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# Revitalization Potential of Marginal Areas for Sustainable Rural Development in the Puglia Region, Southern Italy: Part I: A Review

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**Abstract:** Feeding nine billion people by 2050 will be a challenge due to climate change. There is a significant portion of abandoned and unused marginal lands across the nation and in the Puglia region, in Southern Italy. Innovative techniques and practices in the frame of climate-smart agriculture can help rehabilitate marginal lands into productive and profitable areas. The objective of this study was to systematically review the literature on marginal areas in Puglia, responding to the lack of information in this context and evaluate their revitalization potential. We systematically reviewed the literature on unused/marginal areas and identified related studies dealing with different types of marginal areas and their potential for sustainable rural development. Marginal areas in Puglia represent a range of historical rural landscapes that support biodiversity, the economy, and ecological services. However, the analysis of the current situation in Puglia's marginal areas indicates a lack of infrastructure and scarce resources, which led to land abandonment and the migration of local residents, resulting in the deterioration of the ecological system. Therefore, establishing a sustainable policy is crucial for preserving the local heritage and economy of the region. However, policymakers should carefully study the challenges and opportunities arising from local contexts before embarking on ambitious place-based innovation strategies. The analysis indicates that both biophysical and socio-economic factors are strategic elements for improving the revitalization potential of marginal areas for sustainable development. This review provides useful information regarding the revitalization potential of marginal areas for food, feed, and non-food production, which is crucial in the implementation of a sustainable development strategy for rural communities in Puglia but can also be applied to similar areas in other countries. However, the success of the sustainable development strategy in Puglia's marginal areas should consider the vital function of farmers' self-organization and social capital as key factors in the adoption of agricultural innovations for the revitalization of these areas.

**Keywords:** regional development; abandoned lands; land use planning; regional policy; land management; brownfields

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## 1. Introduction

In Italy, 22 different Rural Development Programmes (RDPs) have been established to tackle rural development challenges. These RDPs include one at the national level and 21 at the regional level, categorized as "less developed", "transition", and "more developed" regions. The National Rural Network Program provides funding for the networking of Italian actors involved in rural development. Because the Puglia region (Southeastern Italy) is classified as one of the regions lagging behind [1], the European Commission's report listed the priorities of the Puglia region (Southeastern Italy), which allocated over EUR two billion for Puglia's RDP between 2014 and 2022 [2]. This RDP focuses on enhancing agricultural competitiveness and maintaining, restoring, and upgrading forestry and agricultural ecosystems, with each receiving around one-third of the region's funding resources [3,4]. In this frame, the regional budget anticipates supporting over 3700 farmers to restructure or modernize their farms and granting business start-up aid to 2000 young farmers [5]. Additionally, investments will be encouraged by activating one specific guarantee fund that will support investments for the restructuring or modernization of agricultural systems, processing and marketing of agricultural products, and the creation and development of non-agricultural activities [6]. In this regard, approximately 30% of agricultural land will be subject to management agreements targeting sustainable development, and focusing mainly on aspects of achieving biodiversity, improving water management, and addressing soil erosion and/or management, which will result in the revitalization of marginal and deteriorated lands. In this context, this review provides insights into the current situation, contributing to the national efforts for the reactivation of a large portion of unused lands in the Puglia region as part of the national RDP titled "National Recovery and Resilience Plan (PNRR)", specifically spoke seven, "Integrated models for the development of marginal areas to promote multifunctional production systems enhancing agro-ecological and socio-economic sustainability", aiming at the revitalization of marginal areas. The project tasks include developing multifunctional production systems, integrated models to develop marginal areas and technological solutions, and the study of the social impact of marginal lands for their activation as alternative production sites considering possible conflicts with competing land use strategies, e.g., food production or nature conservation.

The author's motivation for writing this review was due to the large percentage of marginal lands in Puglia that are difficult to cultivate due to various obstacles. Furthermore, the lack of studies identifying the different types of marginal areas and the absence of review papers inspired the authors to undertake this review. During the writing of this review, the authors tried to answer the following questions: could the actual situation of MAs in the Puglia region be improved in terms of food/non-food production for sustainable rural development? And to what extent can national/regional policies help to revitalize MAs in the region?

The authors believe that the information provided in this review can participate in the efforts to revitalize marginal lands in the region and draw the attention of local authorities, researchers, and decision-makers to make a significant portion of abandoned land in Puglia productive in the future, thereby contributing significantly to the regional economy.

## 2. Identification and Classification of Different Marginal Area Types in Puglia

The definition of an area as marginal is complex and often not explicit. In fact, there is no definition of the marginality of land and its use in agriculture or forestry in the Common Agricultural Policy (CAP) [7] to determine which kind of land falls into this category [8]. Often, the definition of the marginal area might not be limited to the biophysical quality of the land and, as adopted in Europe, can be defined as an area where cost-effective production is not possible under given site conditions (e.g., soil fertility), cultivation techniques, agriculture policies, and legal conditions [9,10]. The wider term of marginality is a multidimensional phenomenon often driven by several interlinked environmental and socio-economic factors. Therefore, the concept of marginal land and its applications can differ depending on the region, country, and organization (Kang et al.) [11]. The authors explain that the terms physical marginal lands, production marginal lands, and economic marginal land are used in different contexts and with varying concerns. This means that marginal lands can refer not only to areas with low production levels, but also to those with limitations that make them unsuitable for agriculture and ecosystem function. While in Europe, land was considered marginal from an economic standpoint, the global definition of marginal land is more expanded to include social and environmental factors, e.g., soil health and topography, and extreme weather events, e.g., flood and arid areas. Therefore, assessing land quality and ensuring its appropriate, sustainable, economical, and efficient use is crucially important, especially regarding feedstock production in marginal or abandoned land [12]. It is opportune, however, to bear in mind that the classification of a site as "marginal" in one place or for one purpose may not necessarily mean that the land is unproductive for all purposes or in all places because its productivity may vary depending on the context and usage [13]. The following subsections will provide an overview of the different marginal areas in the Puglia region and their rejuvenation potential.

### 2.1. Mountain Areas

In Italy, municipalities are classified as totally mountainous, partially mountainous, or non-mountainous based on a legislative system (L.991/52 and L. 657/57) [14]. The majority of Italian mountainous regions suffer from land property fragmentation, infrastructure deficiency, and land abandonment, resulting in unused land and forgotten 'terraces' that were previously cultivated [15–17]. However, the European Association for Mountain Areas (EAMA) recognizes the importance of mountain agriculture, which accounts for 15% of the agricultural utilized area and agricultural workforce in Europe [18]. In Italy, approximately 6% of the population in mountain areas are employed in agriculture, according to the International Trade Administration [19]. From an agronomical point of view, mountain areas are not suitable for grain production, as these are not suited for mechanical agricultural practices [20]. However, some mountain areas are more suitable for fruit trees cultivation and/or other non-food production such as bioenergy crops. Typically, mountain farming is made up of small farms with low input and output systems; however, they produce high-quality foodstuff and various products and services, especially when linked to the tourism industry [17]. Therefore, it is essential to consider socio-economic and environmental factors, particularly in the most marginal mountainous regions, to support development projects and innovative land consolidation policies [14]. The depopulation and land abandonment of Italy's mountain regions since the 19th century have resulted in problematic or underdeveloped areas from an economic development standpoint [21,22]. Such abandonment has led to biodiversity loss, increased fire frequency and intensity, soil erosion and desertification, loss of cultural and aesthetic values, reduced landscape diversity, and reduced water provision [23]. Therefore, future political rural development strategies should prioritize supporting agricultural activities in mountain areas, especially for local farmers operating in mountain/marginal areas, to mitigate depopulation and land abandonment. Such support would ensure a decent income for small-scale/family farms while maintaining productivity and conserving biodiversity. By attracting visitors, mountain areas offer a sustainable development strategy according to Romeo et al. [24]. In fact, the Arouca Declaration (2011) states that tourism can sustain and enhance the identity of a territory, taking into consideration its geology, environment, culture, aesthetics, heritage, and the well-being of its residents [25]. In Slovenia's mountain regions, Trček and Koderman [26] found that sustainable tourism was an important development policy suitable for the conservation of protected mountainous natural and cultural landscapes facing intense depopulation and loss of agricultural land. In Puglia (below Figure 1A), although the region has fewer mountains compared to other regions, there are still areas lacking proper political reform that would help revitalize their development potential. According to the classification mentioned above, the mountainous areas in Puglia can be divided into partially mountainous areas (such as Murgia in central west Puglia, Daunia Mountains in northwest Puglia, and some parts of the Gargano area in northeast Puglia) and totally mountainous areas (a significant portion of Daunia Mountains and Gargano). These areas cover nearly 50% of the regional territory, while the rest of the territory is classified as non-mountainous or plains areas (Figure 1B).

