Journal of Agricultural Engineering

https://www.agroengineering.org/

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Please cite this article as doi: 10.4081/jae.2024.1618

Submitted: 17 June 2024
Accepted: 4 October 2024

Terraced landscapes: risk and liability

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Abstract

Terraced landscapes are preserved elements of the human-influenced environment, maintained by ongoing agricultural activities. Farmers are subject to the periodic collapse of terraces, which are repaired by means of traditional techniques. Unless it can be proven that the collapse was accidental, the owner is liable for the damage caused by the collapse of the terraces or landslides. This topic, applied to Minori (Amalfi Coast, Italy), is interesting for two reasons. First, with the advancement of scientific knowledge, the unpredictability of events diminishes and the liability increases. Second, the intensive construction at the base of the terraces and the economic value of the buildings, enhanced by the landscape context, expose the owners to claims for damages from third parties that are disproportionate to the agricultural income, including claims for amnestied illegal constructions. The result has been an increase in the renunciation of property rights by farmers in areas of high hydro-geological risk. However, the State, which becomes the owner, denies the validity of property relinquishments made by owners solely to transfer risk, cost, and liability to the state treasury. This paper discusses these issues, going beyond the Italian case study, and proposes a different risk allocation related to territorial governance. This study reveals a discrepancy in government decision making and suggests that the division of risk into multiple components could be a solution to this inconsistency.

Keywords: Agricultural terraces, Amalfi coast, liability, property renunciation, risk, terraced landscape

Introduction

The area of the Amalfi Coast in south Italy, which this study focuses on, has been included in the UNESCO World Heritage List since 1997. It is an extraordinary example of Mediterranean landscape with exceptional cultural, natural and landscape values, resulting from its unique topography and historical evolution (UNESCO, 1997). In this context agriculture of citrus groves, olive orchards and vineyards are supported along the terraced slopes bounded by drystone walls (terracing). The drystone walls, that improve the pedogenetic processes, are a fundamental component of this kind of territories and in turn the “Art of dry-stone walling, knowledge, and techniques” was included in 2018 in the UNESCO Intangible Heritage List (UNESCO, 2018).

The historical and cultural dimension of the landscape is so great in the area of interest of this study that it greatly increases the value of the entire territory (Region Campania 1987; Caneva and Cancellieri, 2007; Tarolli *et al*., 2014). Moreover, these terraced areas are built because of this value as a result of the action/interaction of its environmental, natural or cultural components over time (Di Fazio and Modica, 2018). By their nature, terraces in high slope areas are soil reservoirs with positive ecosystem services such as reduction of erosion (Tarolli *et al*., 2014) and increase of infiltration. At the same time these reservoirs of soil on slope territory are destined to for a more or less rapid natural evolution toward the original slope (LaFevor, 2014). Most authors related the landslides occurrences mainly to abandonment or to lack in maintenance, but some others don’t put in evidence a prevalence in abandoned terraces rather than in cultivated (Tarolli *et al*., 2014, 2018; Capolupo *et al*., 2018; Agnoletti *et al*., 2019). The maintenance of cultivated terraces built with dry stone walls is, on the one hand, oriented to surface water regimentation (Asins *et al*., 2016) and, on the other, to the reconstruction of terrace sections following small collapses of the dry-stone wall or deformation (Lesschen *et al*., 2008; Pijl *et al*., 2019; Fang *et al*., 2021). The same spatial planning instrument for this territory (Region Campania, 1987) states in Article 34 that the agricultural terraces may be redone only in accordance with the construction techniques of existing ones. In particular, the use of exposed stonework without stitching of the joints. We can deduce that maintenance is the reconstruction after partial collapses and we can infer that maintenance does not imply safety.

The failures of terraces can take on considerable dimensions during exceptional weather events (Canuti *et al*., 2004; Tessitore *et al*., 2011; Del Ventisette *et al*., 2012). This is a "fragility" of this type of dry-stone terraces built before the development of modern design techniques (Adhémar J. C. B. de Saint-Venant), modern materials (François Hennebique) and modern knowledge of hydrology (Horton) and climate (Gumbel). This "fragility" is a consequence of the farmers' approach to building terraces for productive purposes, carving out small plots of land in steeply sloping areas. Urban development below the terraces came later. Farmers were usually unaware of the additional ecosystem services of the terraced landscape, or at least were not explicitly driven by a desire for an increase in ecosystem services. An in-depth study of management strategies and the role of agronomists (Tarolli *et al*., 2019) illustrates how consistent spatial organization of agricultural practices would be desirable. Terraced landscape provided different ecosystem services (Fusco Girard *et al*., 2019). Among the ecosystem services provided by a terraced landscape with dry stone wall, in such Mediterranean context, are reduced runoff and consequently erosion, increased rainfall infiltration, slope stabilization, and longer concentration times (LaFevor, 2014; Tarolli *et al*., 2014; Stavi *et al*., 2018; Deng *et al*., 2021). Some of these ecosystem services provide benefits not only to the individual farmer but also to the settlements below. Economic investment for terracing and thus the construction of drystone walls and their drainage, has been proportionate to achievable farm income, regardless of ecosystem services. The dry stone wall were sized and built with the acceptance of a “cyclicality” of the ruin of portions of the wall, deformation (bulging) and collapses of large areas due to heavy rain (Esposito *et al*., 2011), which today is mainly associated with abandonment (Di Fazio and Modica, 2018; Milman *et al*., 2018; Stavi *et al*., 2018; Cicinelli *et al*., 2021a).

The concept of risk (ISO 31000:2018, ISO 31073:2022), in this context concerns likelihood and severity of hazardous events. In this case, accepting the term probability for likelihood, is possible do define risk for natural hazards as the probability of the accident occurring multiplied by expected loss in the event of incidents. The expected loss or damage extension parameter depends on the vulnerability function (Agnoletti *et al*., 2015) and the exposed value. Liability is directly linked to risk. In fact, although liability takes on a different scope in different national legal systems, it is always linked to the risk and the preventive measures taken by the owner (Fuchs *et al*., 2007; Agnoletti *et al*., 2015). The increase in scientific knowledge and therefore in the predictability of the event, the effects of climate change, and the increase in constructions downstream expose the owners of the terraces to greater responsibility so as to reduce if not wipe out the value of their property. On the other hand, the interventions needed to secure the terraces are not economically feasible for farmers, if not in fact prohibited for their invasive character by the protocol that protects the landscape. This anthropization that has led residents and tourists to interface with agriculture and the overhanging terraces is the result of a time when the risks were less known, being at the time unpredictable and therefore not associated with a responsibility of the owners of the terraces and the public administration that allowed the buildings.

In any case, for the Italian and some European legislative systems (Freeman, 2004; Schwarze and Wagner, 2007), the liability of farmers for damages caused by the ruin of a terrace varies according to the exceptionality (Schwarze and Wagner, 2007) or not of the event triggering the collapse. The limited spread of private insurance in major European states is presented in (Schwarze and Wagner, 2007).

This variability of farmers liability is consequently linked to the probability of occurrence of the catastrophic event and, therefore, to the return time of exceptional rain events. Ruin of a terrace that produce a damage to a third part, after a rain event with a limited return time is in the liability of the farmer or of its insurance. The same damage, in the case of an exceptional rain event is classified as a catastrophe and the refund is in charge to the State. Some authors (Helmer and Hilhorst, 2006; Miscolta-Cameron, 2016; Hernández-Moreno and Alcántara-Ayala, 2017; Capparelli *et al*., 2018) have discussed the desirability of preventing damage and managing risk, also in view of climate change, by reducing the vulnerability of the underlying system with interventions aimed at reinforcement of the walls or risk mitigation. Such interventions may be the responsibility of the individual owner (dry stone walls reinforcement, maintenance, drainage improvement, etc.) (Milman *et al*., 2018), or the community (retaining walls, diversion structures, etc.). However, when these concepts are applied to realities in which agricultural spaces border and interface with high-value residential properties, the problems due to the disproportion of interests and forces at stake are considerable (Fuchs *et al*., 2007).

