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Perspective

Returning to Integrated Landscape Management as an Approach to Counteract Land Degradation in Small Mediterranean Islands: The Case Study of Stromboli (Southern Tyrrhenian Sea, Italy)

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Abstract: The small Mediterranean islands, unique geographical places where coastlines and mountains converge due to volcanic genesis, are among the most threatened environments on Earth. Their marginality, which has historically led to their use as places of detention and punishment, coupled with the extreme climate and rugged geomorphology shaped by terracing practices, has resulted in the loss of systematic land management. This loss stems from the abandonment of cropland in favor of alternative activities and migrations, impacting essential ecosystem services such as the water cycle, soil fertility, and the cultural landscape. The need to counteract the land degradation in these vulnerable areas has been acknowledged for some Mediterranean small islands, including the UNESCO heritage site of Stromboli in the Aeolian Islands, Sicily, Italy—an especially captivating location due to its active volcano. The agricultural abandonment on terraces, intensively cultivated with olives groves and vineyards until the mid-20th century, has rendered the area highly fragile and susceptible to risks such as fires and soil erosion, particularly as a consequence of extreme weather events, as proven in 2022, which saw a destructive fire followed by storms. To mitigate the negative effects of hydrogeological disruptions, the implementation of integrated landscape management—managing ecosystems at the landscape level—has been proposed. Specifically, an agroforestry intervention, coupled with the restoration of dry stone walls, the shaping of soil slopes by recovering the traditional ecological knowledge (TEK), and the design of water-collecting devices incorporated with the traditional hydraulic knowledge, may be proposed as a strategic approach to minimize the soil erosion risks, adapt to climate change, and extensively restore the use of traditional agrobiodiversity to support the local economy and tourism. A pilot intervention by local stakeholders based on these principles is described as an emblematic agrobiodiversity-based landscape design project in a vulnerable area, aiming at the preservation of the cultural landscapes of the small Mediterranean islands.

Keywords: agroforestry; community; cultural landscape; ecological landscape design; extreme climate events; heritage; *Olea europaea*; sustainable tourism; territory; traditional hydraulic knowledge

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1. Introduction

Due to its geography and history, the Mediterranean is one of the most complex and heterogeneous physical environments, a crossroads of cultures and a place of confluence with extraordinarily rich biodiversity whose origins lie across the various continents of the planet. In particular, these islands represent unique landscapes, expressions of the stratification of cultures over the centuries, geographic sites, and socioeconomic contexts

that require specific strategies for their resilience and development, being highly "sensitive" areas [1,2]. Land degradation phenomena are particularly evident in sensitive territories that present a high level of vulnerability and require therefore specific measures to protect their ecosystems, natural habitats, and soils, particularly in the context of climate change [3]. On these islands, the environmental specificity of the Mediterranean becomes emblematic of both the characteristics of vulnerability and the challenge to identify strategies to ensure the resilience and reconnection of natural and cultural capital. These small islands are unique places where the natural capital, represented by the lithological formations, the geodiversity of the soils, the floristic richness, and the agrobiodiversity, meets the cultural capital, represented by the local history and traditions, the architecture, the traditional knowledge of the land, and the management of the environmental resources [4–8]. Islands may become special laboratories and focal points for the development and testing of actions dealing with sustainability challenges [9].

Owing to their isolation and remoteness from the mainland, the imposed circular economy of the small islands has been grounded since ancient times in self-maintenance agriculture, which has led to multifaced agricultural landscapes, arising from the transformation of the natural—and mainly hostile—environment by man for his productive activities. Therefore, in the Mediterranean islands, agriculture has deep-rooted historical and cultural meaning [10,11]. Nonetheless, due to the intensive outgoing migration flows, the "mass orientation" of touristic policies, climate change, and the increase in the frequency of extreme events [12–14], the Mediterranean landscape, being extensively constructed and modified by man, is intrinsically fragile and vulnerable [3,15]. Throughout the Mediterranean, the level of natural and cultivated biodiversity has been depleted over the years, with the consequent loss of environmental diversity, traditional products, and rural culture [16]. The safeguarding of terrestrial biodiversity and ecosystems passes through the sustainable and systematic management of the natural landscape, which may imply also the functional recovery of the rural landscape when altered. Traditional agriculture, which is based on agroecological approaches, prevails in the small Mediterranean islands and represents a multifunctional land use. Traditional agricultural practices protect the soil from erosion and loss, biogeochemical cycles from alteration, soil fertility from impoverishment, indigenous genetic resources from disappearance, and the local rural culture from oblivion [17–19].

Safeguarding the Mediterranean landscape means preserving its biocultural diversity [20], i.e., biological diversity in all forms in which it occurs (plants, animals, habitats, and ecosystems), but also the diversity of peoples' cultures, which manifests itself through the use of genetic resources, for their nutrition or to support their activities, through the integrated landscape management methodology and agroforestry [21,22].

These islands' cultural landscapes have evolved slowly in the past but entered a period of rapid transformation with the advent of mass tourism and urbanization and, consequently, the abandonment of cropland under the pressure of alternative land uses and migrations [23–26].

Nowadays, additional threats to the agricultural landscape of the small Mediterranean islands include arable land scarcity, the agrosystems' fragmentation, limited access to innovative technology, reduced yields because of climate change, and related increases in extreme events (e.g., floods, storms, wildfires) [5]. The abandonment of agricultural land use has been proven to lead to the depletion of many ecosystem services, including biodiversity, soil fertility and soil biodiversity, water quality and the water cycle, and the landscape [27], and their recovery through innovative strategies may ensure small islands' resilience [28–30].

The need to restore the cultural landscape has become a key challenge in preserving vulnerable territories, requiring the identification of appropriate and resilient interventions that consider the peculiarities and constraints of the environment, together with the socioeconomic structure. Ensuring the resilience of the cultural landscape in sensitive areas requires integrated approaches and integrated landscape management plans [29,31].

In our study, we propose an integrated intervention strategy for the restoration of the cultural landscape in an emblematic island of the Mediterranean, the island of Stromboli in the Tyrrhenian Sea, where extreme events, e.g., fires and storms, have led to heavy soil erosion and consequently losses in fertility, aboveground and belowground biodiversity depletion, landscape loss, and opportunities for agriculture-based economic compromise.

The proposed strategy introduces an innovative approach to be adopted in regions of limited dimensions, like small islands. This approach is based on multifocused actions that address multiple ecosystems—both natural and agricultural—rather than relying on the more common isolated interventions. The goal is to promote the co-occurrence of multiple ecosystem services. To this aim, the specific objectives were (i) to recover the complexity of the natural and anthropogenic ecosystems; (ii) to safeguard the local agrobiodiversity; (iii) to improve water regulation so as to counteract runoff and erosion phenomena; (iv) to recover the traditional hydraulic knowledge; and (v) to promote sustainable tourism.

2. The Case Study

The island of Stromboli, particularly the main settlement of Stromboli (38°48′20″ N 15°14′10″ E), has been chosen for the proposal of a systemic landscape recovery strategy owing to its peculiar physiography and its recent environmental history, which have exposed this sensitive land to accelerated degradation. This small island therefore represents an emblematic and sensitive area under multiple risk drivers.