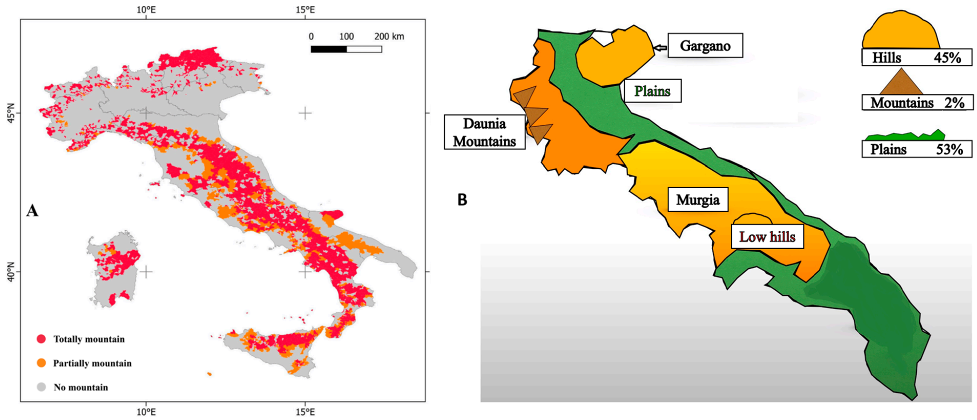


**Figure 1.** Maps showing the distribution of mountain zones and classification in (**A**) Italian (adopted from Godone et al. [14], and (**B**) the Puglia region.

In the following, we provide a brief description of the three Puglia uplands, their agriculture constraints, and their development potential.

- The Daunia Mountains, also known as the Apennines Mountains, cover approximately 1884.8 km$^2$ in the northwestern region of Puglia [27]. This area boasts elevations up to 1151 m above sea level with the highest peak being Monte Cornacchia [28]. The Daunia Mountains consist of four landscape units: Lower Fortore Valley, Mid Fortore Valley and Occhito Dam, Northern Daunia Mountains, and Southern Daunia Mountains [4]. Both the northern and southern parts of the mountains are covered with vegetation such as woodland, pasture, and uncultivated land (Figure 2), accounting for about 37,000 ha [29]. Agriculture and forestry are the main land uses [30], and farms make up 57.7% of the entire territory [28]. Agriculture land consists of forage and cereals cultivation (54%), olive orchards (4.3%), vegetables (2%), and other permanent crops (0.7%) [29]. However, rainfall-induced landslides in the area threatened agricultural activities [27,31,32], limiting the area's development perspectives [31]. Despite the expansion process of inhabited areas and the realization of infrastructures during the last 50 years [31], the area has experienced a significant decrease in population [28,33] due to social and economic problems related to the landslide's phenomena [34,35]. Therefore, the characteristics of the Apennines Mountain areas need to be thoroughly analysed to understand the local agricultural system in order to enhance multifunctional agriculture that would improve the socio-economic situation of the area [28] and overcome challenges related to the occurrence of mudslides as a result of working the soil by farmers for agricultural activities [31].

**Figure 2.** A landscape view from the Daunia Mountains of Puglia (Southern Italy).

- The Murgia area, also known as 'le Murge' in Italian, is situated in the centre of the Puglia region [25]. The rural area of Alta Murgia, which is the highest plateau in the Murgia area, contains Italy's first National Rural Park (approximately 68 ha), created in 2004 [36], and boasts numerous significant historical, archaeological, and paleontological sites [4]. Agriculture in Murgia was limited to flat valleys and depression bottoms where fertile soil had accumulated. The barren karst areas outside of these agricultural zones were unsuitable for cultivation due to an abundance of rocks and were used for grazing instead. Traditional agricultural practices in Murgia involved slope terracing and building dry stone walls with an intangible heritage value to humanity (below Figure 3). However, the abandonment of these techniques has led to the deterioration of the rural landscape, and bulldozers and other machinery are now used to remove/grind rocks from fields. These rocks are often dumped into swallets and caves, further damaging the fragile equilibrium of the karst systems [37]. When discussing sustainability in the Murgia area, it is vital to consider not only the park itself but also the areas surrounding the park perimeter, which are essential for safeguarding specific natural environments and local wildlife species. This helps to maintain continuous ecological corridors for flora and fauna, as outlined in the Park Action Plan [38]. To revitalize the area, it is critical that local residents, associations, and political stakeholders collaborate to discuss their various socio-political visions for the area's future. This must include preserving the natural, historical, and architectural heritage, regenerating and diversifying the local farming industry, establishing a new eco-touristic infrastructure that has a minimal environmental impact, and creating new opportunities in professional sectors related to the agricultural industry, including agronomic research and education, while taking into account sustainability measures.

**Figure 3.** Alta Murgia of Puglia (Southern Italy).

- The Gargano area is a small mountainous promontory protruding into the Southern Adriatic, ranging in height from 400 to 1000 m above sea level, crossed by some low ridges [39]. The maximum elevation is presented by the peaks of Monte Calvo (1055 m above sea level) and Monte Nero (1024 m above sea level). The Gargano landscapes cover an area of 196,000 ha, of which only 14% are urban areas and more than 50% still maintain a medium to high ecological value due to the preservation of seminatural/natural ecosystems (Figure 4) [29,40].

**Figure 4.** The Gargano (San Giovanni rotondo, Puglia).

Agricultural land covers almost 30% of the total Gargano area, mostly forage and cereals (17%), olive orchards (11%), vegetables (0.8%), fruit orchards (0.4%), and vineyards (0.2%). Agricultural activities are mostly practised, typical of marginal lands, in terms of intensive grazing and crop cultivation consisting of non-irrigated crops along with olive groves [29]; Gargano is considered the area with the highest density of olive trees after Salento and the coastal areas of Bari [41]. Intensive agriculture, however, with high-input crops such as vegetables, occurs to a lesser extent, mostly in the plain close to the Lesina and Varano lakes. Recently, land use has completely changed the Gargano landscapes due to rural exodus. Burri et al. [42] conducted a landscape analysis that revealed a significant change in Gargano's agriculture. The traditional farming landscape, which consisted of numerous isolated farms and almost all land being used for cultivation and grazing, has been replaced by a few active farms, extensive grazing, and rural immigration from most areas of Gargano. To ensure the continued economic growth of the Gargano region, it is essential that future agricultural landscape policies focus on preserving natural resources and areas with high ecological value, as well as the landscape's structuring elements. Giordano [40] stresses the importance of local authorities paying attention to establishing vegetation that is in equilibrium with ecological conditions and has a high level of biodiversity, while also preserving existing agricultural practices. To this end, revitalizing the development prospects of the area is crucial.

### *2.2. Internal/Inner Areas*

Geographically located within mountainous areas and far from urban centres [43], inner areas are often characterized by small towns and villages in Italy [44]. These areas face challenges in accessing essential public services, despite playing a vital role in safeguarding the ecosystem and promoting social and economic growth through farming [28]. To address these issues, a National Strategy for Inner Areas (SNAI) was developed in 2012 as a place-based experimental turn in Italian regional policy [45].