The aim of this study is to evaluate whether it is possible and/or appropriate, in the case of admixture between agricultural terraces and high-value buildings, to reconsider the application of risk assessment (and therefore of liability) for any damage resulting from the collapse of the form and also to evaluate if a reconsideration of the risk to partially exempt the agricultural owners from responsibility could be useful and feasible.

Materials and Methods

To discuss the objective of this article, a relevant case study was chosen. For this case study, some of the catastrophic events that have occurred are presented in order to demonstrate that there is a recurrence of hazardous events and that these are not exclusively a consequence of climate change. Thus, it is necessary to assess how and when urbanization has evolved and how much new construction falls in areas potentially affected by possible terrace failures. Having observed the increase in the number of properties at risk downstream of terraced areas, it is necessary to examine the current concept of liability, not only according to the wording of the law, but also according to the interpretation of the Supreme Court. The attempts of terraces owners to renounce ownership of their assets and the attempts of the public administration, which becomes owner following the renunciation, to oppose the renunciations in order to avoid an increase in compensation costs are the result of this examination of the concept of liability. These materials, presented in this section as the result of a logical process, provide a logical basis for arriving at a possible allocation of risk, also suitable for reducing the reasons currently underlying the renunciation of ownership.

The study area

The Amalfi Coast is recognized a landscape of outstanding cultural value (UNESCO, 1997), the result of the integration of the anthropogenic landscape with the natural one, has been selected due to the coexistence and integration of terraces and buildings. The Municipality of Minori shown in Figure 1 is one of the four main coastal areas of the Amalfi coast and is certainly anthropized since the 4th century as evidenced by the remains of a Roman villa in the center of the municipality which is now musealized and can be visited (Ribera and Romano, 2018; Cicinelli *et al*., 2021b).

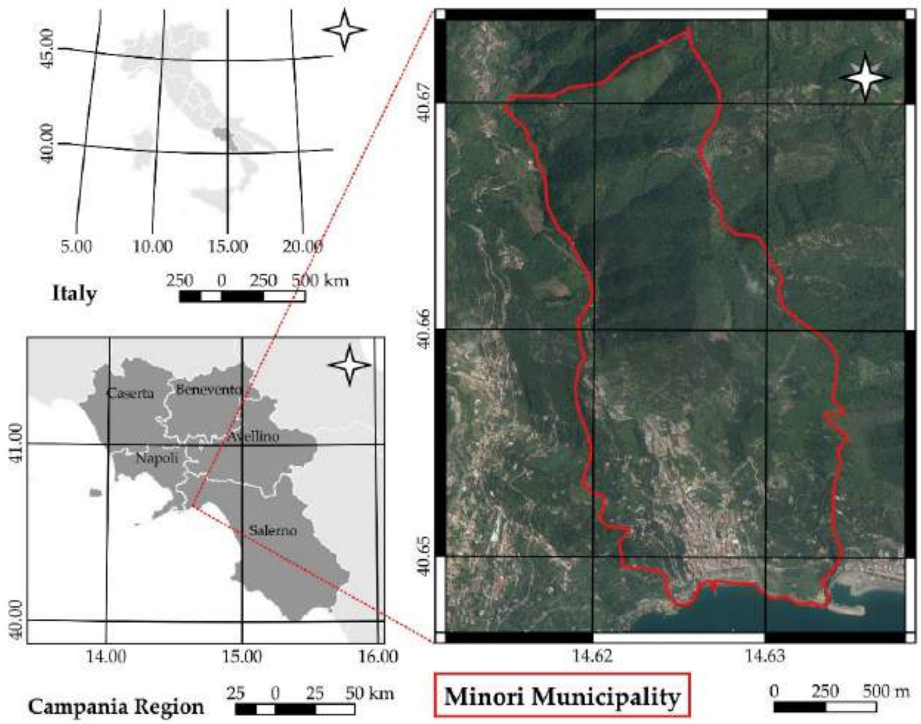


Figure 1. *Study area. Authors elaboration.*

Minori, consisting of the ruins of the Roman villa and a village, could only be reached by sea, until the construction of the *Amalfi Road* (1832-1854) during the kingdom of the *Bourbons*. Today, the administrative territory of the municipality of Minori is of 2.66 km² in the sub-basin of the *Reginna Minor* and about half of it is terraced. The urban settlements were originally limited to the flat areas on the alluvial fan of the Reginna Minor. In the last century, Minori has undergone a great expansion, progressively extending toward the terraced slopes of the surrounding hills. Actually, Minori is a context of high real estate value (average over 5,000 €/m²). Although the abandonment of terraced areas is not particularly widespread in the areas on the hills facing center the urban center of Minori, many abandoned areas are visible in the surrounding districts. This is mainly due to the reduction of economic competitiveness and the fact that only agriculture with traditional techniques and little mechanization is possible on the terraces. "If terracing constituted an interference with the natural environment, in the same way, terraces' abandonment can result in a new significant interference with a potential increase in natural hazards" (Violante *et al*., 2008). Abandonment implies an inevitable restoration of the original geomorphological conditions with widespread slope failure problems.

In 1960, the whole municipality of Minori was subject to a landscape protection order because "*the territory forms natural scenes of rare panoramic beauty with aesthetic and traditional value*" (Italian Ministerial Decree, 1960). The protection order did not imply the absolute inability to build at that time but conditioned construction projects to the prior approval of the superintendent. Further provisions for the protection of the landscape are contained in the *Territorial Urbanistic Plan of the Sorrentino Amalfitana Area* (Region Campania, 1987).

The Plan for the Hydrogeological Structure of the Regional Basin Authority in *Destra Sele* was adopted on 17 October 2002 and then updated on 28 March 2011. According to the current legislation on soil protection, the Plan identifies, among other things, the areas of very high, high, medium, and moderate hydrogeological hazard and risk. Overall, 81.1% of the entire municipal territory, including the entire urbanized area, is indicated in the Plan as being affected by high or very high landslide or debris flow hazard/risk levels (Municipality of Minori, 2016).

The value and uniqueness of these areas is also inevitably in relation to their anthropization and what has been built in the past. However, if the anthropization were to start from scratch, almost none of the current buildings would be allowed to be built. Based on the current urban and territorial plans, it is clear that there are constraints and risks of landslides or debris flow in all the areas where they are built.

(a)

(b)

Figure 2. *(a) Minori west landscape; (b) Minori east landscape. Photos provided by the authors.*

The historical weather events of the Amalfi Coast

The Amalfi Coast and consequently Minori, which is almost at the center, has experienced a sequence of disasters and deaths due to extreme weather events (Budillon *et al*., 2005; Esposito *et al*., 2011; Porfido *et al*., 2013). For example, more than 25 events with more than 150 mm of rain in 24 hours occurred in the 20th century (Braca *et al*., 2007). Among these, at least 3 showed more than 250 mm of rain in 24 hours. The most recent and most significant events occurred in the years 1910, 1924, 1954, and 1966 (Violante *et al*., 2008; Tessitore *et al*., 2011). Previous studies (Budillon *et al*., 2005) have combined historical source analysis with sediment analysis to assess the violence of 10 events that occurred between 1544 and 1879. Violante *et al*. (2008) identified and classified 106 floods that occurred in the last five centuries within the Amalfi Coast, reporting 22 major events for the *Reginna Minor* subbasin.