2.1. The Island

The island of Stromboli (Southern Tyrrhenian Sea, Aeolian Islands, UNESCO site, Italy) (Figure 1), with its peculiar biogeographical nature, is emblematic of the Mediterranean landscape, which manifests itself in a myriad of forms due to the contrasting physical characteristics of the environment, such as the sea and the coastal mountains [32]. Stromboli Island, together with the other seven Aeolian Islands, provides "a rich field for volcanological studies of ongoing geological processes in the development of landforms", therefore being recognized as a World Heritage Site since 2000 [33]. Stromboli has an active volcano [34], with peculiar terrestrial and marine ecological characteristics, and its landscape is the result of dynamic relations between the abiotic and biotic components. The climate of the Aeolian Islands has been characterized over the past 15 years (2009–2023) by dry summers with rare exceptional rainfall, and precipitation concentrated in the winter/autumn seasons (mean seasonal rainfall: 728 mm year^{-1}) [35]. Nonetheless, a general increase in rainfall anomalies has been observed, especially in the Southern Italian regions, in the summertime [36]. This small island (12.20 km^2) has an emerged volcanic cone that reaches the elevation of 926 m a.s.l. and is characterized by rich ecological, landscape, and natural diversity. The piedmont strip in the eastern versant is a hilled and terraced land system; until the past century, it was characterized by vineyards, olive groves, and capper cultivation, which replaced the natural Mediterranean forest, managed with traditional agricultural practices [37]. Systematic cropland abandonment has caused the rewilding of these terraces and therefore the reappearance of the natural vegetation, but has also led to reduced control of the territory. The consequent terrace collapse and the formation of runoff furrows, leading to soil depletion, have increased the risks of wildfires and hydrogeological disruption [38]. In May 2022, an anthropogenic fire, spanning over 240 hectares above the main town, devastated the island, erasing the residual centuries-old agricultural experience and destroying the ancient terraced landscape. A few weeks later, in August 2022, a period of unusually high rainfall (86 mm of rainfall was recorded in the Aeolian archipelago in August 2022) triggered dramatic fire-induced landslides and mudslides, washing away the surface of the burned slope, exposing the volcanic rock substrate, and leaving the slopes completely defenseless and bare [39].

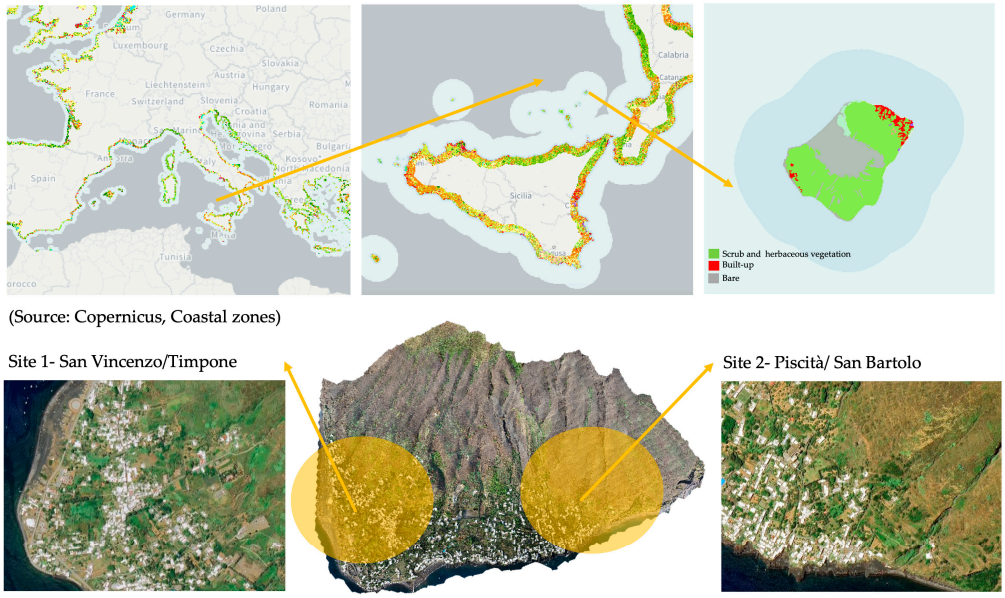

Figure 1. The study site's location. The island of Stromboli (Aeolian Islands, Southern Tyrrhenian Sea) (**above**). Two possible intervention sites for an integrated landscape management strategy (**below**). (Source: Copernicus Coastal Zones) (credit, R.B.; S.B.C.).

Based on these recent extreme events, which have caused the loss and degradation of the terrestrial ecosystems, and the loss of the topsoil due to water runoff phenomena on the steeped sides, two intervention sites, amounting to 2.5 hectares, have been prioritized by local stakeholders for landscape recovery and the prevention of further damage due to the non-governance of stormwater. These sites (San Vincenzo/Timpone, the original settlement, and Piscità) have been chosen for their positions, with both being closely integrated into the urban tissue of the town of Stromboli, which implies also the risk of negative consequences for dwellings and inhabitants (Figure 1).

The two pilot sites have been field-surveyed and utilized for the formulation of an integrated landscape design and management proposal. One of these was interested by a landscape restoration intervention.

2.2. Objectives of the Landscape Design and Landscape Management Concept

The proposed approach aims to highlight intervention guidelines to ensure the Mediterranean cultural landscape's resilience, by preventing environmental degradation trigged by the abandonment of the management of the territory. Although the consequences of cropland abandonment are multifaceted and involve environmental, economic, and social aspects [40], fires and water runoff phenomena are vulnerability factors that act strongly in sloped areas, particularly after the disuse of farmland [41,42]. On the contrary, alternative forms of agricultural and forest land management may reduce their frequency and incidence by acting as territorial preservation strategies. In fact, as far as wild and/or anthropogenic fires are concerned, one of the main risk factors has been specifically identified in the abandonment of farming plots, since uncultivated land patches, exhibiting overgrazing and, in general, recolonizing vegetation, represent a continuous vertical and horizontal fuel, especially under arid conditions [43,44]. It has been also proven that the speed of wildfires' spread is increased by steeper slopes. In terms of water runoff and soil erosion, again, abandoned agricultural surfaces represent sites of vulnerability [45–48]. In particular, abandoned sloped land, no longer actively cultivated, no longer has a water regulation system, and the bare soil, together with intense precipitation, particularly in the arid period, prevents water infiltration, causing the soil's physical erosion and hydrological disruption. Counteracting these phenomena requires a holistic approach

that is able to restore the traditional systemic land management, albeit within the current socioeconomic framework.

Specifically, our proposal aims to restore damaged, sloped landscapes to enhance the regulatory ecosystem services by improving rainfall interception, reducing water runoff, and thereby minimizing soil erosion. At the same time, this approach seeks to boost the provisional ecosystem services by supporting local agrifood production with better water availability, which is crucial in maintaining quality under increasing droughts and heat waves. Finally, cultural services are enhanced through the safeguarding of the rural history and culture.

