the most devastating debris flow (Supra Urno stream, Fig. 1): panel (a) displays the entire modeling dominion, whereas panel (b) magnifies the specific impacted urban area.

Figure 4 shows the simulation results for the debris flows generated by (a) case 1 (Loco stream), (b) case 3 (Puntale stream) and (c) the debris flows of case 4, converging towards Lena Street.

The reliability of the simulation was measured according to the fitness formula:

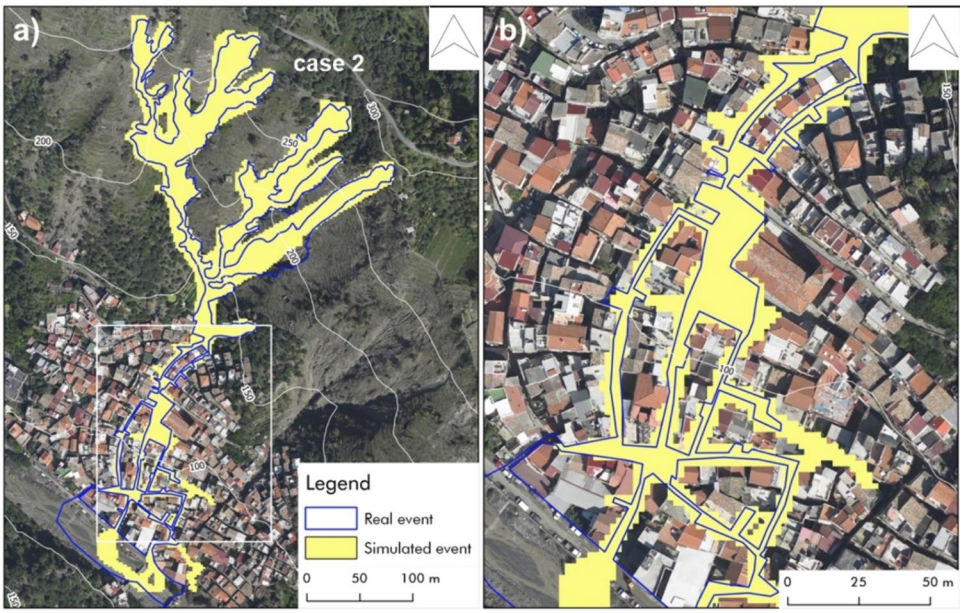

Fig. 3 **a** Comparison among real and simulated event of Sopra Urno debris flow; **b** enlargement of urban area