The SNAI partnership agreement, covering the 2014–2020 programming period, defines inner areas as territories located at more than 20 minutes' driving distance from essential public services such as education, health, and mobility [46]. A study by Martins and Davino [47] indicates that 60% of the national territory is made up of inner areas and subject to a strong marginalization due to local population decline, ageing, a lack of employment opportunities, and a lack of essential public services. This is why the SNAI policy aims to contribute to the country's economic and social recovery by creating jobs, fostering social inclusion, and reversing the demographic decline of inner areas, in terms of both population size and ageing [48]. According to the Territorial Cohesion Agency [49], about 43% of the Italian territory is classified as internal areas (Figure 5) (only 39% of these areas are cultivated).

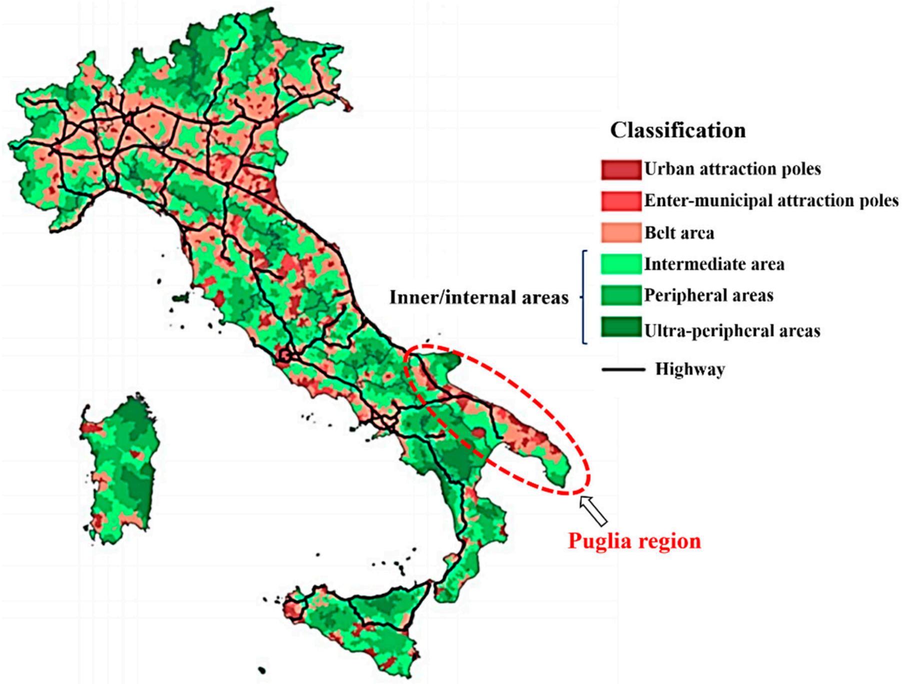


**Figure 5.** Classification map of the Italian inner areas including Puglia region (source: TCA [49]).

In Puglia, however, inner areas make up 51.4% of the regional territory and approximately 1,017,709 people reside in these areas [49]. The SNAI framework has divided the Puglia region into four inner areas: Monti Dauni, South Salento, Gargano, and Murgia. These areas are known for their rich natural biodiversity, which has led to the growth and development of diverse agricultural products [45]. Internal/Inner areas are, in fact, suitable for a wide range of crop production including cereals. In Italy, the National Partnership Agreement (NPA) on inner areas in Italy [45] highlighted that the reduction of the territory intended for agricultural use within inner areas was due to an increase in the surface area covered by forests. If we then consider the 'forest' category, which represents the production base of the national forest, wood, and energy supply chain, over 80% is located in internal areas alone. Although some inner areas have the basics for crop production such as an irrigation water/irrigation system, the reason behind the consideration of inner/internal areas as marginal in Italy is related to socio-economic constraints such as poor infrastructure, unfavourable output/input ratios, inadequate support for agriculture, lack of institutional framework, high cost of rehabilitation, lack of investment, competition for land from other sectors, market and credit facilities, population density, remoteness, and rent paid/low land prices. To face marginalization and depopulation, the SNAI proposes two sets of actions. The first focuses on strengthening essential public services and developing preconditions for socio-economic growth. The second suggests promoting local development projects to revitalize the different areas [45,50]. Additionally, the National Strategy for Inner Areas [45] emphasizes the importance of long-term structural actions to enhance resources and prevent disasters. Development policies and strategies must also consider detailed knowledge of heritage, available resources, and potential risks, followed by agriculture planning aimed at protecting the territory and enhancing local supply chains for food, non-food products, and biomass for energy purposes. This can also provide ecosystem services like carbon sequestration, water purification, and biodiversity, which may be promotable in a green economy process [51].

### *2.3. Valleys*

Geologically, a valley is a long and low area of land between hills or mountains that is typically formed by the erosion of a stream [52]. This subsection will provide a brief overview of the most significant valleys located in the Puglia region, as most of these areas are categorized within mountainous and/or inner areas. The first important valley in Puglia is the Basentello Valley, which is situated on the border between the Puglia and Basilicata regions (Figure 6). Archaeological evidence, particularly at San Felice and Vagnari sites in Gravina in Puglia town, suggests that agricultural activities have been taking place in the valley since Roman times or even earlier [53].

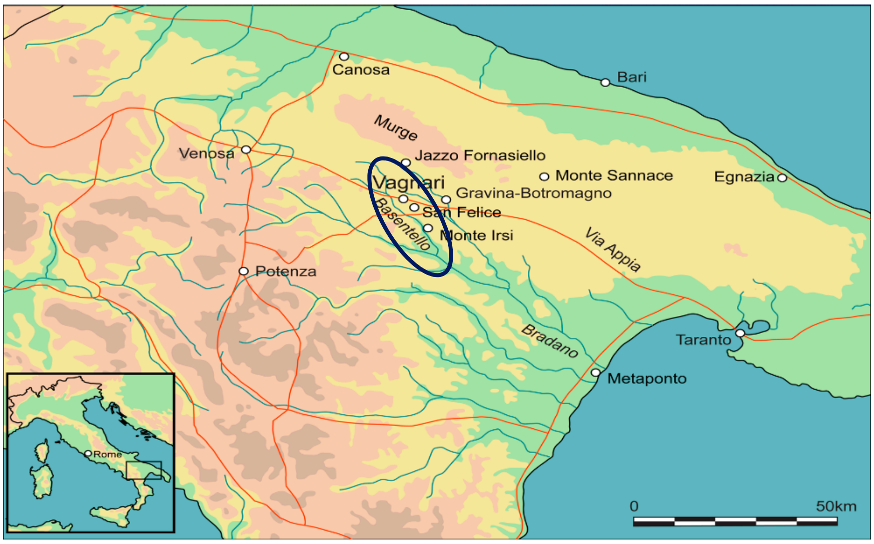


**Figure 6.** Map of Southeast Italy (Puglia) showing the location of Basentello Valley (in the circle) (Source: Trentacoste et al. [54]).

The valley has mainly been used for cereal agriculture, viticulture, olive tree cultivation, harvesting of native plants, and herding of cattle [55]. According to Wigand and McCallum [56], the hilltop areas in the valley, which are usually composed of sandy or sandy-silt soils, have been affected by agricultural activities but are not as sensitive to erosion as the valley slopes or terraces. Considering the soil texture of the valley, the authors noted that the main problem with agricultural land use was related to the additional impact of people, their farming practices, and animals, which might accelerate and increase the rate of landscape change. In particular, improper farming practices such as intensive tillage and grazing at a time when climates are drying, have led to the destruction of the native vegetation in the valley areas, leading to sediment moving down the steep slopes and exposing marine marl/clays to erosion, thereby accelerating erosion and halting soil formation processes. Therefore, revitalization efforts in the area for agricultural purposes should include site-specific techniques such as terrace planting/farming (back to the past) and practices like no-tillage farming to overcome soil erosion problems and improve soil productivity.