Therefore, the proposed strategy focuses on the following integrated intervention priorities: (1) recovering the traditional land management through agroforestry; (2) redesigning the agricultural hydraulic terraced systems; (3) recovering the traditional hydraulic knowledge to support local agrobiodiversity; (4) designing firebreak barriers; and (5) identifying integrated landscape management actions for more sustainable ecotourism.

3. Theoretical Framework

3.1. Return to Agroforestry

Agroforestry has been proposed as a viable strategy for land restoration. Agroforestry represents a traditional land use system that combines forest species with crops, aiming to integrate different provisioning services, such as the products of woodlands and agrosystems [49,50]. In Europe, the land area classified as agroforestry is quite limited [51], accounting for a small percentage of the total surface, and is predominantly located in marginal, sloped areas, where it provides multiple ecosystem services [28,49,52] (Table 1). Agroforestry is expected to expand due to the growing interest in this extensive land use type, not only in rural contexts [53–55] but also in new, unconventional settings, such as peri-urban and urban areas [56]. In these contexts, agroforestry systems may be designed for open spaces as food forests or as part of complex urban and peri-urban green infrastructure for todays' bio-cities.

Table 1. The ecosystem services that can be provided by agrosystems and agroforestry and related processes.

Ecosystem Service		Ecosystem Process
Supply	Primary production	Supply of food, fiber, energy
Regulation	Water regulation	Infiltration and regimentation
	Climate regulation	Local climate mitigation
	Air quality regulation	Carbon storage
	Erosion protection	Adhesion action, runoff contrast
	Pollination	Abundance and effectiveness protection from destructive events
	Natural hazard mitigation	
	Biological control	Pest population control
Support	Habitats	Breeding, refuge, feeding areas
	Genetic diversity	Maintenance of evolutionary processes
Cultural	Aesthetic value, landscape	Ecosystem diversity
	Recreational	Attractiveness and tourism
	Education and science	Awareness of sustainability issues

The presence of agroforestry systems on the small Mediterranean islands is rare, as is the presence of forests, which were largely replaced by cropland during their colonization. Nevertheless, interest in the introduction of this land use type is increasing, and some experimental designs featuring wooded crops or mixed forests and agricultural woody species have been implemented (Figure 2), such as on the small island of Ventotene (Central Tyrrhenian Sea, Latium region, Italy).

Figure 2. A newly realized agroforestry intervention on the island of Ventotene (Central Tyrrhenian Sea, Latium region, Italy). Combination of trees and shrubs of the Mediterranean Maquis, with some of food interest (**left**); combination of grapevines (detail) with shrubs and tree species from the Mediterranean environment (**right**) (credits, R.B.).

Among the multiple ecosystem services attributed to agroforestry systems is the mitigation of land degradation in steep areas, particularly after the abandonment of cropland on slopes and/or terraces [57,58]. Specifically, the terraced landscape, one of the most emblematic cultural landscapes worldwide, exhibits various states of conservation and management, ranging from residual active management to widespread abandonment [59]. On the small Mediterranean islands, the resilience of these terraced systems is only partially supported by active cultivation. Specialized cropping systems require an active agricultural workforce, whereas the local population primarily consists of tourism-oriented residents [60,61]. On these islands, the local agriculture relies less on external resources but is constrained by the low economic productivity of both the land and labor.

The abandonment of active terrace management not only leads to soil erosion and land degradation but also results in the loss of autochthonous agrobiodiversity. The agrifood production of small islands relies on traditional horticultural crops, primarily vegetables, pulses, fruit trees, olive groves, and grapevines [10]. Viticulture on these islands is a well-established practice, and, despite the high costs and challenges of production, the added value of oenological products makes it profitable, earning it the title of "heroic viticulture". However, in some insular regions, grapevine cultivation has nearly disappeared, such as in the Aeolian and Pontine Islands (Southern and Central Tyrrhenian Sea), although efforts for its reintroduction are underway. On the other hand, olive ecosystems have shown greater resilience, likely due to their lower management requirements [10,62]. Olive-based agroforestry systems may serve as strategic land uses on sloped marginal lands, mitigating land degradation while safeguarding local olive landraces and producing highly valued oils [63–67].

On sloped terrain, preserving or introducing olive trees in agroforestry systems can maintain the historical landscapes, protect valuable agrobiodiversity, and support olive oil production, particularly from specialized olive groves on gentler slopes [66,68]. The roots of trees and shrubs further help to stabilize the soil. A gradient of olive-based landscapes could be hypothesized along slope gradients to enhance these functions (Figure 3).

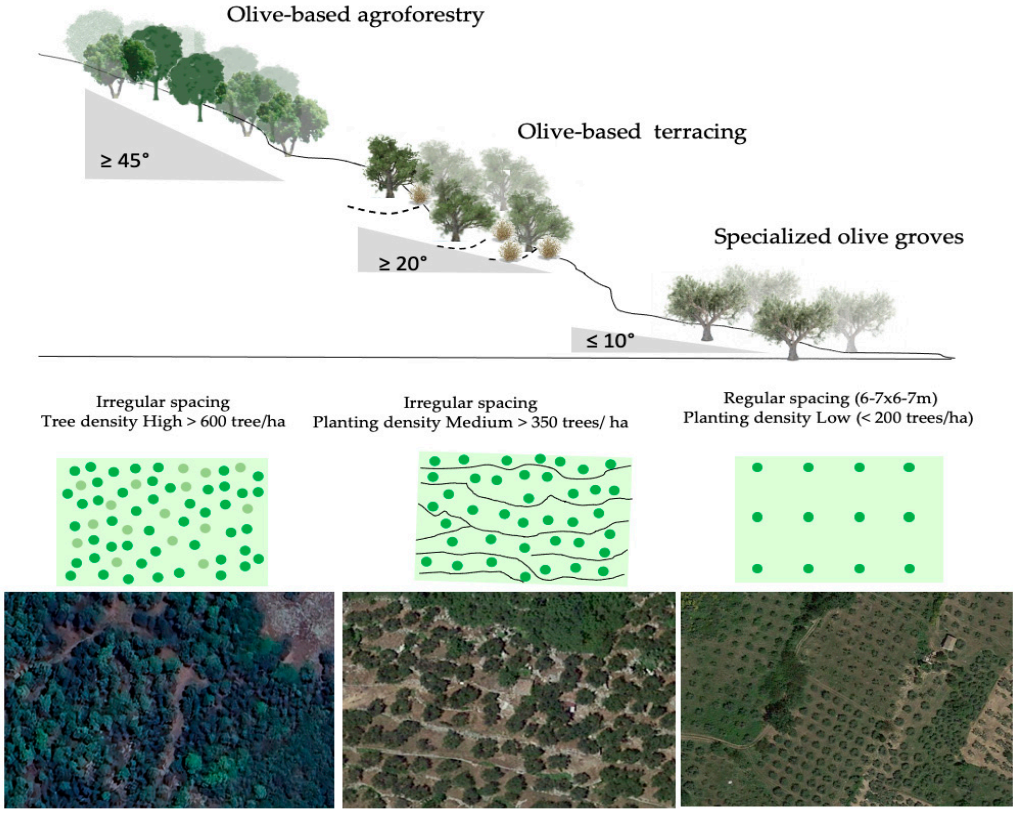

Figure 3. Layout of the hypothetical distribution of olive-based agroforestry systems in relation to slope. From top to bottom: forest species + olive trees (olive forest); olive trees + fruit trees +shrubs; specialized olive groves (credit, E.B.; R.B.).