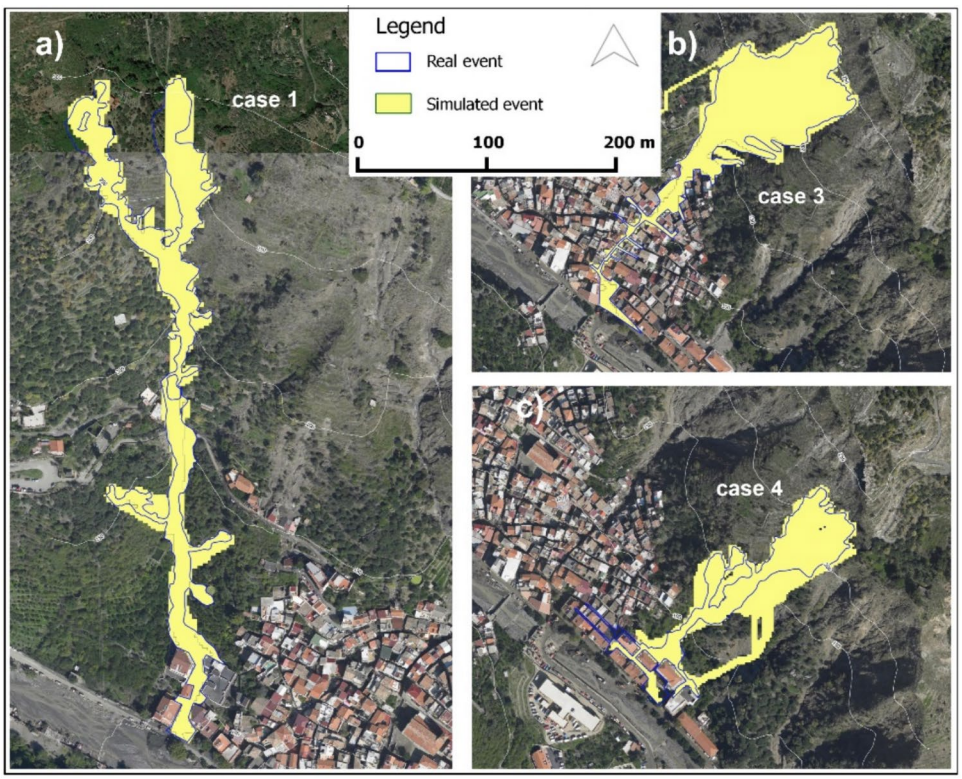

Fig. 4 Comparison among real and simulated events. **a** Loco stream (case 1); **b** Puntale stream (case 3); **c** Lena Street (case 4)

$$\sqrt{\#(R \cap S)/\#(R \cup S)}$$

where R is the set of cells corresponding to the real event, S is the set of cells corresponding to the simulated event, # counts the number of cells of the set.

The numerical values are reported in Table 1, indicating the reliability degree of the simulation and highlighting the efficiency of the SCIDDICA-SS2-UT model within each specific area.

We can therefore claim that the SCIDDICA-SS2-UT model has been satisfactorily validated on the 2009 disastrous event, and this digital twin is now able to check the effectiveness of the protection works. For instance, a first test was carried out considering the effect of a 5 m wall

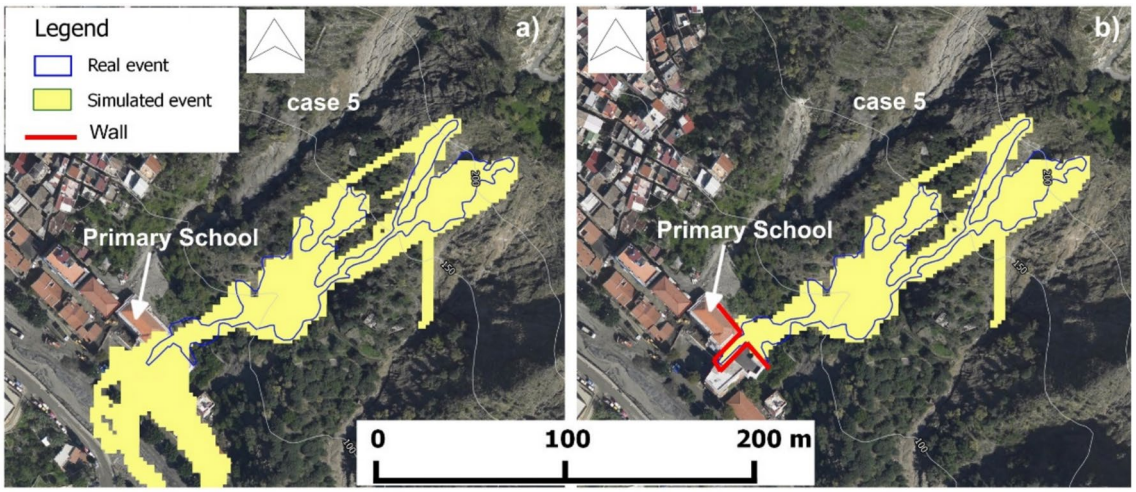

Fig. 5 Simulated impact of case 5 debris flow upon the primary school: **a** without protective wall **b** with wall

Table 1 Values of the fitness function for different cases

Detachment zone	Entire debris flows	Only urban tissue
Case 1—Loco stream	0.79	Insignificant
Case 2—Sopra Urno stream	0.82	0.91
Case 3—Puntale stream	0.86	0.88
Case 4—Lena Street	0.75	Insignificant

protecting the primary school (case 5): the wall efficacy in protecting the school building is self-evident as reported in Fig. 5.

4 Protection Works and Simulation of Their Impact During Emergency Events

Protective structures were emplaced with the primary aim of defending the urban area from future debris flows. The slopes above Giampilieri were covered by a cement layer, as supposedly the best solution to prevent the occurrence of a possible disasters in untended, agricultural lands.

The works, which began immediately after the disaster, were initially focused on clearing the streets of mud and debris, and demolishing the buildings damaged beyond repair. Meanwhile, a project for the protection of what was left of the town was taking shape, even though it would be completed in practice 10 years later (Navarra 2020). More than 200 million € were granted to build such protection works and to fund different types of indemnities (Arena 2020; Navarra 2017).