The Itria Valley (Valle D'Itria), located on the Murgia plateau in the Puglia region (Figure 7), boasts a breathtakingly beautiful and traditional landscape. Making a good example from the participatory approach, different stakeholders in the valley came to the fact that valuing and protecting the landscape requires acknowledging the appeal it holds. By understanding the area and identifying its strengths and weaknesses, a comprehensive plan was developed to enhance the valley's landscapes [57] in the frame of a sustainable development process. The plan was based on a well-organized and integrated network of cultural and environmental assets, and local private and public actors. Ciola and Tanzarella [58] conducted a test on the integrated management of environmental and cultural heritage in the valley using SAC—Environmental and Cultural System, also known as "trulli". The findings suggest that the creation of networks and the integration of assets and actors have contributed to the advancement of sustainable development and tourism in both tangible and intangible aspects. This includes the aesthetic elements of the countryside, the architectural and historical heritage across the region, the quality of food and wine produced through traditional low-intensity agriculture, and the quality of life as well as the experience of residing in traditional dry stone houses known as 'trulli' scattered throughout an exquisitely beautiful and well-organized landscape


**Figure 7.** Location of Vally d'Itria, Southern Italy.

## *2.4. Saline Soil Zones*

Around 20% of the world's agricultural lands and half of the irrigated regions are affected by salinity [59], impacting approximately 400 million hectares of land [60]. Mazhar et al. [61] indicate that seawater intrusion and human activities are the primary causes of soil salinization, poor soil permeability, nutrient shortages, reduced vegetation coverage, and restricted land use efficiency in the coastal zones. However, once remediated and treated, coastal saline–alkali soils can become valuable resources for food production and afforestation. There is a significant amount of abandoned and low-yielding saltwater land in the world's coastline zone. In Italy, which is one of Europe's most salt-affected countries, soil salinization accounts for 3.2 Mha, and it is prevalent in practically all areas to different degrees, as reported by Salvati and Ferrara [62] and Dazzi and Lo Papa [63]. Salinization is a major source of soil deterioration in the Mediterranean region, and Italy is considered a hotspot for land degradation and desertification. Recent case studies have shown that soil salinization is still increasing, especially in Southern Italy (e.g., Puglia region) (Figure 8), where over-exploitation of irrigation water due to crop intensification and food production has occurred in the past twenty years [64].

Soils with high salt concentrations are unstable, have a low infiltration rate, and a lower water-holding capacity. These soils have low organic matter, low biodiversity, and a stressed microbial community. Plants living in saline environments experience osmotic stress, lack of nutrients, and toxicities, resulting in ionic imbalances [65]. The saline zones will become uncultivable if the salinity problem is not addressed. As a result, finding answers to this challenge is critical. Several agronomic strategies for reactivating saline soils for agricultural productivity, environmental services, and economic growth of these zones have been presented. Leaching of salts from the topsoil to lower depths down below the root zone is a simple and traditional method of saline soil remediation [66]. Leaching is cost-intensive and dependent on the availability of water and a proper drainage system as well, as it reduces the total nitrogen (TN) and total organic carbon (TOC), microbial activity, and soil fertility. In this regard, Phyto-desalinization or phytoremediation can be a promising alternative, where salt-tolerant plants (Halophytes) offer significant interest as they are naturally found in saline environments and have wide applicability. Hussain et al. [67] reported that high-yielding salt-tolerant cultivars can be successfully cultivated in saline and marginal arid lands. In addition, they can be used for food, fodder, oil production, pharmaceuticals, and cosmetic purposes. Moreover, organic wastes, such as manure, straw, etc., have been shown to improve leaching during desalinization, soil fertility, and nutrient availability. Therefore, organic farming in saline areas may also be explored as a reclamation strategy. Phyto-desalinization is a slow process; however, it is the most economical, eco-friendly, and sustainable method of all the reclamation techniques [65].

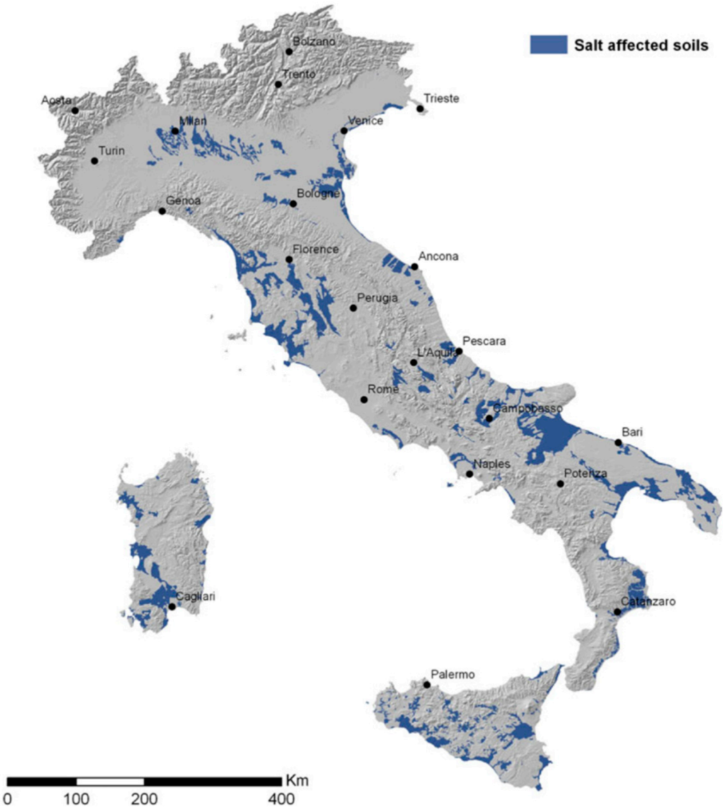


**Figure 8.** Distribution of salt-affected soils in Italy [63].

### 2.5. *Brownfield*

Brownfields are typically found on old industrial sites that have been contaminated by industrial and/or intensive agricultural activities. Generally, pollution phenomena are generated by agricultural activities with high use of pesticides and/or by anthropic activities, such as industrial plants or waste disposal sites [68]. According to the Contaminated Land Rehabilitation Network, brownfields are defined as "sites that have been affected by previous use, are abandoned or underused, may have contamination issues, are typically found in urban areas, and require intervention to be put to good use again" [69]. Even in agriculture, Scordia et al. [70] estimated that at least one heavy metal and/or metalloid (HM&M) contaminates 137,000 km$^2$ of EU agricultural land in concentrations above the limits set for agricultural soils [71]. This land must be remediated before it can be reused for food production to protect both human health and the environment. In this regard, non-food industrial crops have been found to accumulate HM&M in their aerial biomass, thus helping remove toxic elements from the soil [72–75]. About 2.5 million sites in Europe require remediation [76] while in Italy, 39 areas, covering 146,171 hectares, are included in the National Priority List of contaminated sites [77]. Tonin and Bonifaci [69] reported that Italy alone has over 100,000 hectares of contaminated land that need to be restored, posing health risks and threatening water, soil, and air quality. However, if restored, these sites could provide opportunities for economic development, reduce land usage, and preserve biodiversity. To achieve this, the Italian government invested EUR 500 million in 2020 to revitalize contaminated land as part of its "Green Revolution and Ecological Transition" mission. The main goal of this investment is to rehabilitate abandoned industrial sites with unidentifiable polluters and give these "orphaned" sites a new purpose, promoting a circular economy and reintegrating them into the real estate market [78]. In Puglia, Scaffidi [79] investigated the socio-economic and cultural aspects of the reactivation of neglected/marginal areas. In particular, the research analysed brownfield reactivation as an activator of social economies and new benefits for local communities. The author has pointed to the Puglia region as a place where the cultural and social dimensions have been favoured by the local administrations which have invested in processes of reactivation of these resources, entrusting them to the local communities. This is the case where the Bollenti Spiriti Program (established in 2005) has contributed to urban and regional development thanks to the involvement of communities, the creation of social enterprises, and the reactivation of marginal areas [80].