In the Amalfi Coast, a statistical distribution of expected events, with centennial or millennial return times, is attributed based on the rainfall probability curves, statistically regularized with the Gumbel distribution. In addition to this distribution of extreme events, a second Gumbel distribution of rare events is considered in the Mediterranean, which is added to the previous one (http://www.idrologia.polito.it/gndci/rapporti/Napoli.htm; Totaro *et al*., 2024). Due to the orographic conformation of the Amalfitan area, the presence of terraces, and the peculiar urbanization of the alluvial fans, considerable damages and victims are recorded for alluvial meteoric events. There were over 200 deaths in 1910, over 100 in 1924, and 318 in 1954. This was also the case in the neighboring areas, for example, in 1581 there were 300 deaths and in 1773 there were 400 deaths (Violante *et al*., 2008). These events happened in times before climate change and the abandonment of terracing in southern Italy.

In general, it can be said that these rare events, which for each locality have return times in the order of a century, cause floods in the area followed by a widespread collapse of the terraces with consequent damage and victims (Tessitore *et al*., 2011). The urban development for tourism purposes, which in the coastal area is typically close to the sea, near the mouth of the rivers, only aggravates the situation.

Today the perception has changed from the time when natural disasters were less well known, unpredictable and unavoidable. Faced with the awareness of the inevitable repetition of natural events reported in the chronicles of past centuries (Porfido *et al*., 2012), planning with scientific methods and risk analysis that reduce the area of unpredictability is now proposed. On the other hand, we note the widespread attitude of scientists and experts is to invoke the “maintenance” of the territory, understood as the panacea for all problems. With the support of statistics, immense amounts of data, and increased knowledge, weather events followed by disasters are now described on the basis of return time and predictability considerations. Disaster is systematically linked by experts to faulty land management and poor “maintenance”. The inevitable attribution of responsibility follows. The question of attribution of responsibility arises even after the occurrence of comparatively minor events that cause damage to only one or a few owners. For centuries, farmers have observed the periodic partial deterioration of terraces, according to the natural tendency to restore the original geomorphological conditions. The farmers have undertaken maintenance work on the stone walls and the periodic reconstruction of collapsed sections of masonry in patient work to counter their natural deterioration. The increase in scientific knowledge entails a concomitant increase in the responsibility of the owner of the terraces for damages caused to third parties by their collapse, reducing the possibility of invoking the fortuitous event and force majeure.

A risk function for natural hazard quantification

An in-depth analysis of the evolution of the concept of vulnerability, hazard, and risk was proposed by Fuchs *et al*. (2007). The authors introduced a risk function to quantify natural hazards (Eq. 1):

$$R_{i,j} = f(P_i; A_j; Vu_{j,i}; PE_{j,I}) \quad (1)$$

in which:

- $R_{i,j}$ is the risk for one or more buildings j as a function of scenario i
- P_i is the probability of the occurrence of defined scenario i
- A_j is the value at risk of object j
- $Vu_{j,i}$ is the vulnerability of object j as a function of scenario i
- $PE_{j,I}$ is the probability of the exposure of object j to scenario i

This research is concerned with landslides and debris flow and the related risk to real estate. Therefore, component Aj can be replaced with RE (real estate value), and Eq. 1 can thus be rewritten as:

$$R = f(P; RE; Vu; PE) \quad (2)$$

where function f is conceptually a product of components. Based on these assumptions, the sensitivity to changes in each component can be assessed. The component evaluations based on the case study characteristics are presented in the Results section.

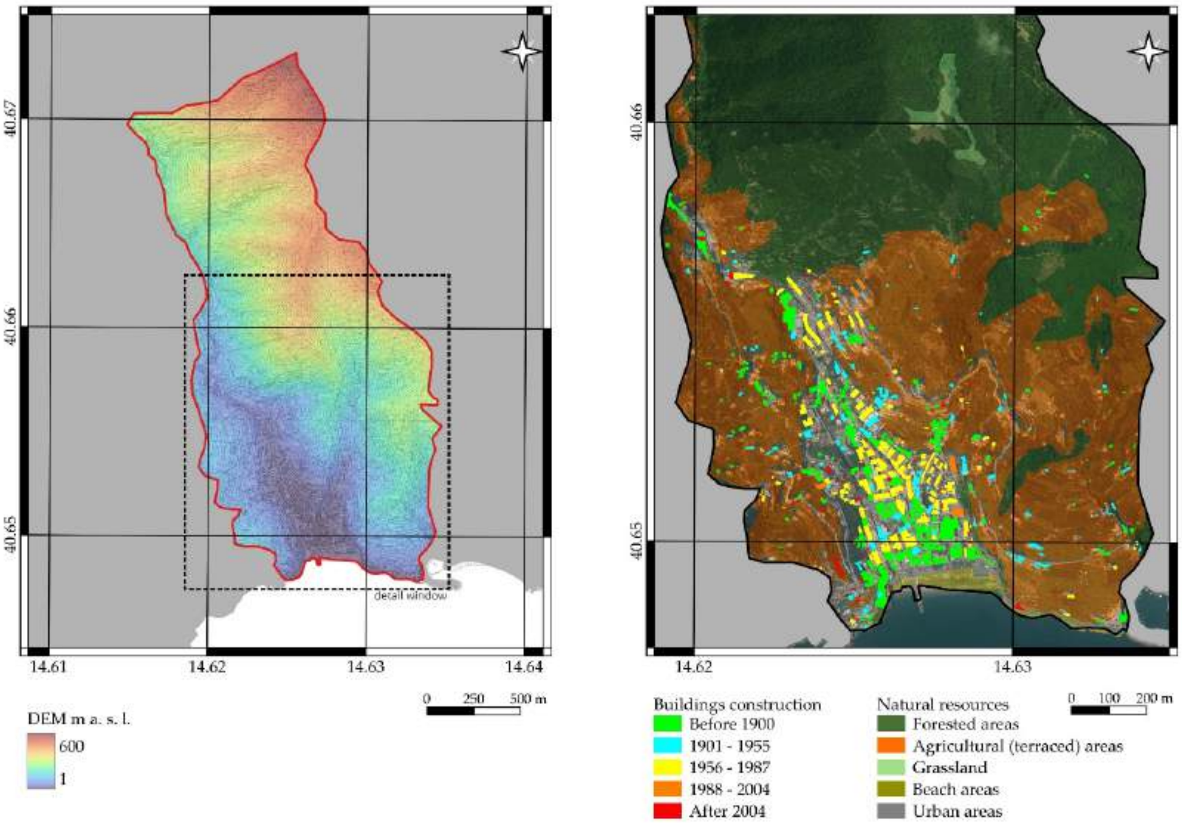
Minori real estate and evolution of risk

This study only addresses risk to buildings and not to other property or people. The evolution of the settlement of Minori is shown in Table 1.