Agroforestry can serve as a nature-based solution to combat land degradation, and specific combinations of tree crops and natural shrub vegetation may function as multifunctional barriers. "Green barriers" designed to counter various degradation processes could also incorporate agricultural biodiversity, particularly in areas near population centers [69]. Some pilot small-scale barrier projects, based on integrating botanical species and agrobiodiversity, have been designed according to functional and spatial intercropping criteria (multi-layer barriers), aimed at counteracting issues such as desertification. The planting of new hedges with low-flammability plants has been identified and implemented as green firebreaks, especially in the farmland–urban interface [70]. On the Mediterranean islands, *Opuntia ficus-indica* and other *Opuntia* species have numerous traditional uses and are widely used in hedge designs. These species, native to South America, are so widespread in the Mediterranean that they have become iconic in the "Mediterranean garden" landscape, as widely defined [17]. Following land disruption from abandonment or extreme climate events, *Opuntia*-based agroforestry could be a strategic solution for the restoration of island landscapes in the context of climate change [68,69,71].

3.2. Traditional Hydraulic Knowledge and Water Interception and Storage

The Mediterranean is one of the ecosystems that is most exposed to the consequences of climate change, particularly rising temperatures and alterations in rainfall patterns. These changes have led to prolonged and severe droughts, as well as an increased frequency of extreme rainfall events [14,15]. Consequently, water interception and storage is a key topic in the Mediterranean region [72].

The issue of water resource management has been a millennia-long challenge for the small island systems in the Mediterranean due to their geographic isolation. As a result, they have traditionally developed sophisticated systems for the interception, storage, and distribution of freshwater for various purposes, particularly agriculture. For some

small islands, such as the Pontine Islands, historical reconstructions of traditional water management systems are available. Gallia (2013) [73] provides an example from the island of Ponza (Northern Tyrrhenian), where traditional techniques for the collection, storage, and distribution of rainwater were based on advanced surface and underground channels, as well as the architectural forms of the houses.

The water availability on the islands has always been influenced by physiographic factors such as precipitation, the presence or absence of orographic relief, the soil permeability, and the presence of aquifers. Additionally, the islands' sizes and distances from the mainland determine the ease or difficulty of obtaining an external water supply.

Recovering some of this traditional hydraulic knowledge may help to improve water management, especially in the absence of structural interventions for the interception and distribution of water.

3.2.1. Restoring Dry Stone Walls

Terraced landscapes are part of the cultural heritage of the Mediterranean and represent a hydraulic–agrarian system of immense ecological and environmental value, among the most widespread in the world. These terraces are characteristic of the coastal mountains of the Mediterranean, showcasing a centuries-old history of land use and water resource management in steep terrain. They are designed to intercept water and reduce surface runoff by modifying the soil morphology for hydraulic regulation. Many terraced landscapes in Italy are recognized as UNESCO World Heritage Sites [33], such as the Prosecco Hills (a viticultural landscape) in Northern Italy and the Southern Amalfi Coast. Other terraced landscapes, like the olive groves of the slopes between Assisi and Spoleto in Central Italy, are designated as Globally Important Agricultural Heritage Systems (GIAHS) [19]. Terraced landscapes provide multiple ecosystem services, including biodiversity conservation, soil erosion prevention, landslide mitigation, soil fertility maintenance, microclimate regulation, and the preservation of traditional agricultural practices and knowledge. However, many terraced areas have been abandoned by farmers, leading to the loss of traditional agricultural production and the creation of landscapes that are highly vulnerable to hydrogeological instability, landslides, and wildfires [41,74,75]. The lack of maintenance of dry stone walls and the abandonment of active cultivation on terraces are recognized as key factors in soil instability and erosion in sloping areas [76,77]. Additionally, uncultivated land becomes an ideal fuel source during fires, which spread quickly in steep areas [78]. On the other hand, when actively managed, terraced landscapes can act as barriers to environmental degradation, especially in the current context of climate change [41,79]. The construction of terraces is a form of traditional hydraulic knowledge that ensures sustainable water management. This is achieved by leveling sloping surfaces, which promotes water infiltration into the soil, and through the use of dry stone walls that act as embankments, regulating the relative humidity through water condensation. An example of this knowledge is the traditional "Giardino Pantesco" on the island of Pantelleria (Sicily, Italy), a circular walled structure that regulates the water availability for *Citrus* trees. This allows these water-demanding species to thrive without irrigation [80]. Moreover, the presence of crops and the turnover of roots in the soil, combined with traditional soil fertility management practices that preserve organic matter, indirectly enhance the terraces' water retention capacity by improving the soil texture [57]. Dry stone walls remain a resilient feature of the rural culture on these islands [81], although many have fallen into decay due to the abandonment of their maintenance. In recognition of their multifunctionality, the art of building dry stone walls was included on the UNESCO Intangible Heritage list in 2018. Today, the recovery of terraced systems is often carried out in a fragmented way, typically through individual initiatives on small plots of land, rather than at a landscape scale. Large-scale recovery efforts, involving multiple stakeholders, are essential to combat land degradation. The active management of terraced landscapes is crucial to ensuring their resilience in the face of climate change. The restoration, stabilization, and functional recovery of terraces through systematic maintenance are internationally recognized as

strategies for sustainable land management [59]. However, such efforts must adhere to the traditional construction techniques, as modern construction methods for stone walls have been shown to be inadequate for slope stabilization.

3.2.2. Recovering Rural Hydraulic Architecture

For a long time, the water supply system on small islands, such as those in the Tyrrhenian Sea, was based on the architecture of cisterns, featuring sophisticated systems of impluvia, compluvia, and canals, as well as house designs that utilized rooftops for the collection and storage of water underground [73,82]. The cisterns, although varying in size, shared a common construction style. They were dug into the rock and consisted of a series of adjacent galleries with barrel vaults, connected by arched openings. The front wall was composed of masonry, and there were various openings for air circulation, which helped to prevent water from stagnating [73,83]. The water supply and management techniques heavily relied on the maintenance of these structures, which, for centuries, met the water needs of the islands' inhabitants. The traditional water management also extended to agricultural use, as seen in the construction of underground rooms, pits, and wells.

This traditional knowledge of water use, which persisted until the mid-20th century, began to disappear in the 1970s due to tourism pressure, new patterns of settlement, and the decline in agriculture's economic role in the Tyrrhenian Islands. The sharp reduction in agricultural activity decreased the demand for water and, coupled with the loss of traditional water management practices, led to increased environmental risks, such as erosion, due to a lack of control over agricultural land. Today, many traditional water collection structures, never maintained, have been abandoned and fallen into disrepair, particularly after the State took over the water supply for smaller islands.

On the other hand, tourism and high seasonal population pressures, along with increased demands for traditional agrifood products, have reignited the interest in agricultural activities, once again raising the need for freshwater for production purposes.