### 2.6. Marginal Arable Lands

Marginal arable lands are areas where farming has been discontinued without being replaced by other activities like urbanization or afforestation. Changes from arable lands to marginal ones occur due to land degradation and can be caused by several biophysical and socio-economic factors such as abandoned agricultural lands [81], afforestation of arable land, and the regeneration of new systems like agro-silvopastoral [82]. Today, researching the processes that drive land use changes is becoming increasingly important [83]. Therefore, it is crucial to identify the factors behind these changes. In Italy, there are limited arable lands that are often fragmented, but there is potential for expansion in both cultivated areas and production. However, traditional agriculture in regions like Puglia, which includes both herbaceous and fruit tree crops grown under rainfed conditions, often results in low economic returns. Rising prices for key inputs like fertilizers, seeds/seedlings, pesticides, and herbicides have exacerbated this situation in recent years [84]. Moreover, in their study, Zavalloni et al. [85] pointed out that some stakeholders have observed how the present process of land abandonment might be a result of the discontinuation of years of support which had encouraged the expansion of agriculture in marginal lands. Other studies have shown that local socio-economic as well as other environmental factors play a crucial role in explaining the conversion pattern of arable land. For example, desertification, caused by climate variations and human activities, is a major cause of agricultural land degradation, which can result in economic losses, social issues, and ecological damage. Canora et al. [86] indicated that a number of southern areas in Italy are threatened by land degradation processes and are at risk of desertification. In some cases, this can lead to land abandonment and the displacement of indigenous people. The assessment of sensitivity to desertification is important to plan relevant actions and to improve the use and management of natural resources.

A number of quantitative studies carried out in southern areas of Italy to assess the sensitivity to desertification showed that a large percentage of areas are at risk of desertification. In Puglia, for example, a study by Ladisa et al. [87] evaluated the areas that are at risk of desertification using a set of indicators that included both socio-economic and environmental factors specific to the region. By integrating these factors into the ESAs (Environmental Sensitive Areas to Desertification) model, they created a comprehensive set of indices on both regional and administrative scales using GIS. Their study on the Vegetation Quality Index revealed that nearly half of the Puglia region (46.1%) has low vegetation quality and is, therefore, at risk of degradation. Moreover, taking into account the physical factors (e.g., soil, climate, and vegetation), their analysis of desertification risk showed that more than half of the Puglia territory (51.7%) is in a critical state, while the risk percentage is increased significantly (80.1%) when considering human-induced factors. At the province level, the physical factors indicate that Taranto is particularly affected, where 80% of the territory is considered critical, followed by the provinces of Lecce, Brindisi, and Bari, where 63%, 59%, and 55%, respectively, of the land is at risk of desertification.

The effect of human-induced factors, however, indicates that the worst situation is in the provinces of Foggia and Brindisi, both with 90% of land classified as critical to desertification, followed by the provinces of Taranto, Lecce, and Bari, where 87, 77, and 60% of the territory is classified as critical to desertification processes, respectively. Bearing in mind this situation, and in order to effectively address land degradation challenges in Puglia, policymakers should consider the diverse responses of landowners to physical and economic factors when devising land use change policies.

### *2.7. Xylella-Infected Areas*

Upon analysing the land use in the Puglia region, it has been found that the region's scenery is mainly composed of century-old olive trees that are spread out among the surrounding farmland or orchards. These are typically associated with family-run agriculture activities, such as small-scale farms [88]. As per the definition adopted by the regional olive-culture development plan "Piano di Sviluppo del Settore Olivicolo" ERSAP (1987), olive-growing lands are considered marginal when they are unsuitable for bringing economic productivity to a level that justifies community investment [89]. These lands may have steep gradients, outcropping rocks, a lack of labour, low value of cultivars, and various difficulties. At present, the analysis of the current situation of olive-growing areas indicates that the majority of these areas are at risk of being further abandoned due to various factors [90]. These include but are not limited to the discontinuation of farmer income aid following the Fischler reform of the Common Agricultural Policy (CAP) [91], the demographic decline, and the ageing of farmers involved in olive cultivation [90]. In addition, the outbreak of the plant quarantine bacterium (*Xylella fastidiosa* subsp. *pauca* (Xfp)) has hastened land abandonment (Figure 9) and its damages such as erosion, fires, over-grazing, and biodiversity losses, impacting the local economy and threatening the olive industry and the symbolic crop and landscape that are typical of the area [92].

**Figure 9.** Xylella-infected field (Gallipoli, Puglia, Southern Italy).

In fact, the Puglia region is defined by its olive trees, which can be found across arable and pastoral land [93]. When it comes to landscape governance, it is common to create new definitions to better understand certain concepts and develop effective strategies and tools for intervention [94]. In this section's introduction, it was stated that land classified as productive in one area may be considered marginal in another. This is evident in the situation of Xfp-infected regions in Puglia, where the outbreak of Xfp occurred in late 2013 [95] due to favourable climate conditions [96] causing significant harm to the olive ecosystems in Puglia [97]. When these agroecosystems are lost, the land becomes unproductive/marginal, leading to unfavourable socio-economic consequences.

Recent scientific evidence indicates that the range of areas infected with Xfp has expanded significantly, resulting in various socio-economic and cultural damages [98–100].

An assessment of the socio-economic impact conducted by Cardone et al. [101] revealed that the spread of Xfp has led to reduced yields, productivity, and profitability, as well as a decline in export opportunities and employment options, counterbalanced by increasing imports. From an environmental point of view, Ali et al. [102] conducted an environmental impact assessment of Xfp in Puglia and found that the loss of olive trees, which are prominent woody plants in the region, has had negative effects on the delivery of crucial ecosystem regulating services. These effects include climate and erosion regulation, natural hazard regulation, and pollination effects. The loss of olive agroecosystems and its related loss of ornamental resources, primary production, cultural heritage, and biodiversity components (genetic diversity, composition, and structure of native habitats) has contributed to the marginalization of a significant part of Puglia's territory. Numerous attempts have been made to control the spread of the Xfp disease. Proposed measures include mandates from both the EU [103] and national governments, as well as techniques such as controlling the Xfp and vector populations [104], plant breeding, and integrated pest management [105]. Other suggested strategies include introducing Xfp-resistant olive cultivars [97] or other fruit tree species [106,107] to prevent the spread of the disease, protect regional landscapes, and minimize economic losses. However, these efforts have faced various challenges such as public resistance to control measures, stakeholder reluctance, misinformation from some media, and insufficient action from certain government authorities [92]. Therefore, biophysical and socio-economic constraints in Xfp-infected areas highlight the need for action by regional authorities to revitalize these areas. Such actions should be based on assessing the magnitude of losses and weighting assigned by different stakeholders.

## 3. Suitability of Different MA Types for Feed, Food, and Non-Food Production

Recent research has shown that progressive climate change is likely to impact crops in many parts of the world, affecting ecosystem services and, therefore, food security [108]. Hence, the search for alternative land sources to overcome these challenges is needed. From the viewpoint of land use planning, identifying suitable locations for crop production in marginal land is important for decision-makers [109]. In Section 1, we identified seven types of marginal areas that make up a significant portion of Puglia's regional territories. This has caught the attention of policymakers in the region because it presents an opportunity to use these areas for agriculture and stimulate the regional economy. To identify areas with particular features, remote sensing technologies, such as geospatial technologies, can be used to determine land that is not suitable for commercial agricultural use due to its biophysical features [110]. Recently, mapping of marginal lands has been frequently conducted across different regions, scales, and methodological approaches (e.g., [12,111]). For example, a recent study by Alhajj Ali et al. [107] used climate and soil data to carry out the land suitability analysis for the cultivation of economically viable fruit tree species within the Xfp-infected olive-growing areas in the Puglia region, considered marginal areas due to social and economic limitations. The authors used combined information for each climate and soil parameter to obtain the overall suitability maps for the six proposed fruit tree crops using GIS (Geographic Information System). Their results were helpful for the selection of the right immune/resistant tree species for replacing olive trees in Xfp-infected zones, providing guidelines within the decision-making process to encourage the planting of some underrepresented fruit tree crops with viable economic value. However, to better understand and classify the different types of marginal areas in Puglia, we need to examine the limitations of current geospatial technologies in determining the suitability of marginal land for food, feed, or non-food production. In this section, we will use case studies and hypotheses proposed by the authors to gather information on the suitability of different marginal area types for agricultural use.