The main artwork consists of a huge "containment wall/drainage channel" about 450 m long, 11 m minimum width, 9 m high, with the dual function of serving as an embankment for the debris/mud flows and to convey them along a controlled route; this starts from Supra Urno stream, descends to Puntale stream, trespasses the town boundary along the destroyed Vallone street, sinks before Piazza Pozzo, emerges beyond the townlet, and finally flows into Giampilieri river (Navarra 2017, 2020). This colossal work (Fig. 6) can also intercept possible debris/mud flows from the most dangerous areas of Supra Urno and Puntale; minor works of the same type protect other areas (Fig. 6).

All the debris flows of the same size as those of 2009 starting from the areas of Supra Urno stream and Puntale stream have been again simulated on the Giampilieri orography, now including the presence of the main artwork (Fig. 7a). Such debris flows represent the greatest threat to the village of Giampilieri, that's why the colossal containment wall/drainage channel was there built. The digital twin was used to evaluate the efficiency of the wall/channel, within which possible new debris flows would run. (Fig. 7b). The SCIDDICA simulation results demonstrate a sufficient protection of the lower areas, i.e. the flows don't overcome the artwork. Critical points are the beginning of the main wall/channel and about seventy meters downstream, where the debris flows reach the maximum height.

All the 2009 debris flows of Supra Urno stream conveyed on Chiesa Street, while the digital twin shows in the new situation how the main wall/channel intercepts the flows in several points and decreases the local impact.

The simulation results demonstrate a sufficient protection of the lower areas of Giampilieri village, even though territory cementification prevents the previous land-use.

Fig. 6 The new settlement of the Giampilieri's territory with the main and secondary drainage channels

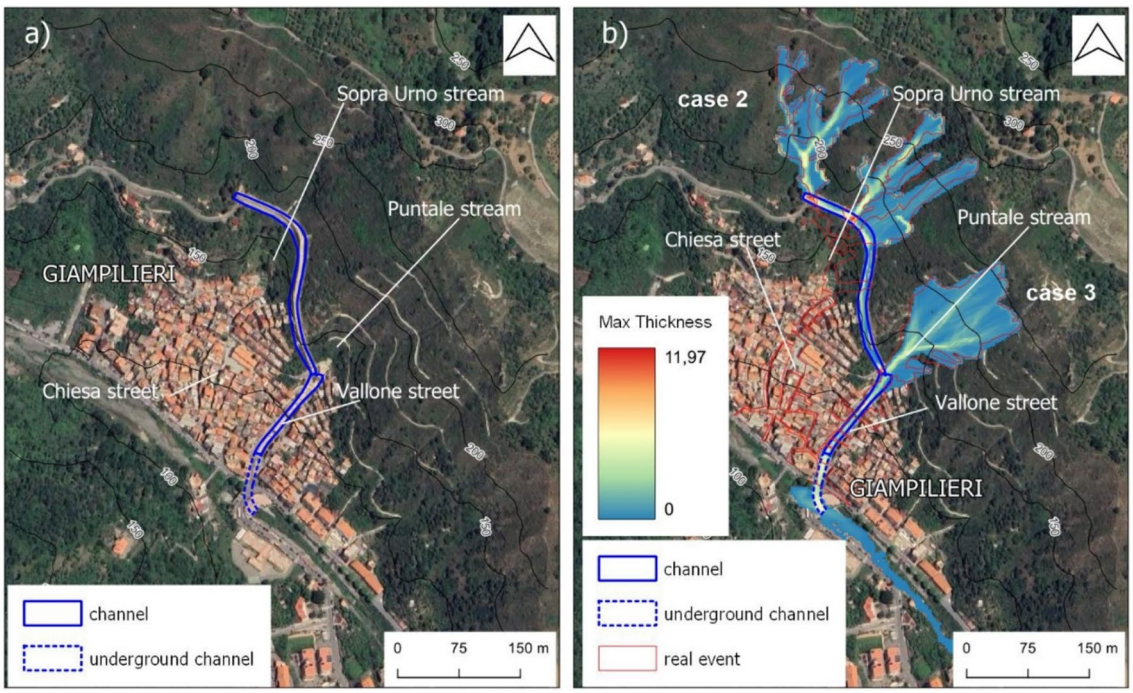

Fig. 7 **a** The great wall/channel; **b** simulated debris flows of Sopra Urno (case 2) and Puntale stream (case 3) areas on DEM modified by protective works