Table 1. *Evolution of constructions.*

Construction period	Increase in number of buildings	Total number of buildings	Increase in soil consumption (m^2)	Total soil consumption (m^2)
Before 1900	-	179	-	40,026
1901-1955	125	304	14,884	54,910
1956-1987	124	428	27,386	82,296
1988-2004	15	443	2,646	84,942
After 2004	293	736	7,474	92,416

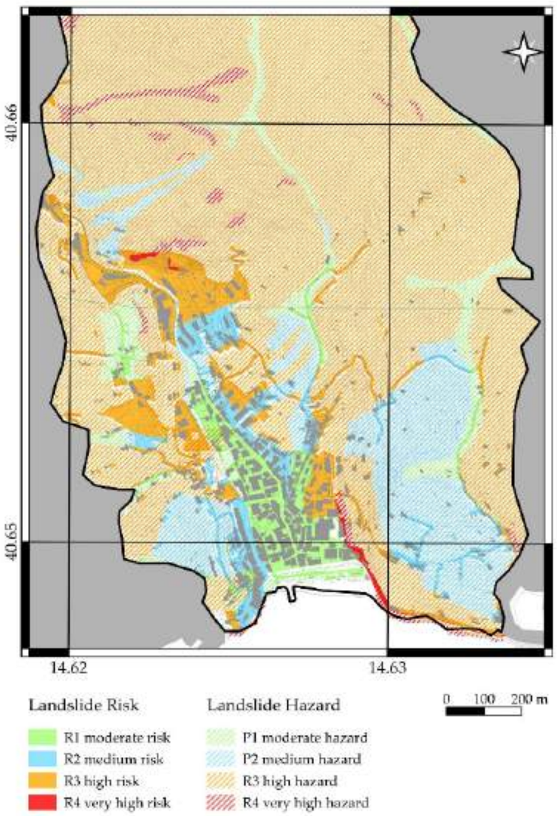
Figure 3a illustrates the morphological characteristics of the study area. As evidenced by the digital elevation model (DEM; Tarquini *et al*., 2023), the region exhibits a highly intricate topography with altitudes ranging from 1 m to 600 m asl. Forested and agricultural areas are located at higher elevations than the urbanized area, which is mostly below 50 meters above sea level and is predominantly located in the southern part of the municipality. Therefore, the subsequent figures are focused only on this area. **Figure 3**b shows the spatial distribution of the main natural resources of the area, including the terraced areas (adapted from Appendix C.2.2, Municipality of Minori, 2014) and depicts the evolution of the built environment over time (adapted from Appendix D2.2, Municipality of Minori, 2014). Buildings constructed between 1956 and 1987 are in yellow. These are illegal buildings but were amnestied with the building amnesty of Italian Law no. 47 of 1985 or made according to the municipal plan in place before the application of hydrogeological constraints (the Plan for the Hydrogeological Order dates back to 2002). In fact, it is necessary to consider that the building amnesty governed by Italian Law no. 47/1985 has also allowed the amnesty of building abuses, with the exception of those in contrast with constraints imposed prior to the execution of the unauthorized works and which entail absolute inexpiability. Similar provisions are provided for in the second building amnesty governed by Italian Law no. 724/1994. At present, the pardoned buildings are also legal. The buildings in cyan were built between 1901 and 1955, and the buildings in green before 1900 and are, therefore, legal, regardless of the hydrogeological constraints that have arisen. Thirty percent of the total volume (about 25% of the area) was built between 1956 and 1987. As can be seen in Figure 2(b), almost all of these buildings are in areas of high or very high landslide risk according to the Hydrogeological Plan of 17 October 2002 (updated in 2011).



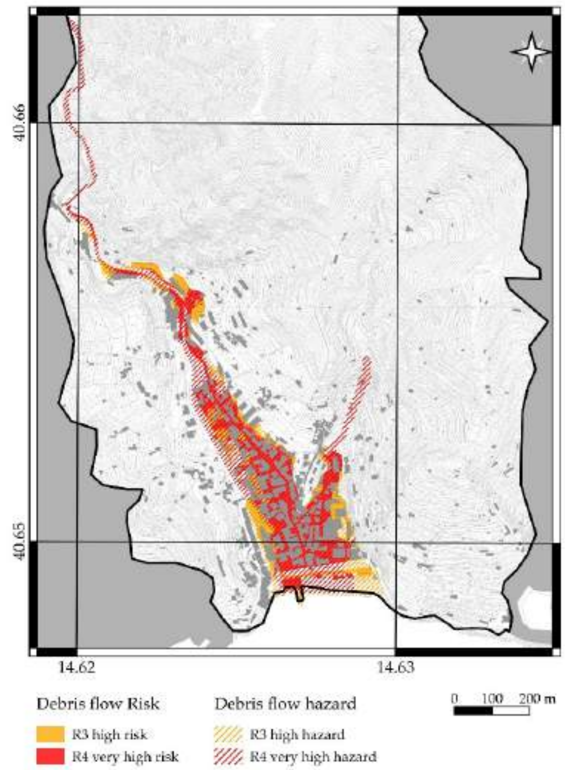
(a) (b)

Figure 3. *(a) Terrain Digital elevation model of the study area describing the orographic characteristics. Authors elaboration based on TINITALY provided by Italian INGV (b) Buildings according to the period of their construction and main land use destination of the study area. Authors elaboration based on the Municipal Urban Plan of the Municipality of Minori.*

Figure 4a shows the areas characterized by high and very high landslide risk: the former is in yellow while the latter is in red (adapted from Appendix 1.1.5.a-b; Municipality of Minori, 2014). Most of the buildings that fall in this area were built between 1956 and 1987 shown in **Figure 3**b. Looking at **Figure 4**b, which represents the debris flow risk (adapted from Appendix 1.1.5.c-d; Municipality of Minori, 2014), and **Figure 3**b, which shows the existing buildings, it can be deduced that almost all of the buildings are included in the area characterized by high or very high debris flow risk.



(a)



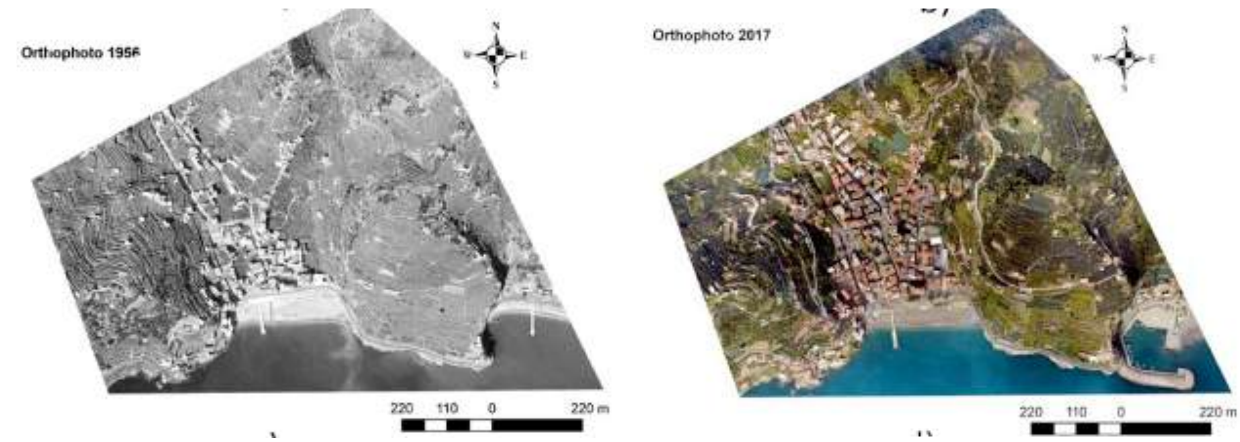
(b)

Figure 4. *(a) Landslides risk and landslides hazard according to the Hydrogeological Plan. (b) Debris flow risk and debris flow hazard according to the Hydrogeological Plan. The two figures were produced by the authors and are based on the Municipal Urban Plan of the Municipality of Minori.*

It is possible to assess the increased risk by looking at **Figure 5** a,b (Capolupo and Boccia, 2018). **Figure 5**a is a mosaic of images collected from the flight survey of the *Gruppo Aeronautico Italiano* (GAI) in 1956 in contrast to **Figure 5**b, which is a mosaic of aerial photos acquired during a flight campaign conducted by the coauthor in March 2017 (Capolupo and Boccia, 2018). A comparison of these orthophotos shows a clearly visible evolution of the buildings. This anthropization process results in increased risk from debris flows and landslides.