*3.1. Site-Specific Land Use Suitability*

It is estimated that around 2.7 billion hectares of land globally are classified as marginal for agricultural cultivation. Out of this, approximately 1.5 billion hectares are currently unused and may be suitable for farming [10]. Many of these marginal areas could be reclassified if they were used more efficiently. For instance, Liu et al. [112] suggest that a vast portion of marginal land could be used to increase land availability for biomass production. With the advancements in remote sensing technologies, it is now possible to assess the suitability of each marginal land type for specific products/purposes, which has shown promising results [105]. According to Dhananjoy et al. [113], site-specific cropping system management is the preferred method of precision agriculture, which can also be suitable for marginal and small farmers. Using GIS, Mandal et al. [114] indicate that the first step in the land suitability assessment is the selection of site-specific factors and assigning their weights. Second, the produced layers of factors can be integrated to prepare a land-suitability map. Based on the information in the literature, we believe that the study of site-specific conditions of different marginal area types for different agriculture purposes can be evaluated by considering single or combined climate, land topography, soil quality, and ecological indicators. In the following subsections, we briefly explain these indicators and how they can influence the revitalization potential of different marginal areas in the Puglia region.

3.1.1. Climate Suitability

The existence of certain plants in a particular ecosystem is influenced by precipitation and temperature, which are the most important factors affecting plant growth [115]. As a result, there is a specific altitudinal zonation of plant ecosystems in each biogeographic region. This is because the mean annual temperature decreases progressively with altitude (thermoclimate) [116]. Consequently, changes occur everywhere on Earth based on temperature and precipitation [117], which are correlated with the altitudinal zonation of plant ecosystems. The physical continent or bioclimatic belts as well as the biological plant content or vegetation series can be recognized as a function of these changes using the concept of universal vegetation series jurisdiction. Therefore, this concept can be applied to any place on the planet [118]. Recent research findings highlight the significance of climatology and bioclimatology in comprehending the impact of climate on crops, such as grapevines and olive trees. This pertains to the assessment of yield losses and the determination of suitable cultivation areas. Various global databases containing bioclimatic indicators, such as WorldClim, CHELSA, CliMond, ecoClimate, ENVIREM, and MERRAclim, have gained attraction as valuable resources for the scientific community. This heightened accessibility to climate data has been highlighted by Noce et al. [119]. Gratsea et al. [120] emphasized that bioclimatic indices have now become indispensable in making valuable decisions regarding the selection of appropriate crops for agricultural purposes. However, to assess the potential changes in crop distribution due to climate change, an appropriate modelling technique should be applied [121]. Ideally, a physiological model should be utilized to accurately predict the impact of environmental changes on crop growth. In a study by Läderach et al. [122], the physiological model was used considering the complex interactions between cocoa trees and various shade trees that modify the crop's microclimate and soil water content. The authors concluded that the model was able to predict the future impacts of climate change on cocoa farming. In marginal areas, several techniques have been used to study climate suitability for the growth of specific crops. For example, a study by Kenny and Harrison [123] used a latitude-temperature index (LTI) in combination with a winter severity constraint to assess the climate suitability of grapes in different regions of Europe. The authors carried out a detailed analysis using period mean and individual year data, which allows for the identification of core areas of suitability for each of four broadly defined grape cultivar groupings (cool to hot-climate grapes). Similarly, Odeh et al. [124] used spatial analysis techniques to identify marginal agricultural regions suitable for growing pongam (*Pongamia pinnata*) and Indian mustard (*Brassica juncea*), and determined the base socio-economic viability of investments for the production of biodiesel in the identified areas. The previously mentioned study by Alhajj Ali et al. [107] proved that climate data can be useful in producing suitability maps for some underrepresented fruit tree crops, which can be planted in Xfp-infected marginal areas to maintain the landscape biodiversity and, therefore, the sustainability of the agroecosystems while minimizing the risk of land abandonment.

#### 3.1.2. Land and Soil Suitability

Various soil rating systems have been developed for different regions and purposes [12]. These systems provide an estimation of the "average" soil texture of the profile up to a depth of 1 m. The Visual Soil Assessment (VSA) system, originally developed by Shepherd [125], is officially provided by the Food and Agriculture Organization (FAO). Based on the VSA approach, the Soil Quality Rating (SQR) system was elaborated by Mueller et al. [126]. This system is a field guide designed to assess soil quality for agricultural crop production using modern scientific soil methods. The indicators used in this approach are similar to biophysical criteria suggested for describing and defining natural constraints for agriculture in Europe [127]. The EU Commission uses these criteria for designating areas that face natural and other specific constraints for agriculture (ANCs; EU regulation No 1305/2013 [128]). Several studies indicate the importance of soil indicators for the identification of the best crop that can grow better in a specific type of soil (suitable soil for suitable cultivation). For example, Gerwin et al. [12] quantified 380,000 km$^2$ of marginal lands for biomass production in Europe using soil-quality indicators. The authors concluded that Europe offers a large potential for renewable resources from marginal sites. Similarly, for mapping land use suitability in marginal areas, Li et al. [129] considered six soil properties, including soil organic carbon (SOC), texture, pH, cation exchange capacity (CEC), soil depth, and soil drainage. The authors used five methods: geometric mean, Rabia, square root, Storie, and weighted average to produce five agricultural land suitability indices where land areas were grouped into five classes—highly suitable, moderately suitable, marginally suitable, marginally not suitable, and permanently not suitable. Their results indicate that crop diversity on marginal soils often occurs in the form of cassava or legume intercropping with maize, as well as other cereals such as millet and sorghum. Following a similar analysis, Snapp and Silim [130] found the Pigeon pea to be tolerant to low soil fertility and commonly grown in marginal environments, and concluded that the presence of crops such as cassava, pigeon pea, or cowpea in a given region is a promising indicator of land quality.

#### 3.1.3. Ecological Suitability

Land use planning policies often fail to consider the bigger picture of the landscape's history and suitability for different uses. Land suitability refers to how well a particular piece of land is suited to a specific use [131], and it is a tool that helps to set the best locations for future land use [132]. This concept aligns with the Sustainable Development Goals (SDGs) since it aims to create a landscape that allows for the sustainable use of natural resources while preserving the functioning of ecosystems and maintaining a good quality of life for present and future generations [133]. Land Suitability Analysis (LSA) involves assessing the landscape's ecological features alongside land use requirements and restrictions. By using LSA in land use planning, it is possible to contribute to the sustainable development of rural areas by identifying the most suitable crops and tree species that provide both economic and ecological benefits. Specifically, crops and species that are adapted to the land require fewer inputs such as irrigation or fertilization, and they improve soil properties, contributing to the long-term goal of revitalizing degraded landscapes. A recent study by Franco and Magalhães [133] combined land use suitability analysis and land use change analysis to evaluate land use policies in a rural marginal area in Southeast Portugal. The study highlighted the importance of these methods in identifying areas where landscape recovery efforts should be funded. More studies, such as those by

Haughton et al. [134], Lovett et al. [135], and Turley et al. [136], have been conducted to determine what constitutes marginal land from a cartographic perspective. These studies utilized GIS mapping to identify the availability of marginal lands for different agricultural purposes, such as cultivating energy crops. The studies primarily focused on biophysical categories that influence land quality and are represented through maps. In addition, the Agricultural Land Classification (ALC) scheme is a consistent indicator used to assess the marginality of land, which ranks land based on its capacity for crop production and presents the information in a map format. Li et al. [129] emphasized the importance of accurately mapping the suitability of agricultural land to effectively manage both current and future agricultural land use. Such mapping is crucial for decision-makers to develop strategies for the sustainable use of land resources. Given that a significant portion of the land in the Puglia region is considered marginal, there is a need for an ensemble approach to generate a spatial distribution map of agricultural land suitability in these areas. Additionally, it is important to identify the distribution and extent of different marginal area types in the region, considering the available quantitative climate, soil, and topographic data.