Rainwater is a clean (not chlorinated) and free source of water; it is socially acceptable and environmentally responsible, promotes self-sufficiency, and helps to conserve water. Rainwater harvesting systems are able to collect, store, and distribute water, reintroducing ancient techniques used in the dry areas of the Mediterranean and mountainous regions. Many systems were found throughout the Bosphorus during the Byzantine period, intercepting water veins running at altitudes with descending terracotta pipes connected to sequences of underground terrace-like reservoirs surrounded by retaining walls [84,85]. In recent times, during WW1 in the Eastern Alps, both the Austro-Hungarian and Italian armies used soil-dug cisterns, served by systems of fan-shaped paved surfaces located upstream (catchment areas). Although rainwater catchment is an old technology, there have been many improvements over time through product innovation.

Defining strategies for the sustainable management of water resources, through the revival of traditional hydraulic architecture, could help to mitigate the risks of prolonged drought by regulating water runoff, thus preventing soil erosion; it also could allow the introduction of technological innovation to support local crops, e.g., through precision irrigation.

4. Integrated Landscape Project Proposal for Landscape Resilience

Many actions have been proposed and implemented to revive the agriculture-based economy in small islands, although they are mainly focused on the recovery of a single or a few depleted agrosystems [60,61,65,67]. These strategies, aiming to safeguard the islands' biocultural landscapes, should be based on integrated, systemic, and multiscale approaches, as more recently proposed [86,87]. In particular, landscape restoration, and the recovery of its multifunctionality, should be applied at the landscape level, as interventions at the scale of individual ecosystems often fail to bring significant benefits for comprehensive landscape rehabilitation. However, prototype interventions can serve as valuable tools to raise collective awareness about the advantages of land management in preventing or

counteracting land degradation phenomena. On the island of Stromboli, an integrated and multiscale landscape project has been proposed to develop strategies aimed at reducing surface water runoff and mitigating the consequent soil erosion and depletion, supporting, at the same time, the local rural tradition. In this context, for the piedmont strip of Stromboli, the integration of water interception devices into the terraced landscape has been proposed in an area characterized by steep peri-urban land, where remnants of terraces and olive groves still exist (Piscità site) (Figure 1). The landscape project is based on the redesign of the remaining architectural structures—such as the stone walls—and the incorporation of new architectural features, perfectly integrated into the terraced landscape. Furthermore, we report on a pilot action carried out by local stakeholders on a sloped area severely damaged by a fire and storms.

4.1. Redesigning the Cultural Landscape for Climate Change Adaptation

This proposal focuses on the recovery and reinterpretation of the cultural landscapes on the small Mediterranean mountain islands. The primary aim is to provide local stakeholders with knowledge to develop strategies and actions that optimize the management of the natural and cultural capital. This will be achieved through the application of ecological design principles, the transfer of technical–scientific knowledge for the restoration or reconstruction of the cultural landscapes—primarily terraced areas—and the enhancement of local agrifood chains. Additionally, the project aims to develop local skills to combat land desertification and the degradation of landscape mosaics on islands by improving the resilience and multifunctionality of agroforestry systems. Stromboli's ancient cultivated landscape is marked by dry stone walls. Approaching the island from the sea reveals a landscape composed of terraces planted with capers and centuries-old olive trees (the plantation of olive trees has been systematically practiced since the late XVIII century on the island), supported by either dry stone walls or stone lunettes. The terraces are sustained by dry stone walls built with volcanic stones, locally known as "living stone" (Figure 4). The traditionally built stone lunettes, constructed from porous "dead stone", capture moisture from the air and release humidity at night, acting as microclimate control devices (see Section 3.2.1). These slow-release structures once controlled the natural wilderness, preventing the encroachment of the Mediterranean "silva". Today, however, the landscape is largely unmanaged and uncultivated, with fragmented land ownership and abandoned olive trees, left unharvested and affected by a number of fire episodes. To return to a water regulation system on the terraced slopes, for Stromboli, a rainwater harvesting system has been proposed to reduce stormwater runoff from uphill and solve the drainage and erosion problems. To address this, the system that we propose for Stromboli can store a large amount of rainwater and could be suitable for climates where rainfall occurs with infrequent, larger storm events (as in recent times) [35]. We use the terraces located upstream as roofs or gently draining surfaces to improve the water collection feasibility (eventually using nonwoven materials or geomats) and driving the water into large-capacity reservoirs. Local stones will be used to pave the slopes, creating runways that direct rainwater into collection areas. Rainwater tanks could be selected in various sizes and materials: we propose to use 5000 to 10,000 liters. The retaining stone walls surround the cisterns, integrating the cylinder-like shape into the preexisting landscape. In particular, these cylinder-shaped reservoirs will be "masked" by stone lunettes, similar to those that currently retain the ancient olive trees (Figures 4 and 5). The frequency of the tanks along the terraced landscape of Stromboli could be organized so as not to overlap with the catchment areas, preferably using the parts with reduced slopes (where the terraces are not so frequent). Constellations of four to six tanks could be arranged within a sequence, with different ones covering the other wall terraces. Water can be distributed from the tanks by gravity or by mobile pumping systems (often supplied by firefighters) to provide pressurized rainwater (eventually connecting to an inground irrigation system). Additionally, the stored water may serve as a resource for firefighting, as the risk of fires has increased due to the abandonment of the land.