5 A Transdisciplinary Viewpoint

One wonders how the founders of Giampilieri dared to build a townlet whose main streets coincided with the courses of the Giampilieri river tributaries. In hindsight, that was almost equivalent to guarantee a catastrophe, considering the posterior soil degradation in the slopes above the town. These correct, though somehow short-sighted, considerations don't take account of the historical evolution of the territory: they do not allow for an in-depth analysis of the issue, thus hampering an articulate, preventive recovery plan, which cannot be committed to a single discipline.

5.1 The Saracen Culture

With the fall of the Roman Empire and the subsequent domination of the Vandals and Ostrogoths, the decline of Sicily was accentuated, the subsequent Byzantine conquest (or reconquest if you prefer) brought no improvements except in the Syracusan territory and in "islands of civilization" marked by Western Roman monasticism. In the remaining areas we have a regression from Greek-Roman agricultural techniques to a "pure survival" agriculture (Amari 1858).

The penetration of the Saracens into the island, which began in 827 and was completed in 878 apart from very small zones of resistance, changed the fate of Sicily (Amari 1858).

The expansion of Islam led to the absorption and diffusion of the cultures of the conquered countries, particularly important was the conquest of the Sassanid Empire (roughly corresponding to Persia, today's Iran), whose hydraulic and irrigation technologies allowed a complex and, in some respect, an unsurpassed management of the territory in the agricultural sector; to this we must add the experience acquired in the drought regions of Arabia and the Maghreb (Barbera 2000).

The Saracen domination of Sicily led to a real and profound settlement of the conquerors. In the field of agriculture, for instance, they carried out a process of retro-innovation ante litteram, they recovered the good agricultural practices of the Greek-Roman era, yet innovating the culture by introducing new products; most importantly, they settled the territory by developing a complex fine water control system (Bassal 1995; Bolens 1972; Di Gregorio 1904; Watson 1983): terraces, dry stone walls, "gebbie" (جبيبيا), cisterns, wells, and arranging waterways with "senie" (سينيا) and "norie" (نوريا).

A system of terraces allowed agricultural activities on steep terrains, water entry and exit points were skillfully established for each plot of land, with dry stone walls and containment tanks to distribute the water and to protect the soil from intense rainfalls (Bassal 1995; Bolens 1972). This system also allowed an easy soil maintenance and undergrowth cleaning against bushfires.

The numerous watermills, whose presence in the area is documented since the twelfth century (Ortolani and Spizuoco 2014), were built after a safe channeling of the water, and this explains why some streets in Giampilieri align with the watercourses that fed the mills. The mills were the poles of attraction for the creation of villages in the area, which reached a peak in the seventeenth century.

The Norman conquest of Sicily did not represent an involution of agriculture, agricultural practices were maintained and transmitted without substantial problems until 1492. In fact, the management of the land and not the ownership remained in the hands of those who had the necessary skills to manage them. In 1492, the depreciable, expected and feared edict of expulsion for non-Catholics, mostly Jews and Muslims, arrived from Spain. Part of them were forced to simulate a conversion, especially the stewards of the nobility; the nobles had interests in maintaining the sources of income represented by the optimal management of their lands in terms of agriculture and animal breeding and therefore protected the new converts (Bernard 1995). The assured survival of the Saracen culture can be attested by the presence in the Sicilian language even today of technical terms of Saracen origin still in use in the agricultural sector such as those previously reported for example in Arabic language.

The descending parabola in the region coincided with the universal, modern mechanization of agriculture in industrialized countries, aimed at the exploitation of flatlands in a context of economic globalization; in poorer, developing countries, however, the low cost of labor allowed to preserve the ancient, agricultural techniques and skills (Lanza and Fernandez 2024).

5.2 The Dark Side of Globalization

The social processes that affected Gampilieri are well known and are common to many areas of southern Italy and the world. With the intensification of international economic exchanges and investments on a global scale and with the rise of the culture of consumerism, local territories and communities were rapidly transformed between the twentieth and twenty-first centuries. Overall, the world economy has resulted in an increasing interdependence of national economies on the one hand and the loss of sovereignty of local communities in terms of culture, traditions, customs, thought and heritage on the other (Giddens 2002). Driven by an increasingly pervasive consumer culture, people tend to move from the countryside to the cities, abandoning their territories. It is evident how these processes have led to profound social, cultural and political transformations (Brand and Wissen 2021).