## 4. Revitalization of Agriculture in Marginal Areas through Innovation Initiatives

In response to the difficulties that agriculture faces due to climate change, eco-innovation initiatives such as climate-smart agriculture are being highlighted as key solutions [137–139]. These initiatives involve developing new products, processes, and services that can generate more economic value while also reducing environmental impact [140]. In the following subsections, we will discuss some of these eco-innovation techniques/initiatives and their potential implementation for revitalizing agriculture in marginal areas.

### *4.1. Wastewater Treatment and Reuse for Irrigation*

It is believed that water availability significantly impacts agriculture, affecting both crop quantity and quality. In Italy, the current water balance shows that annual water demand may exceed the available fresh water. In the Puglia region, the hot and dry climate with increasing variability in rainfall patterns and intensity poses serious problems for irrigation water resources in some areas [141], complicating crop cultivation. Additionally, saltwater intrusion in coastal aquifers is becoming critical to the regional territory [142], affecting about 20% of the Puglia region, where normal plant growth is almost impossible due to high levels of salinity [143]. To address this, the development of water resources through untraditional means is becoming essential. Treated wastewater as an alternative water source for irrigation has been a topic of discussion, especially in regions of water scarcity [144]. Today, the importance of wastewater treatment and reuse in agriculture has attracted more attention, as it offers both economic and environmental benefits, presenting not only as a valuable water resource but also as an alternative fertiliser due to the presence of valuable micro and macronutrients which can reduce the use of chemical fertilizers [145,146]. Compared to deep groundwater exploitation or desalination, it leads to lower energy costs. It also helps to reduce nutrient removal costs, which, in turn, protects surface waters through irrigation. Furthermore, it diverts wastewater from its outlet, reducing nutrient discharge to the environment [147]. As a result, wastewater reuse helps to improve the water quality of the receiving bodies. This results in a win-win situation where significant synergies can be achieved between the urban and agricultural sectors while preserving the environment [148].

In a semi-arid marginal area of the Puglia region, Palese et al. [90] tested a sustainable management model, based on the recycling of urban wastewater for irrigation in an olive orchard for over eight years. Their results indicate that the management module is productive and profitable, and socially and environmentally sustainable. However, for the successful implementation of non-conventional water in marginal areas, agricultural policies should focus on supporting and encouraging its adaptation by promoting the study and development of supplemental irrigation schemes through rural development programs or other regional/local funding schemes. Pedrero et al. [149] worked on reusing reclaimed wastewater to irrigate nectarine. A three-year study (2012–2014) was conducted in a commercial nectarine grove (*Prunus persica* L. Batsch.) cv Big Top grafted on GF-677, planted in 2008 and located in Trinitapoli (Northern Puglia). The results indicated the positive impact of reclaimed wastewater on fruit quality parameters and showed that this water can be a good alternative to freshwater in marginal Puglia areas. Other studies in Puglia showed the same trend of the benefits of using treated wastewater for irrigation [150,151]. Consequently, treated wastewater represents one of the best strategies for sustainable water management in the Puglia region.

### *4.2. Agrivoltaic Farming*

Agrivoltaic farming has the potential to be both economically and environmentally beneficial to both growers and consumers. Initially, an agrivoltaic (AV) system was simply a system that produced crops and electricity on the same land [152–154]. However, in recent years, the increasing concern about energy costs and the agricultural crisis has led to the consideration of a system as an AV system only if it can produce healthy crop yields [155]. This is because solar panels can introduce shadows in the agricultural system, thus reducing the light (PAR) that is useful for plant photosynthesis. Despite this, the system could provide a unique approach to generating clean energy with solar panels that can be used for smart irrigation systems or recharging electric vehicles/devices for agricultural use. Moreover, this energy can be used for activities such as self-consumption on the farm or processing of crops like grapes, figs, olives, and tomatoes. Additionally, in rural and marginal areas, there could be the opportunity to establish 'energetic communities' that produce green energy. Solar panels can be either fixed or mobile (tilting) and can be placed close to or above the crop canopy or in the inter-rows, thus reducing the shade on the plants. The cultivation of different crops is possible since panels can allow up to 60–70% of photosynthetic radiation to reach the leaves [156,157]. Most studies on agricultural systems with solar panels focus on annual crops such as vegetables and cereals [153,154,157–159], with limited information on fruit tree species or grapevines. The use of AV systems in fruit tree crops, which could be interesting in many marginal areas, is limited to a few species such as pears [160], apples [161], and wine grapes [162,163]. In addition, some crops such as red berries, grapes, and kiwifruit have shown satisfactory adaptation to shade and were able to produce relatively high yields under the shade of panels. In general, berries and fruit tree species are less sensitive to shade compared to annual crops such as legumes, cereals, and tubers, which can face a dramatic reduction of yield with 25–50% shade [155]. In fact, the physiological response and the consequent yields of different fruit tree species grown under the solar panels vary as climate, soil type, and weather conditions can vary according to the geographical locations of the field. For example, Jiang et al. [164] found that 19% of panels provided suitable shading for kiwifruit, as it led to less impact on kiwifruit growth and yield while increasing water productivity with reduced water consumption. On the contrary, preliminary results by Duchemin et al. [165] on raspberries indicate a 20–32% yield reduction in AV systems compared to raspberries protected by plastic coverages; however, fruit quality remains the same. Similarly, Ferrara et al. [166] found that vine yields under solar panels were slightly reduced (−10 to −15%) compared to vines grown under the full sun in Northern Italy (Veneto region) over three seasons of field experimentation. However, a recent trial in a Primitivo vineyard in the Puglia region found that AV vines yielded more than full-sun vines [Ferrara p.c.].

In recent years, there has been an increase in the occurrence of negative climatic events such as spring frost, heat waves, and droughts. Agrivoltaic systems can mitigate these effects together with the adoption of cultural practices, i.e., pruning times [167] and have a positive impact on crop growth, in particular on crops well adapted to the climatic conditions of the area such as fig, winegrape, blackberry, etc. The presence of solar panels can create a better microclimate for crops during periods of rising temperatures and limited water supply. This is particularly beneficial in areas that are prone to such problems and can greatly benefit marginal areas. While crops that are shaded by solar panels may experience a reduction in yield, it is opportune to weigh the benefits of the renewable energy generated by the AV system which could be used for processing innovative agricultural products [165] to stimulate a circular economy. For instance, in the case of winter wheat, there was a yield reduction of −18.7%, but the system generated 246 MWh of electricity, resulting in an overall production that was 56% higher than the combined production of the crop and the solar panels in two separate locations [155]. This is an important consideration when planning to establish AV systems in marginal areas, abandoned lands, and regions with hot and dry climates that are common during the growing season, such as areas with Mediterranean climatic conditions (although not limited to these areas). In this regard, the AV system appears to be a suitable approach to enhance electrical self-sufficiency and reduce dependence on fossil fuels in the future.

*4.3. Agroforestry*

Agroforestry is an eco-friendly method of land management that enhances overall production by combining crops, tree crops, and forest plants and/or animals. This is done simultaneously or sequentially while utilizing management practices that are in line with the cultural norms of the local population [168]. The traditional techniques that form the basis of agroforestry include tree intercropping, shaded perennial cash crops, silvopasture, windbreaks, alley cropping, riparian buffer strips, forest farming, productive hedgerows, and tree woodlots for land rehabilitation and fallow regeneration. The primary goal of agroforestry is to provide numerous productive functions and services (as illustrated in Figure 10).