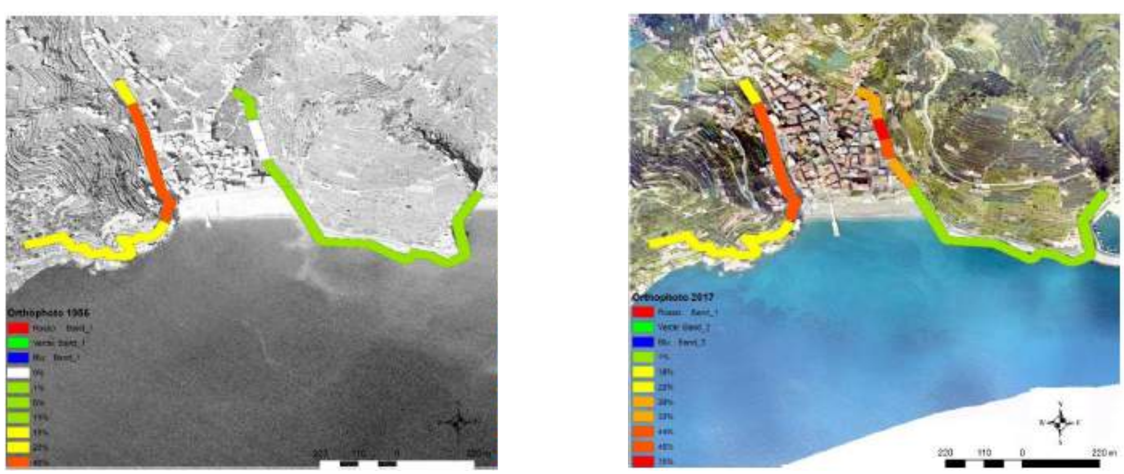
Figure 6 a,b show how the Expeditious Vulnerability Index (EVI) (Capolupo and Boccia, 2021), an assessment for landslides in the areas immediately below the terraces, has changed over time precisely as a result of post 1956 construction at the foot of the terraces. The EVI index is an indicator developed to quickly identify areas most vulnerable to debris flow events. This index is given by the ratio of the sum of the volume of buildings in the considered area divided by the size of the identified vulnerable areas. The vulnerability of the areas is obtained from the ratio of the displacement distance L of the debris flow to the length of the slope. The more the length of the slope is less than L, the greater the vulnerability of the areas. The EVI index is expressed as a percentage, and higher percentages indicate greater exposure to landslide risk.

Figure 7, **Figure 8** and **Figure 9** show how landslide risk in the event of terrace failure is perceptible to an ordinary observer. The ongoing building activity, although not very perceptible, is still present, considering that the value of the properties generally exceeds 5,000 €/m^2.



(a) (b)

Figure 5. *(a) Mosaic of GAI orthophotos (1956); (b) Mosaic of orthophotos obtained by the authors in March 2017.*

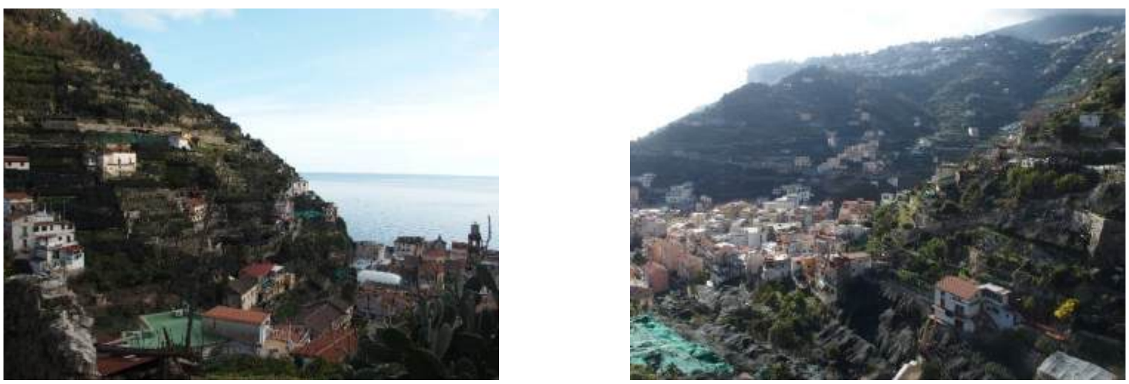


(a) (b)

Figure 6. *(a) Application of the EVI for landslides to the 1956 context; (b) Application of the EVI for landslides to the 2017 context.*

(a) (b)

Figure 7. *(a) and (b) New buildings camouflaged among the terraces. Photo provided by the authors.*



(a) (b)

Figure 8. *(a) and (b) The mix of houses and terraces. Photo provided by the authors.*

(a) (b)

Figure 9. *(a) Reconstruction of retaining walls using traditional techniques; (b) The collapse of the retaining walls shows the construction techniques. Photo provided by the authors.*

Maintenance and construction techniques

After the occurrence of an instability, the cause is attributed to poor land maintenance. In the case of terracing, it seems appropriate to start with simple structural considerations. The masonry that supports each terracing is drywall, which has a height of between 2 and 5 m. Historically, many walls were originally built with reduced heights, and, with the continuous formation of sediments upstream, they were raised up to their current conformation, with a typically rectangular wall section with approximately vertical faces.

In the steepest areas, which are more prone to landslides, the height of the walls is greater than 2 m. Assuming a height of 2.5 m and considering that the soil is of average texture and not very cohesive, we can approximate an angle of friction of 30° and a specific weight of 2,000 kg/m^3. Under normal conditions, we can consider a thrust of the order of 20,000 N/m, which would require a section greater than 1 m to minimally guarantee the tilting of the retaining wall. The collapsed sections, shown in **Figure 9**b, have wall thicknesses of the order of 50 cm.

If the terracing fails to drain during a heavy rainfall event, the retaining wall must resist hydrostatic pressure and even greater thicknesses are required. Such thicknesses are never observed. Landscape protections require that terraces be rebuilt only with traditional techniques. Consequently, maintenance interventions are often aimed at the restoration of existing walls or at the regulation of surface waters. Surface water regulations aim to prevent the condition of hydrostatic pressure in cases of intense rainfall events, which favor runoff. However, in cases of long intensity events, surface regulation does not prevent the soil from saturating at depth. In such cases, effective drainage would be required, using modern techniques not widely practiced in marginal agriculture. Economically viable maintenance for the type of agriculture practiced consists, in fact, in the restoration of pieces of retaining wall, structurally intended for a limited duration and prone to risky conditions in cases of long and intense rainfall events, such as that of 1954.

Case law on liability and waiver of property rights

Liability for damages

There is no specific rule in the Italian legal system that expressly provides for the obligation of the owner of land where there are terraces and dry stone walls to keep them in a good state of maintenance. However, this obligation is connected to the general principle of *neminem laedere* (Latin for: injure no one), from which it follows that the owner of the upper land must build, where they do not exist, and maintain, where they do exist, retaining walls in the event of the tangible danger of landslides or landslips toward the lower land (Italian Supreme Court of Cassation Judgment, 1994).

Regarding the damages caused to third parties as a consequence of the collapse of the dry walls of the terraces, defined as the stones that constitute their structure or by landslides and landslips, the owner(s) of the land(s) on which they stand are responsible. This responsibility is regulated by Articles 2051 and 2053 of the Italian Civil Code. Article 2053 of the Italian Civil Code, on the subject of the owner's liability for damages resulting from "the ruin of a building", provides that: "The owner of a building or other construction is liable for damages caused by their ruin, unless he proves that this is not due to defective maintenance or construction defect". It is common ground in legal doctrine and jurisprudence that Article 2053 of the Civil Code allows the owner to escape liability by proving force majeure or fortuitous event (Italian Supreme Court of Cassation Judgment, 2005), understood as an "unforeseeable and inevitable event, endowed with its own and exclusive causal autonomy" (Italian Supreme Court of Cassation Judgment, 2010).