Of course, not everything about these processes is to be read in a negative light. Globalization processes have been analyzed in terms of both their positive and negative aspects. Among the aspects most often highlighted are the speed of communication and the circulation of information, but also the opportunity for economic growth for nations that had long remained on the margins of global economic development, the reduction of space–time distances, and lower costs for the end user due to increased competition on a global scale.

On the other hand, it is increasingly evident that globalization has brought with it exploitation and environmental degradation. Especially in its neo-liberal version, this process (or sum of processes) has also clearly contributed to increasing social inequalities (Wisman 2011).

Although the middle class has grown in the global South, inequalities have increased in the North and the South. Other effects often highlighted are the loss of local identities and the increase in power of economic multinationals at the expense of public welfare initiatives and the autonomy of territorial economies.

As the case of Gampilieri clearly shows, these global processes have local impacts. In particular, the local agricultural economy, previously diversified and organized in various productions on the same plots of land, has not been able to resist international competition based on monocultures in large flat, industrially managed territories; only a few secondary local productions, closely linked to the local climate, are exceptions.

The abandonment of agricultural activities, especially in steeply sloping areas, has meant a deterioration of containment structures and a progressive loss of Saracen culture and, thus, a loss of local identity and knowledge. The new generations have been unable to give continuity to the sophisticated agricultural techniques of their fathers, which has led to new social inequalities and young people who are often highly disoriented.

The inability or impossibility of continuing to exercise fine control over water has led to serious land degradation in a few decades, which, in the context of climate change, is the origin of the Giampilieri catastrophe. This catastrophe will most likely not remain an isolated case, as it will generate future catastrophes in numerous territories in the Mediterranean area and elsewhere where these conditions occur.

A growing number of scholars have long pointed out that if one were to brutally assess the gains (reduction in costs for the end user due to increased competition on a global scale) and losses (definitive degradation of territory) in the context of globalization, surely the outlay over time to secure the territory far outweighs the "supposed" benefits obtained from globalization.

It is, therefore, clear that possible solutions must abandon the dogma of profit maximization and the growth paradigm, which tends to exclude all non-economic considerations. If production increases, it matters little whether it is produced at the expense of future resources or the environment's health.

Many voices are now pointing out that, given the scale of change, it is no longer possible to find a specific and discrete answer for each part of the problem. Instead, it is essential to look for complex solutions that consider the interactions between natural and social systems. The environmental and social crises are not separate crises but rather complex crises that affect society and its environment simultaneously. Therefore, solutions require an integrated approach to combat poverty, restore dignity to the excluded, and protect nature (Bergoglio 2015).

In addition to environmental indicators, other signs that show how urgent it is to identify corrective actions today concern the increase in NEETs (Not in Education, Employment or Training): Western adolescents locked in their rooms are more interested in virtual life than in real life, while on the contrary in countries affected by climate change, wars and political persecution young people brave mortal dangers just to migrate and ensure a minimum chance of survival for themselves and their families. These problems cannot be addressed without thinking about profound social transformation.

6 Retro-Innovation by Migrants: A Smart Solution?

Unfortunately, environmental degradation akin to the one experienced in Giampilieri before 2009 resonates across the Italian Mediterranean area (Salvati et al. 2010), necessitating preemptive actions. However, duplicating the identical safety protocols enacted in Giampilieri following the 2009 catastrophe would not be viable as a preventative measure. An alternative approach could entail advocating for virtuous solutions capable of reinterpreting historical wisdom and expertise through a contemporary lens, a concept often referred to as "retro-innovation".

In recent times, amidst contemporary environmental and societal dilemmas, there has been a surge in demand for an equitable, ecologically sound, and resilient transition founded on socio-economic and gender equity, accessibility, security, health, and well-being. This has spurred significant social retro-innovations (Stuiver 2006), blending past elements and practices with present and future needs and perspectives.

In recent years, pivotal retro innovations have successfully reinvigorated primary sector production. Community-driven procurement methods, known as "alternative food networks" (AFNs), have spearheaded this endeavor. AFNs emerged from civil society mobilizations to counteract the dominance of modern food systems. Their primary mode of operation involves shortening supply chains, advocating for ethical small-scale farming, promoting quality seasonal produce at fair prices, and fostering meaningful producer–consumer relationships (Goodman et al. 2012).