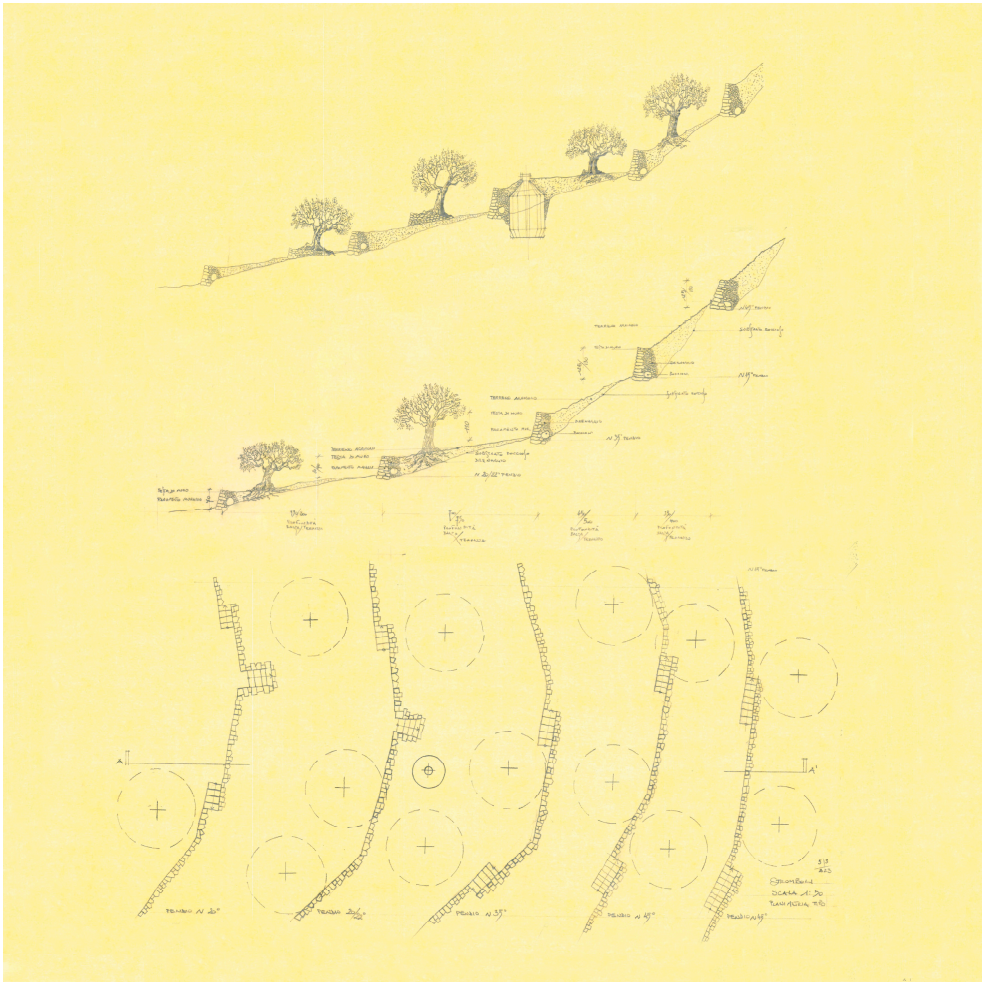

Figure 4. Plan for the project for the recovery of the dry wall structures on the sloped land of Stromboli and the positioning of the water harvesting devices in the terraces. The handwritten text in the drawing outlines the main technical characteristics of the project (scale 1:50). For slopes >35°–45°< (top, right): stonewall header, 125–130 cm; terrace width, 350–500 cm. For slopes >20°–35°< (bottom, left): stonewall header, 70–90 cm; terrace width, 700–800 cm (credit, F.V.C.).

These reservoirs will collect water during the autumn–winter months, which can then be used for irrigation during the spring–summer season, particularly if the olive groves are revived for quality olive production. It has been reported that the importance of irrigation will increase in the future as a climate change adaptation strategy, particularly in olive cultivation [88], with water availability being a crucial productive input to enhance the yields, as well as the trees' physiological processes like photosynthesis and the olives' quality attributes. By designing water reserve devices, it would be possible to optimize the crop's water use efficiency and irrigation techniques. Based on the mean annual rainfall measured in the Aeolian archipelago, although traditional olive cultivation is still essentially conducted under rainfed conditions, the interception capacity of the designed tanks could support emergency irrigation for higher olive quality and to provide a water supply for newly planted olive trees or forest trees, increasing the extent of agroforestry. This opportunity represents an innovation arising from the recovery of traditional knowledge. By focusing on the olive-based landscape, this project will also promote the *in situ* conservation of the local olive genetic resources and support traditional landscape management, emphasizing the integrative value of agroforestry. The redesign of the damaged terraced land patches serves as a pilot project within a broader strategy for the control of soil erosion through agroforestry and ecological restoration. The innovative approach to these technologies, which consists, paradoxically, of rediscovering forgotten traditions, will significantly

reduce soil surface runoff, particularly in vineyards and olive groves on drought-prone slopes in the Mediterranean region. Field-based studies are exploring resilience actions that involve family farms, aiming to inform policies that target smallholders and define best practices. These actions are currently underway, as depicted in the drawings below (Figures 4 and 5), which illustrate the project's current state.

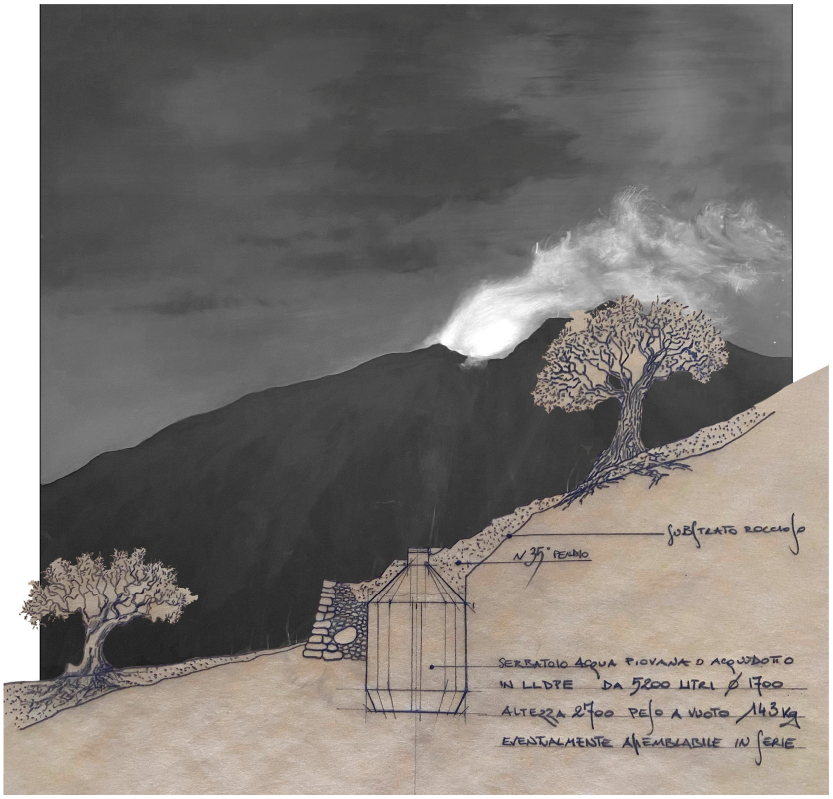

Figure 5. Section of the water harvesting device integrated into terraces dedicated to olive cultivation. The handwritten text in the drawing outlines the main technical characteristics of a rainwater tank installed on a 35° slope over a rocky substrate. The tank is constructed from LLPDE (linear low-density polyethylene) and has a capacity of 5200 liters (diameter 170 cm, height 270 cm; empty weight 143 kg). It can possibly be assembled in series. The design also features the volcano in the background (credit, F.V.C.).

The architectural approach to the restoration and cultural development of Stromboli Island could be considered as part of the rebuilding of the cultural landscape. It takes into account the concept of "cultural heritage", which represents a community's memory of the past and its knowledge, skills, and values. Cultural heritage is intertwined with everyday life, shaping the experiences of the people within it—the community, stakeholders, policymakers, and professionals participate in a collaborative project. The local community, including property owners, local administration, associations, and residents, has the dual role of being responsible and active in achieving common goals. In this context, we propose a pilot action plan carried out by local actors for a site-specific landscape restoration intervention.

4.2. Nature-Based Solution for Wildfire and Water Runoff Containment: A Pilot Action

To counteract the abandonment of cropland, rewilding, and the decline in agricultural yields due to climate change, it is essential to adopt land conservation strategies that preserve the multifunctionality of agricultural and agroforestry systems. These strategies must also maintain the cultural heritage that is intimately linked to the landscape or, in cases of degradation, facilitate its restoration and re-functionalization.