With regard to the fortuitous event, Italian jurisprudence has highlighted that, "since the concept of the fortuitous event must be anchored to the general criterion of foreseeability with the ordinary diligence of the good father of the family, which is resolved in a judgment of probability, the subject cannot be charged with the obligation to foresee and prevent, in the infinite series of natural or human events that can theoretically occur, even those events of external origin that present such a high degree of improbability, accidentality or abnormality that they can be compared, in practice, to unforeseeable events" (Italian Supreme Court of Cassation Judgment, 2005). The fortuitous event is described as a "sudden event, exorbitant from the *id quod plerumque accidit* (what happens most often), with respect to which there is no human force capable of preventing it; in short, an absolutely unpredictable and inevitable event, endowed with its own and exclusive causal autonomy, as, for example, when we are in the presence of a phenomenon which, unleashing in a sudden and impetuous way the destructive forces of nature, assumes such huge and shocking proportions as to overwhelm every bulwark placed to safeguard men and things" (Italian Supreme Court of Cassation Judgment, 2005).

Regarding cases in which the damages caused to third parties do not derive directly from the structural elements of the collapsed dry-stone wall but from the landslide or due to the lack of maintenance or lack of restoration of the terracing, the responsibility – so called responsibility "for custody" – is based on Article 2051 of the Civil Code, according to which "Everyone is responsible for the damage caused by the things he has in custody, unless he proves the fortuitous event" (Italian Supreme Court of Cassation Judgment, 2014). This points out that the activity of the supervision and prevention of harmful events constitutes the content of a real obligation that Article 2051 places on those who have the availability of a thing and works in favor of the associates, including – and with particular reference to – the owners of underlying properties located in a sloping area, unless proof of the fortuitous event is provided. The injured party, in order to obtain compensation from the custodian, is required to demonstrate only the existence of the damage and its causal derivation from the thing, regardless of whether it or its intrinsic characteristics are dangerous or not (Italian Supreme Court of Cassation Judgment, 2018). For the custodian, on the other hand, to exempt themselves from liability, it is not sufficient to prove their diligence in custody but must prove that the damage resulted from a fortuitous event (Italian Supreme Court of Cassation Judgment, 2017). As with liability under Article 2053 of the Italian Civil Code, as a result of advancing scientific knowledge, the unpredictability of an event tends to decrease and, consequently, the scope of liability tends to expand.

Waiver of property rights

Under Italian law, therefore, owners of property are liable, subject to proof of fortuitous event or force majeure, for the damage that the property produces. For constructions that, due to their state of decay and location near other assets, require costly maintenance and may cause extensive damage through their ruin, a question has arisen as to whether owners may renounce ownership.
Although no Italian law expressly provides for the renunciation of the right to property ownership, Italian legal doctrine admits it on the basis of an interpretation of some provisions of the Civil Code.
Renunciation is considered a faculty inherent in the ownership of available rights (Comporti, 1988; Sicchiero, 1998; Administrative Justice Council Sicily, 2009; Rovereto District Court, 2015; Italian Council of State, 2020). Renunciation has a direct effect – the extinction of the right of ownership – and an indirect effect – the acquisition of ownership of the property by the State pursuant to Article 827 of the Civil Code (according to which "immovable property which is not the property of anyone is part of the State's assets"). The purchase takes place *ex leg*e and does not require the State's acceptance.

Attorney General's Office opinion

In 2018, the Attorney General's Office (Avv. Gen. Stato 4.3.2018 no. 137950) confirmed the principle of renunciation of real estate but identified some tools available to the State to make invalid renunciations of property "troublesome" and harbingers of possible liability. The above mentioned note, dealing with the renunciation of a real estate property at risk of hydrogeological instability, decides, for the nullity ex Art. 1343 of the Civil Code, for the illegality of the cause, on the renunciation that is put in place for the sole selfish purpose of transferring to the State Treasury ex Art. 827 of the Civil Code – and therefore to the community – the costs necessary for the consolidation works, maintenance, or demolition of the property and the responsibility for any

damage. A further reason for nullity is identified under Article 1345 of the Civil Code in the illicit motive, which exists when it is recognizable from the act of relinquishment of the property or is reasonably inferable from extrinsic and objective elements.
The Attorney General's Office observes that proof of the illicit motive for the renunciation can be provided by attaching and demonstrating objective elements (such as the inclusion of the property in the hydrogeological risk plans drawn up by the Basin Authority; previous and documented flooding episodes that have affected the property; contingent and urgent ordinances issued by the mayor as government official) from which it is possible to infer, with the necessary degree of plausibility, that the act of renunciation had, as its sole purpose, the assumption of responsibility by the State for the expenses for the maintenance and restoration of the property, together with the responsibility (civil and penal) for future instability.

Results

The results presented in the first part are related to the previous jurisprudential analysis of the concept of liability related to the increased risk caused by unauthorized and amnestied construction. While the second part of this section is related to the definition of the risk components for the quantitative assessment in the case study.

Increased risk from unauthorized buildings

The owners of property on which terraces are found could also be called to answer for damages caused to unauthorized buildings, whose existence follows a lack of supervision of the territory by the public administration. In this regard, the orientations of jurisprudence are not peaceful. According to a first orientation, after the occurrence of the event, the property of the person to whom the unauthorized property belongs is damaged, since the illegitimate construction still constitutes an element of his property, and is not a "*non-asset*"; therefore, his damage must be compensated according to the principle of *neminem laedere* (Italian Supreme Court of Cassation Judgment, 2014).According to other rulings, the damage suffered by an unlawful property is non-existent because the unlawful property is not likely to be traded on the market (Italian Supreme Court of Cassation Judgment, 2011, 2013). This jurisprudence recalls the protocol on expropriation for public utility, according to which unauthorized buildings are not susceptible to compensation unless an amnesty has already been issued. In such cases, in settling the compensation, the criterion of the overall market value of the asset and of the land on which the asset stands is not applied; only the area is assessed.
For example, the Supreme Court (Italian Supreme Court of Cassation Judgment, 2011) in a judgment regarding a landslide caused by the construction of a municipal road that damaged an unauthorized property qualified the damage as non-existent, as the unauthorized property was not able to be exchanged on the market. The Supreme Court decided similarly in judgment no. 8038 of 21 April 2016 with respect to a landslide caused by a construction site and the claim for damages proposed by the owner of a building built illegally downstream.

Another more recent order of the Supreme Court (Italian Supreme Court of Cassation Judgment, 2019), relating to damages from the overflow of rainwater due to the negligent maintenance of a road's sewer pipes suffered by the owner of an illegally built building, clarified that the construction violation, ex Art. 1227, para. 1 of the Italian Civil Code ("If the negligent act of the creditor has contributed to causing the damage, the compensation is diminished according to the seriousness of the fault and the entity of the consequences deriving from it"), breaks the causal link between the owned asset – in this case, a municipal road – and the damage suffered by the interested party, resetting the responsibility pursuant to Art. 2051 of the Italian Civil Code.

In Italian law:

- when the harmful event is linked to several actions (or omissions), the problem of the competition of a plurality of causes finds its solution in Art. 41 of the Penal Code, by virtue of which the concurrence of causes does not exclude the causal relationship between said causes and the event, the event being traceable to each of the causes, unless the exclusive causal efficiency of a single cause is proved, even if it is attributable to the same victim of the offense, to be considered suitable to prevent the event or reduce its consequences;
- the abusive nature of the asset is capable of determining the effect of exclusive causal efficiency in terms of the causative events of the damage to be compensated;
- if it is true that liability for damages arising from things in custody is based on the duty of precaution, it is equally true that the principle of solidarity (*ex* Art. 2 of the Constitution) requires those who come into contact with the thing to adopt appropriate conduct to restrict, within reasonable limits, the burden on third parties in the name of the reciprocity of the obligations arising from civil coexistence.