Moreover, retro-innovation has facilitated the revival of valuable abandoned agricultural and husbandry techniques, ingeniously reintegrating them into contemporary contexts with commendable outcomes (Stuiver 2006). Undoubtedly, the foremost challenge lies in resurrecting nearly forgotten methodologies. Presently, only a few farmers, predominantly elderly, retain the requisite expertise; the prevailing social milieu doesn't incentivize many young Sicilians to embark on such ventures, yet the influx of migrants from North

Africa brings individuals, largely custodians of the invaluable Saracen culture (Lanza and Fernandez 2024).

Extending a welcoming embrace to these individuals, coupled with a targeted retro-innovation program and sustainable economic support amid efforts to address the costs of rehabilitating degraded territories, could herald a territorial renaissance, particularly in areas where degradation remains reversible.

In this vein, widespread reception initiatives, modelled after the renowned Riace paradigm, a small municipality in Calabria (Baban et al. 2018; Driel and Verkuyten 2020, 2022; Tedde et al. 2021), could present a feasible pathway forward if meticulously organized to counter the economic and demographic crises plaguing numerous territories. Prioritizing the reception and integration of migrants and asylum seekers from diverse origins not only affords them opportunities for settlement and community contribution through employment and social engagement but also facilitates territorial revitalization via the repurposing of abandoned infrastructures, such as defunct schools or public housing, thereby fostering urban renewal and architectural heritage preservation. Active involvement in migrants' social and economic spheres can, for instance, catalyze and invigorate various public-interest ventures, including the cultivation of forsaken farmlands or the promotion of local handicrafts.

This holistic approach could bolster the economic self-sufficiency of individuals and entire communities by harnessing local resources to forge economic and social prospects for all residents. Thus, it could catalyze the rejuvenation of territories while tackling contemporary challenges constructively and positively.

7 Discussion

Our transdisciplinary approach to Giampilieri's disaster has innumerable facets and raises a series of questions that need to be considered.

Is an obligatory solution to secure the territory through massive cementation at the heights of the village?

Here we report the warning from Lan Kelman (2007), UN consultant for natural hazards, which reminds us of the need to seek alternative solutions to the dangerous ones of overbuilding:

> Despite decades of evidence from research and practice demonstrating that reliance on structural approaches increases disaster risk over the long-term, structural approaches are frequently preferred without properly considering complementary or alternative measures. Examples of structural approaches are walls, dams, dykes, levees, and reservoirs. While they provide some benefits, decisions to implement them and nothing else are usually made by emphasizing the short-term benefits and discounting the long-term costs.

So, what other solution could have been pursued?

The optimal solution would have been the restoration of the existing water control structures that had proven themselves so well over the centuries, in other words, a path of retro-innovation. This would have made sense, especially after the debris flows of 2009, which followed the great forest fire of 2006. But, at a political level, such a vision of the problem was not considered, as these techniques were classified as a legacy of the past not up to today's standards. In any case, there should have been no lack of awareness of an imminent catastrophe, which needed to be taken care of. Surface protection of slopes by grass covering techniques, knowingly widespread throughout the country (Apollonio et al. 2021; Verrascina 2013), have (culpably?) been ignored. The immediate application of these techniques (European Commission 2021) not only could have avoided or significantly mitigated the 2009 disaster, but it would also have resulted in a definitive land use change.

This solution could also be applied after the disaster, but, in any case, it would have entailed prompt care of the territory to be defended against fires and careful monitoring of the flows of water to ensure that no critical landslide trigger points form. For a de facto abandoned territory, this is difficult to manage.

Another consideration concerns the sustainability of the safety works, which must be considered not limited to Giampilieri but to the hundreds, if not thousands, of environmental situations in Italy, which could evolve in the same Giampilieri scenario and which need to be made safe even before disasters can occur.

Climate changes are becoming crucial, we are heading towards periods of drought interspersed with violent rainfall, such as the flash flood that triggered the debris and mud flows in Giampilieri. Climate Change has decreased precipitations and increased temperatures in Mediterranean Climate Regions. The frequency of winter precipitation would decrease although extreme rainfalls would increase (Cramer et al. 2018; Polade et al. 2017). Both drought and flash floods predispose to strong soil erosion and in many cases, this will give rise to flood phenomena such as in Giampilieri.