A noteworthy pilot intervention has been carried out on the island of Stromboli by a local voluntary association [89], aiming to restore a one-hectare (0.7 hectares) sloped area in the Piscità locality, severely affected by a wildfire and subsequent storm in 2022 (Figure 6). In particular, the intervention aimed to recover depleted ecosystem services in a injured sloped land surface by promoting the co-occurrence of better water infiltration, soil stabilization, biodiversity, and ecosystem conservation. The intervention, detailed in the association's updates, was based on the revival of traditional ecological knowledge and sustainable forestry engineering practices, making use of the local biodiversity to re-establish ecological balance. The key steps of the pilot action were as follows.

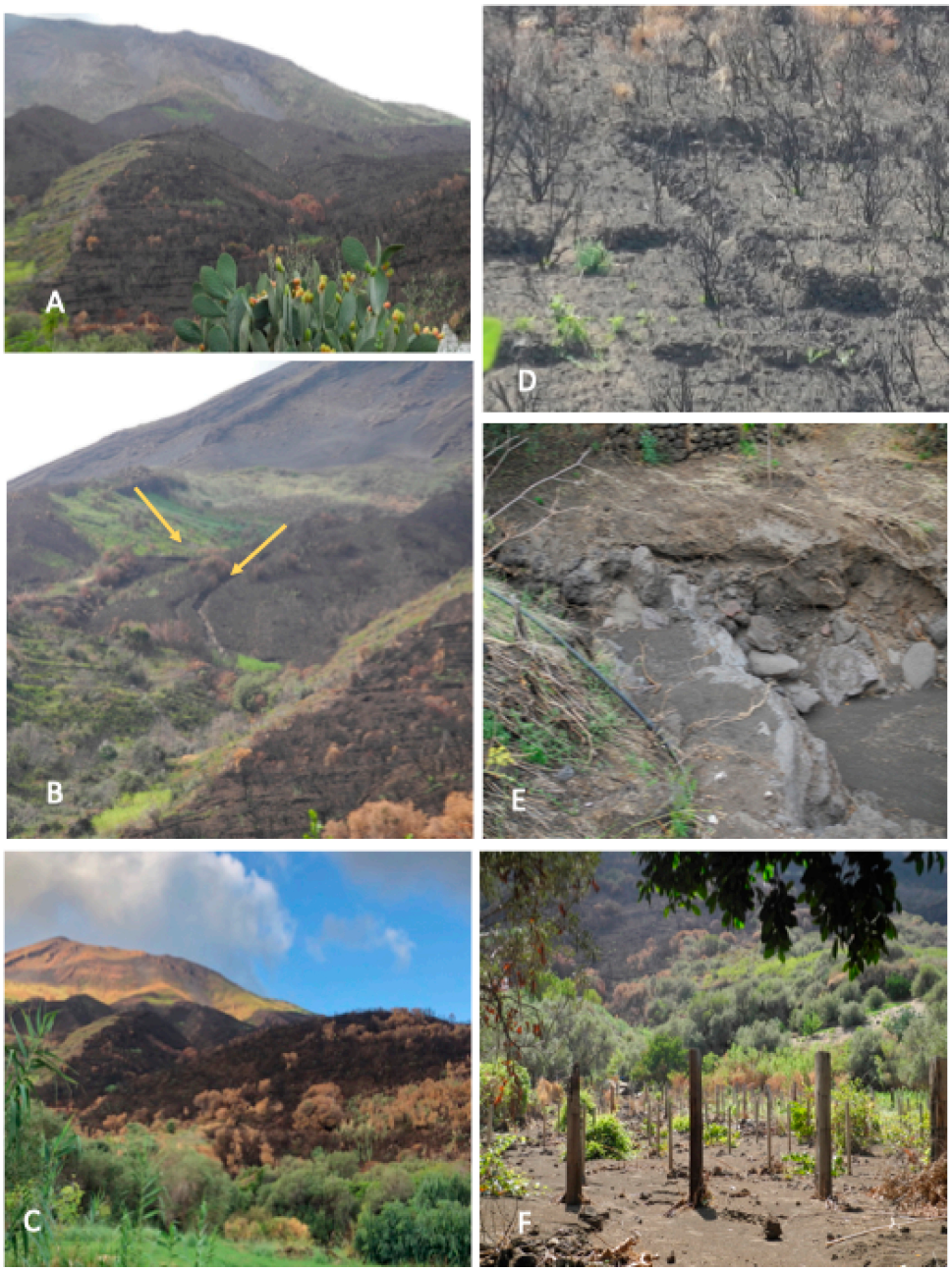

Figure 6. Effects of the uncontrolled fire and water runoff on the landscape mosaic of the piedmont belt of the Stromboli volcano. (**A**) The extension of the burned area; (**B**) natural runoff streams (arrows); (**C**) details of damaged olive crops; (**D**) effects of fire on abandoned terraces; (**E**) superficial soil erosion; (**F**) flooding of the vineyards in the downstream area (credit, R.B.).

- Surface Cleaning: The first step involved thoroughly clearing the surface area, removing debris and damaged vegetation caused by the fire and storm. This was critical to prepare the land for subsequent restoration actions.
- Restoration of Dry Stone Walls: Dry stone walls, a traditional feature of the island's terraced landscapes, were either repaired or rebuilt. These walls are vital in controlling soil erosion and supporting the terraces where agricultural activities, such as olive and caper cultivation, take place.
- Recovery of Ancient Olive Trees: The existing ancient olive trees, an integral part of the island's agricultural heritage, were carefully recovered through reshaping and pruning. Olive trees have deep cultural and economic significance and play a role in maintaining the island's biodiversity and soil stability.
- Construction of "Fascina" Barriers: Using traditional forestry techniques, "fascina" barriers—bundles of branches and low-flammability biomass (e.g., prickly pears cladodes) tied together—were constructed to reduce surface runoff and prevent further soil erosion. This method not only stabilizes the soil but also enhances water infiltration and protects newly planted vegetation.
- New Plantations: New olive trees and caper plants were introduced to replace those lost in the fire. These species are well adapted to the island's climate and are significant for both local agriculture and the preservation of the cultural landscape.

This restoration intervention (Figure 7) may serve as a model for other areas affected by land degradation, highlighting the importance of merging traditional ecological knowledge with modern conservation efforts, based on an holistic approach.

Figure 7. Landscape redesign for water runoff prevention: (**A**,**B**) "fascine" strips realized with wooden pegs that retain dead biomass; (**C**) fireproof biomass, such as *Opuntia ficus-indica* cladodes; (**D**) caper plants reintroduced on the restored slopes; (**E**) traditional employment of prickly pears as a multifunctional fruiting barrier (credit, S.B.C.).

In particular, the sloped land's stabilization has provided conditions for the functionalization and reintroduction of Stromboli's traditional crops, e.g., the specialized olive cultivation and the olive-based "coltura promiscua". The employment of the species *Opuntia ficus-indica* was coherent with the indication that prickly pears can accelerate the natural regeneration of Mediterranean woody species in areas under desertification [*69*].