It is clear that this last orientation, if it prevails, precludes the owner of the terraces from being responsible for damage caused to unauthorized buildings. However, they remain responsible for authorized buildings and for those that are unauthorized but subject to amnesty (those, as mentioned, built mainly between 1956 and 1987).

Risk Components

Value Component RE

Based on the characteristics of the built heritage shown in Table 1 and considering the (2), the value component RE can be expressed in a disaggregated manner. Real estate value was practically equal to the cost of construction until the road was built (1854) and, therefore, the terraces were built at a time when the value exhibited was at most the cost of construction ($\mathbf{RE_{costr}}$). The current value of these properties is now, on average, five or more times the cost of construction. This is due to increased value resulting from improved accessibility, tourism development, and other benefits. A second component with the increased value ($\mathbf{RE_{incr}}$), which is at least five times higher, must therefore be considered. A third component ($\mathbf{RE_{aft1900}}$) is associated with properties built between 1900 and 1954, with a RE value already somewhat higher than the cost of construction, but without the full awareness of risk that emerged after the 1954 flood event. The buildings constructed between the flood of 1954 and 1987 (the first building amnesty) were built at a time when the concept of hydrogeological risk was known. Nevertheless, they were permitted or tolerated, thus increasing the value at risk. Therefore, a fourth component in the value of the built environment (**$RE_{aft1954}$**) can be identified. Buildings constructed after 1987 and, in particular, those after 2002 (entry into force of the Hydrogeological Plan) fall into a further category. These buildings were constructed with full awareness of the risk and thus fall into a fifth category of exposed value (**$RE_{aft1987}$**). Therefore, the exposed value can be expressed as the sum of the five terms (Eq. 3):

$$RE= RE_{costr} + RE_{incr}+ RE_{aft1900}+ RE_{aft1954}+ RE_{aft1987} \quad (3)$$

To give an order of magnitude, considering the surface areas presented in Table 1, estimating the cost of construction as one-fifth of the present value, and imagining a constant number of floors for the buildings, we can give the proportions of the four components:

$$\%RE_{costr} = 1/5 * 40026/92416*100 = 8.7\% \quad (4)$$

$$\%RE_{incr} = 4/5 * 40026/92416*100 = 34,6\% \quad (5)$$

$$\%RE_{aft1900} = 14884/92416*100 = 16,1\% \quad (6)$$

$$\%RE_{aft1954} = 27386 /92416*100 = 29.6\% \quad (7)$$

$$\%RE_{aft1987} = (2646+7474) /92416*100 = 11\% \quad (8)$$

Vulnerability Component Vu and Probability of Exposure PE

Two different components emerge from the cartographies attached to the basin plan: the “landslide risk zone” and the “debris flow risk zone”. These areas have been identified on the basis of a “hazard” map, but according to the current definition of a natural hazard, we can consider it as a product of vulnerability and the probability of exposure of buildings. Considering this source, by aggregating Vu (vulnerability) and PE (probability of exposure), the components were integrated into the term **VuPE**.

Vulnerability to debris flow, as assessed in the plan and resulting from the collapse of large, terraced areas of the basin, affects virtually all of the built-up area. This vulnerability is increased by the building density in the alluvial fan at the mouth of the *Reginna Minor* and the obstruction in the built-up area. Certainly, in the unfortunate event of a debris flow, this is followed by partial damage to the built-up area. For past floods of considerable scale, the cost of restoration has been borne by the State. In Italy, as well as in the European tradition (Damm *et al*., 2013), catastrophes such as Giampilieri in 2009, Sarno in 1998, Cinque Terre in 2011, Salerno in 1954, *etc*. are usually associated with public compensation, as they are considered unpredictable and inevitable (in Italy, insurance taken out by individual owners for this type of event is not widespread). We associate a debris flow with Vulnerability times Exposure ($\mathbf{VuPE_{df}}$) because it is a general event and we imagine that the compensation is provided by the State.

A second case is related to landslides. The vulnerability of buildings to landslides affects only buildings under terraced slopes. Due to the nature of landslides, affected buildings usually suffer damage, but these are individual buildings, and therefore the relationships involved are between agricultural owners and owners of the exposed buildings or properties. This second component of the vulnerability associated with landslides ($\mathbf{VuPE_{ls}}$) is related to the restoration of private property. In the present case, the buildings exposed to landslide risk, being on the sides of the conoid, are less exposed to the debris flow, and therefore the two vulnerabilities are disjointed.

Probability component P

The analysis shows that the occurrence probability (**P**) has only apparently increased. In fact, the return time of extreme events has not changed substantially even due to climate change. Indeed, studies on the increase of the frequency of extreme events due to climate change in the Mediterranean area are discordant. Based on data projections generated using the Monte Carlo method in the study conducted by (Peres and Cancelliere, 2018), the frequency even seems to be reduced. The rainfall intensity distribution may have shifted toward intense events, but the reduction in annual precipitation appears to reduce the probability of having an outlier event at each Mediterranean location. In general, the probability of extreme rainfall events has increased or will increase (Nearing *et al*., 2004; Pachauri *et al*., 2015; Hernández-Moreno and Alcántara-Ayala, 2017).

In addition to climate change, the ability to assess the return time of weather events that may be critical changes. This reduces the definition of the "unpredictable event" to cases truly outside of those predictable with regular return times predicted by the two-component procedure. Considering a time of concentration duration of the order of one hour for the *Reginna Minor* basin (mainstream length of about 5 km, area of about 5 km^2), considering the historical series of rainfall data, it can be assumed that, with a 100-year return time, at least one rainfall event greater than or equal to 75 mm in one hour can be expected. This could trigger landslide events.

However, debris flows and landslides can also be caused by long lasting, non-intense events. For example, again with a 100-year return time, an event of 110 mm in 24 hours could trigger landslides or even a debris flow. In a landslide liability judgment, it could be argued that an event of 75 mm in one hour should not be considered unpredictable. This awareness of the probability of occurrence of events was acquired at a time after the construction of the terracing. It can be argued that the perceptions and awareness of the probability of occurrence have increased tremendously with increased measurements of rainfall data and developments in probabilistic computing over the last century, while the probability of occurrence has likely changed little due to climate change.

Discussion

The objective of this paper was to assess whether it would be possible to reconsider the allocation of risk for damage caused by terrace collapse. In particular, in cases where agricultural terraces coexist with high-value real estate, in order to partially relieve agricultural owners of this liability. Based on the proposed case study, the reviewed case law and the methodology for calculating the risk function for quantifying natural hazards, the results of this work highlighted two issues, which are discussed in the next two subsections. On the one hand, a discrepancy in the State's behavior, which generates an increase in risk by supporting the construction transformation of the territory, including through amnesties, and at the same time invalidates the farmers renunciation of their ownership to avoid responsibility for possible damages. On the other hand, the possibility of defining non-stationary risk by dividing it into two components, one intrinsic and one induced. This would ensure a fairer division of responsibility between public and private owners, as shown below.

Landscape preservation requirements necessitate the use of traditional restoration techniques. This limits the possibility of using techniques and/or materials that could increase the stability of the slopes. Technological innovations and using innovative synthetic materials would allow terraced areas to be stabilized but are not aesthetically or economically sustainable. These solutions do not correspond to the type of economically sustainable maintenance practiced by farmers, which involves reusing the same stones after they have collapsed. As a result, the structural characteristics of the walls have a limited lifetime, and the risk of landslides can be greatly increased during periods of prolonged and intense rainfall.