A retro-innovation looks the best solution in terms of sustainability, but who will carry out this project?

Sicily and Italy more generally are experiencing a heavy demographic crisis. A large part of the territory is being depopulated, and it risks remaining abandoned, especially in small urban areas and the countryside. This is accompanied by a strong intellectual migration towards Europe and North America and phenomena such as NEETS.

There are willing young people capable of receiving this precious inheritance of Saracen culture from the last farmers, but they are too few compared to the territories in danger.

The solution may come from welcoming migrants, some of whom already possess this Saracen culture. Reference is made to migrants from the geographic belt from North Africa to Iran, passing roughly through the Arabian Peninsula, Israel, Lebanon, Syria, Turkey and Iraq. There are also valuable integration experiences of migrants outside this geographical belt, who have easily and willingly acquired the local agricultural culture from the last custodians (Baban et al. 2018; Driel and Verkuyten 2020, 2022; Tedde et al. 2021). This demonstrates that these migrants can contribute to retro-innovation plans if properly welcomed.

8 Conclusions

The transdisciplinary analysis of the Giampilieri disaster and the rehabilitation of its territory here presented has illuminated the potential revitalization of many similar regions grappling with reversible soil degradation. This revitalization effort could be facilitated through the support of sustainable retro-innovation projects, potentially led by North African migrants who possess invaluable knowledge of Saracen agricultural practices that have historically enriched Sicily's landscape and economy.

The SCIDDICA (Digital Twin) numerical simulations allowed us to foresee the effects of the debris flows of the same size as those of 2009 on the Giampilieri orography, now including the presence of the emplaced safety installations, whose extension excessively overbuilt the area. We conclude that there exists now sufficient protection for the village, yet the works involve a poor land use.

The findings underline the imperative for systemic solutions that transcend disciplinary boundaries to effectively address environmental degradation and mitigate future risks. Although conventional approaches, such as extensive cementing, may produce immediate benefits, they often exacerbate long-term problems and fail to address the underlying causes.

An alternative approach, in other words, should involve the reintegration of ancient wisdom and skills, complemented by modern technologies and knowledge. This would offer a promising avenue for sustainable land management. By revitalizing traditional water control structures and agricultural techniques, communities can draw on historical knowledge to address contemporary challenges. The innovative agricultural methods of the Saracen culture are a testament to this approach, as they not only sustained the Sicilian landscape, but also shaped its cultural identity over the centuries.

However, the successful implementation of retro-innovation initiatives requires collaborative efforts between different stakeholders and a strong political commitment to land governance. Given the demographic changes and intellectual migrations that are reshaping local communities, it is imperative to explore solutions that transcend traditional boundaries. Welcoming migrants, particularly those with Saracen cultural knowledge, presents an opportunity for collaboration and knowledge exchange.

Moreover, as climate change exacerbates environmental risks, proactive measures become increasingly urgent. Retro-innovation therefore emerges as a sustainable strategy to safeguard territories from future disasters, subordinate to strategic planning and resource allocation. Prioritizing investments in environmental resilience and community empowerment can pave the way for a more resilient and inclusive future, especially in vulnerable regions like Giampilieri.

Indeed, the Giampilieri disaster underlines the imperative for complex approaches to environmental management. By embracing retro-innovation and drawing on the expertise of migrants, communities have the potential to address contemporary challenges while safeguarding their cultural heritage and ecological balance. Through transdisciplinary collaboration, we can seek to navigate towards a more sustainable and resilient future for all. Of course, the path ahead is fraught with obstacles and progress will not always be linear, but taking a radical perspective based on incremental steps is probably the best way forward in the current circumstances.

In this conclusion, we draw inspiration from the invaluable contributions of Nino Lo Bello (23/08/1949–11/07/2023), whose unwavering commitment has illuminated the path toward more sustainable and inclusive environmental management. Nino Lo Bello served as a tireless point of reference for Sicilian movements advocating for the environment, water, agriculture, people's rights, and peace. Despite facing challenges from the Mafia due to his dedication, he remained steadfast in his principles. He was the founder of "Fa' la cosa giusta (Do the right thing)" in Sicily, served as president of the "Association for Peace and Development" in Southern Italy, and notably advocated for the Sicily Region law on agroecology.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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