Fifty ancient olive trees have been recovered through pruning interventions, aiming to regenerate a healthy and performing crown (Figure 8); in particular, stable yield production has been achieved, in accordance with recent indications [90]. New propagation materials have been employed to increase the local olive oil (EVO) production through the organized cultivation of more than 100 new trees and the acquisition of a micro-oil mill (Oliomio 80 Mori) for the common use of all of the Stromboli families involved in olive cropping.

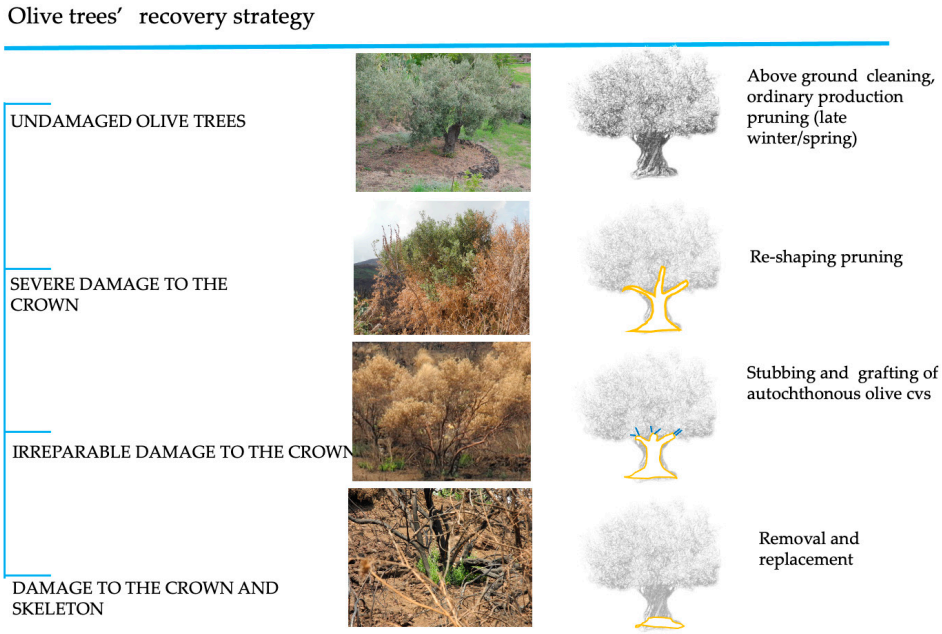

Figure 8. Schematic representation of different types of crown and skeleton management for olive trees' vegetative and productive growth recovery after damage (credit, R.B.).

In light of the increased frequency of storms and eruptive phenomena (e.g., those that occurred in July 2024), which have resulted in the formation of slabs of compressed sand in the upper part of the mountain, causing rainwater to slide rapidly over the surface and accelerate its descent into and outside of the torrents, infrastructural interventions such as the restoration of stream outlets and the construction of expansion tanks are necessary, alongside agricultural reorganization.

The described pilot action represents a short-term climate change adaptation strategy. Although designed for a specific site, it has the potential to be applied on a broader landscape scale, such as the Stromboli piedmont urban belt. In particular, this landscape reorganization could be extended to 100 hectares in the piedmont area, building a containment strip up to the altitude of 200 m a.s.l.

By enhancing the regulatory ecosystem services—including rainfall interception, reduced water runoff, and minimized soil erosion—alongside promoting cultural services that preserve the island's agricultural and agrifood heritage, as well as provisional services (e.g., high-quality olive crops, olive oil, and capers), this project exemplifies a bottom-up approach to integrated landscape management. A long-term adaptation strategy should be collaboratively developed by local stakeholders and decision-makers to prepare for a warmer, drier future with altered precipitation patterns. Such a strategy would rely on co-occurring ecosystem services and increased stakeholder awareness of their value. This can be achieved through tools such as Living Labs, which are based on scientific projects with high levels of stakeholder involvement. The goal is to co-design innovative actions, prioritize intervention areas, and enhance local knowledge through systematic monitoring. In addition, these long-term strategies could encourage sustainable ecotourism, particularly when the small islands within an archipelago are connected and promoted together [91], where the landscape becomes a key component of the local products. The quantification of the derived ecosystem services (ecological, cultural, economic) could lead

to appropriate territorial management plans, and this challenge will be addressed during the future development of the proposed approach.

Islands, by their nature, present unique challenges for environmental conservation due to their rich biodiversity and frequent designation as protected areas. However, islands also embody distinct socioeconomic contexts, highlighting the need for policies that foster "inclusive islands" through the principles of efficiency and equity. These principles are essential to promoting both competitiveness and territorial cohesion, transforming the islands' diversity into a valuable opportunity for sustainable growth.

5. Conclusions

The land use of the small Mediterranean islands has historically been based on the systemic exploitation and regeneration of environmental resources for agricultural production, at least until the last century. With the rise in competitive activities, land and landscape transformation became driven by predatory mass tourism. The abandonment of holistic environmental management, which was essential in the past for local agrifood production, has led to ecosystem simplification and fragility, habitat and biodiversity loss, soil erosion, and the depletion of the soil's functionality. As a result, there is a need to identify management practices that conserve water, reduce soil loss, and prevent agrobiodiversity simplification. Changes in land use, based on the recovery and reinterpretation of the previous, now-abandoned land management through an integrated landscape design project, could contribute to the resilience of the biocultural landscapes of endangered small Mediterranean islands, if promoted by local stakeholders through participatory phenomena to implement multidisciplinary approaches. This multidisciplinary approach, involving architects, landscape agronomists, and environmental economists, characterizes this proposed landscape restoration project for the island of Stromboli, aiming to reinstate the traditional water management and agriculture for landscape resilience. It is an integrated design that aims to establish a relationship between beauty, functionality, and economic profitability. This regeneration occurs by reconnecting fragmented parts of the landscape and respecting the inherited elements while integrating new design approaches in the context of small islands. Our goal was also to indicate strategies for the support of ecotourism. A mass tourism-based economy is not a long-term solution for sustainable development, especially in the face of climate change. The recent COVID-19 pandemic underscored the limitations and vulnerabilities of such economies, leading us to focus on an agricultural landscape proposal—traditional in concept but modern in execution. This project fosters subsidiarity and develops territorial expertise, transforming challenges into opportunities, with Stromboli serving as an example for other marginal islands across the Mediterranean. Olive-based agricultural systems on shallow soils and steep terraces provide essential ecosystem services, including support for local economies. In particular, agroforestry systems, representing extensive agricultural models, can preserve the natural capital and local agricultural identities with low production input requirements. However, the feasibility of an integrated landscape management approach is limited by the fragmented land ownership typical of small islands and by the lack of active farmers. This challenge, however, can be overcome through increased awareness among local stakeholders, not only of the importance of restoring ecosystem services but also of their potential role in the recovery process. Lastly, encouraging stronger engagement from actors, stakeholders, and research institutions in co-design and participatory actions aimed at ecosystem restoration could be a vital strategy in addressing future climate constraints. Given the ongoing extreme weather events impacting many Mediterranean islands, including those known worldwide, e.g., Ischia, Capri, and Procida, it is essential to set strong examples of holistic land management approaches, even if limited in scale.

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