The risk of collapse can be reduced, but not entirely excluded, by maintaining agricultural land (Tarolli *et al*., 2014; Capolupo and Boccia, 2018) and managing surface water (Asins *et al*., 2016) or, in the case of abandonment, by reforesting slopes (Agnoletti *et al*., 2019). Therefore, this study does not pretend to find a solution to the problem of abandonment of terraces but proposes a different distribution of risks. While the risk of collapse cannot be eliminated, it is clear that government policies such as building amnesties have increased the induced risk, discouraged farming in terraced areas with high hydrogeological risk, and exacerbated the problem of abandonment. On the contrary, with specific support measures and a fair distribution of risk, it is likely that farmers would not be induced to abandon the terraced areas.

Discrepancies in State behavior

As can be seen from the results section, it is anomalous that the State has attempted to invalidate the deeds of renunciation of ownership of terraced areas because they are possible sources of liability for damage to third parties. The anomaly derives from the fact that it is precisely the State's regulations that, in regulating the activities of the transformation of the territory, the amnesties, and the vigilance of the municipal administrations over the territory, have allowed the built-up area to increase for a century and therefore also the value exposed in areas at risk. In the face of such an oddity, an equitable division of responsibility could be obtained by subdividing the risk into several components linked to non-stationarity. From this division of risk, a division of responsibility between public subjects, owners of terraces, and owners of exposed properties would also therefore follow.

Non-stationarity of risk and liability

The risk for the owners of the terraces, in the case under consideration, is associated with the sum of two components: the first is intrinsic to the idea of changing the land use ($\mathbf{R_{intr}}$), and the second, which somehow transcends the risk known ex ante by farmers, is induced by the behavior of third parties and administrations ($\mathbf{R_{indu}}$). In this study, $\mathbf{R_{intr}}$ refers to the awareness of farmers who own terraced areas of the risk associated with the presence of underlying buildings, with a property value equal to the cost of construction until 1900. The $\mathbf{R_{indu}}$, on the other hand, refers to the induced risk component of the real estate value due to the amnesties and due to the increase in the volume of real estate itself, despite the full awareness of the risk by those who authorized and constructed the buildings.

$$R=R_{intr} + R_{indu} = P*(VuPE_{df} + VuPE_{ls}) * (RE_{costr} + RE_{incr}+ RE_{aft1900}+ RE_{aft1954}+ RE_{aft1987}) \qquad (9)$$

The non-stationary nature of R is related to an increased awareness of the probability of occurrence and vulnerability but also, more importantly, the variation in the value exposed. This concept of non-stationarity, used to provide an appropriate response in changing circumstances, is similar to the concept of dynamic risk assessment.

The non-stationarity of risk has in some cases had the "extreme" consequence of inducing the owners of the terraces to relinquish ownership and inducing the State, which has become the owner and thus the holder of the risk, to oppose such relinquishments. Evidently, the unacceptability of liability lies in the increase in liability in the face of profits from the agricultural use of the terraces. If the risk components are considered separately, a quantitative difference emerges. The second component arose from causes induced either by the owners of the properties potentially exposed to the risk themselves or by the administrations. With this distinction, R would result in Eq. 10:

$$R = R_{intr}+R_{indu}= P*VuPE_{ls}*(RE_{cost} +RE_{aft1900}) + P*(VuPE_{df} +VuPE_{ls}) * (RE_{incr} +RE_{aft1954}+ RE_{aft1987}) \qquad (10)$$

Different from equation 9, in equation 10 it is possible to clearly distinguish a first part related to the calculation of R_{intr} and a second part related to the calculation of R_{indu}. The first part (R_{intr}) is given by the product of the probability of the event times the vulnerability/probability of exposure to landslide risk times the property value equal to the construction cost of pre-1900 and pre-1954 properties. The second part of the equation (R_{indu}) is given by the product of the probability of the event times the sum of the vulnerability/probability of exposure to landslide risk and the vulnerability/probability of exposure to debris flow risk times the market value of the pre-1954 and post-1954 buildings, including condoned properties, that were built despite knowledge of the hazard. The induced (R_{indu}) risk would be significantly higher than the intrinsic (agricultural) risk. In the case of landslides, liability could be limited only to properties that existed prior to the increase in awareness of landslide risk (1954) and could consider the value of the construction rather than the market value. In this way, an induced risk in the event of a landslide would also come into play, which could lead to liability also for the administration that condoned or authorized the property and the owners of the exposed properties themselves.

Conclusions

Based on the assumption that terraces tend to return to their natural arrangement (Violante *et al*., 2008) and that maintenance and renaturalization interventions can partially address this (Tarolli *et al*., 2014; Agnoletti *et al*., 2019), the evolution of the Minori case study has been investigated and the resulting risks explored.

It was assessed that a liability was associated with the risk of damage to third parties brought about by terrace collapse. This risk has varied over time as a result of authorized or condoned building activity and the increases in property value. Although terraces provide important ecosystem services, they are being abandoned because agricultural practice is onerous. It has been pointed out that the State does not intend to add terraced areas to the public estate when presented with risk-motivated waivers by owners.

The non-stationarity of the risk has been associated with a temporal variation of the liability, which has been split into two components: the first known and accepted by farmers; the second connected to the public or private actions of third parties. This second component dramatically increased the risk. It could be argued that the increase in the value of real estate included in this component is independent of any specific public will. However, the exposed value has also increased as a result of the choices made by the public administrations in their land use policies. In conclusion, it would seem that the second component should be associated with public compensation in the event of a damaging event.

In the introductory section, it was pointed out that private insurance remains limited in major European countries. This lack, in relation to the case study, is mainly due to the high level of insurance premiums - which should be parameterized to the exposure value - and to the absence of a legal obligation. The insurance obligation has recently been discussed in the Italian State Law (Italian Regulation, 2023). The legislation introduces the obligation to insure against catastrophic risks such as earthquakes, floods and landslides, a novelty in the Italian legislative landscape. The obligation to take out private insurance policies to cover damage caused by a catastrophic event allows the State to avoid using public funds to compensate for the damage. At present, the obligation only applies to companies for damage to their own property; extension to ordinary citizens is still under discussion. However, this measure cannot be considered as a solution to the problem addressed in this study. The problem addressed in this study is related, on the one hand, to the high imbalance between hypothetical third party claims and agricultural income. In contrast, this study focused on the common practice of renouncing property ownership by terrace owners. Requiring insurance for owners of exposed properties cannot be a solution to the increased risk due to the increase in exposed value as a result of decisions made by the public administration in land use planning or in the supervision of construction activities.

Risk-sharing seems appropriate in the case of agricultural terracing. In this case, the low profit achievable does not allow the farmer to implement risk reduction measures, such as reinforced concrete piling, masonry of a thickness proportionate to the pressure of the soil and water, drainage, protective mounds or retaining structures, etc. However, such measures would probably also be prevented due to the local landscape value. Terraced agriculture has not received substantial economic benefits from the development of the underlying country. In addition, the type of agriculture is not competitive with more recent advances. Inappropriate oversight of building activity in the past, building permits issued in areas that are clearly at risk, and the increase in value of exposed properties with the transition from rural to tourist areas all lead to the confirmation of the idea that risk has increased. The increase in scientific knowledge reduces the invocability of the fortuitous event and force majeure in the event of damage to third parties and, as a consequence, there are frequent acts of renunciation of property by owners of terraced areas in areas at risk in order to escape this increased responsibility. The proposed division of risk into two components would help to overcome this incongruity. Of course, this study does not exhaust the possible ways to address the issue. It is intended to lay the groundwork for a broader discussion of risk allocation in the future.

Author Contributions: "Conceptualization, B. L. and M. G.; methodology, B. L., M. G. and G.D.; landscape analysis B. L. and G.D.; legal analysis M. G; writing, original draft preparation, review and editing, B. L., M. G. and G.D. All authors have read and agreed to the published version of the manuscript."

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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