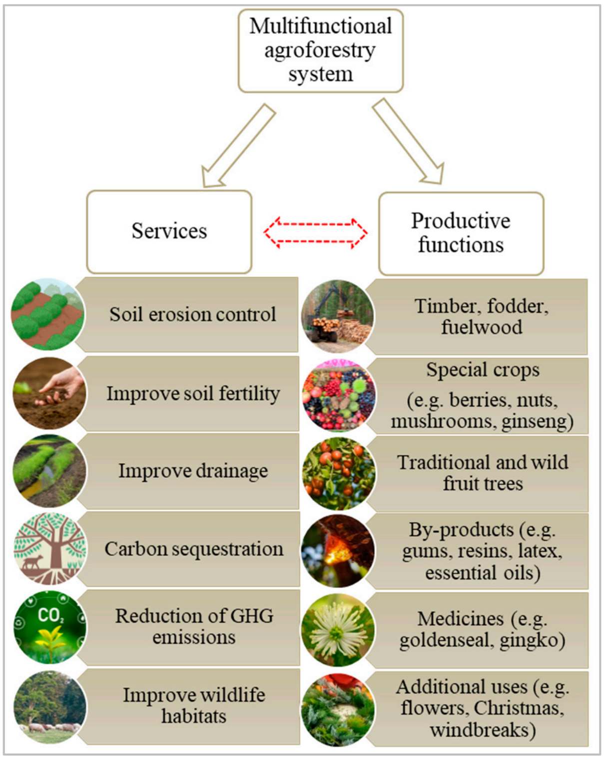


**Figure 10.** Potential services and productive functions provided by the agroforestry system (adopted from Blanco-Canqui and Lal [169]).

By developing and utilizing multipurpose trees and integrating them into agroforestry farming systems, sustainable solutions can be provided for improving livelihoods, sustainable land management, food security, environmental protection, and climate-change mitigation and adaptation [170,171]. It is believed that the agroforestry system has the potential to significantly reduce atmospheric $CO_2$ levels and mitigate climate change by sequestering carbon compared to other land uses. Estimates suggest that the aboveground agroforestry systems can store carbon ranging from 0.29 to 15.21 Mg C hectare$^{-1}$ year$^{-1}$ while up to 1 m of soil depth can store 30–300 Mg C hectare$^{-1}$ of carbon [172].

Agroforestry gained attention in the 1980s as a way to increase and sustain agricultural production in marginal lands [170]. In the USA, efforts to convert such lands have mainly focused on using perennial grasses and woody crops for biofuels or feedstock [173,174] or implementing conservation habitat programs to improve ecosystem services [175]. Both options offer benefits but neglect landscape multifunctionality by focusing solely on production or conservation aspects [176]. To revitalize agriculture in marginal lands, future land design must address both aspects simultaneously. To connect production and conservation, researchers suggest using agroforestry to integrate profitable food and non-food crops in these areas [177–180]. In Italy, agroforestry has long been an integral part of landscape management. The country's diverse agroclimatic conditions [181] have led to a multitude of agroforestry systems, which are often abundant in biodiversity. Italy has a significant agroforestry area in Europe, ranking fourth with 1.4 million hectares. It also has the second-largest area of high-value trees in silvoarable and agroforestry and the fourth-largest area for livestock agroforestry systems [182]. Although agricultural technologies have improved, the success of agroforestry in Italy depends on a balance between respecting traditions and embracing innovation. In certain areas of central and Southern Italy, as well as Sardinia, a silvoarable system is practised [93] where cereals are grown commercially between scattered oak trees at densities ranging from 7 to 250 trees per hectare, known as "seminativo/pascolo arborator" in Italian. In Puglia, silvoarable systems are predominantly linked to woodlands [183], and wooded hedges are also used as part of the agroforestry system [184]. In the central-southern regions of Italy, the rural economy of the Apennines was based on agro-silvopastoral transhumance systems, which unfortunately led to a reduction in the shrubland area and forests due to fire, charcoal production, and overgrazing of natural vegetation [185]. Reducing grazing in these marginal areas could lead to the recolonization of shrublands and forests [186], thereby enhancing biodiversity and ecosystem services. In addition, plantations of trees like pecan, or other local species like carob, could diversify the production of fruits, timber, and even truffles [187], thus increasing the attraction of marginal locations in the Puglia region. Agroforestry has long been known as a multifunctional land use that can increase habitat diversity, protect against erosion, and reduce the need for agrochemical inputs [188]. Furthermore, agroforestry systems based on tree plantations could absorb greater amounts of carbon, mitigating future increases in atmospheric $CO_2$ [189]. Despite their productive role in diversifying farm income and developing sustainable farming systems, the environmental and aesthetic roles of agroforestry should be highlighted. Increasing knowledge and awareness of their potential applications would encourage their uptake by local residents in the rural areas of Puglia.

### *4.4. Plantation of Halophyte Plants*

Halophytes are a valuable biological resource, making up around 1% of land-based flowering plants [190]. They are dispersed across 120 different families, with approximately 3000 species and 550 taxa [191]. Like wild plants, Halophytes can adapt to harsh environmental conditions such as salt, drought, and extreme temperatures by utilizing processes dictated by their genetic code. They can absorb large amounts of salt and transport it to other parts of the plant [190–193]. These characteristics make Halophytes survive in soils or water with high salt concentrations. They have significant economic value as they can be used as food, oil, medicine, and raw materials in food processing [194]. As most soil/water saline zones are concentrated by the seas/oceans, and due to the vast availability of coastal lands (oceans represent 70% of the Earth's surface), experts predict that marine agriculture, which involves cultivating crops along the coastline, will become an important sustainable solution for the reactivation of these areas [195], especially after the discovery and development of several salt-tolerant crops. For example, some types of Halophytes, called also saltwater vegetables, with varying degrees of salt tolerance, can be irrigated with seawater or planted on salty and alkaline soils. Their economic value is that they contain edible parts, as in regular vegetables [196], and are rich in protein, vitamins, and trace elements like iron, selenium, and zinc. This has made them popular as a sustainable food choice in coastal/saline zones. In areas like the Puglia region, Halophytes can be planted in marginal lands or along the coastal areas to help remediate saline soil, prevent coastal erosion, and contribute to food security. Hence, it is important to incorporate Halophyte plants into local agriculture, not only for economic development but also for freshwater conservation and social development.

### *4.5. Community-Based Initiative (the Establishment of an Eco-District)*

It is widely acknowledged that traditional natural resource management methods need to be re-evaluated to better suit the highly variable and diverse farm conditions typical of resource-poor farmers [197]. The eco-district approach offers a site-specific, natural-based solution for managing local resources sustainably. By bringing together farmers, citizens, tourist operators, associations, and public authorities, eco-districts aim to fulfil the economic and sociocultural potential of a specific geographical area. This approach is based on ecological principles and practices that support a biodiverse agroecosystem capable of sustaining itself. Eco-districts have great potential to be established in several marginal areas in the Puglia region, similar to bio-districts recognized by several regional councils in Italy [198]. This action can add value to food and non-food products from these areas, ensure a decent income for farmers and enterprises, enhance the cultural value of the area, and preserve biodiversity. In the past, the Common Agricultural Policy (CAP) has prioritized cost and productivity competition, which has resulted in the concentration of production in a few regions and the marginalization of entire areas [199]. However, the adoption of eco-districts as a new approach that focuses on product quality could change the competitive advantage of these marginalized areas. By developing specific product niches based on local resources, these areas could establish a unique market position and compete based on quality rather than cost and productivity. In this regard, eco-labelling of products from these areas could further add value to local products. Currently, there is no information on the establishment of eco-districts in Italian marginal areas, including the Puglia region. Therefore, this review embraces the term "eco-districts" to establish a joint effort in select marginal areas in the Puglia region to coordinate and organize activities throughout the food chain to ensure the food security and sustainable development of Puglia rural communities.

## 5. Future Perspectives and Recommendations

The analysis of available information indicates that farmers already operating in marginal lands have their own unique techniques that work best in certain historical, social, and economic contexts. As new information and methods emerge, farmers may adopt more profitable and environmentally friendly techniques, taking into consideration that what works well in one place might not be effective in another. Overall, the analysis of the current situation in Puglia suggests that some marginal areas have high potential for sustainable rural development through food/non-food production. However, because agricultural production requires a combination of labour, capital, land, energy, and other farm inputs to generate the outputs, the most efficient combination to rejuvenate agriculture in marginal areas will depend on various factors such as the prices of these resources, the establishment of new regional-specific agricultural policies in marginal areas, the ability/acceptance to implement new techniques, and the price of the final product. To ensure success in managing these areas, it is important to take a bottom-up approach. This means building platforms and partnerships among stakeholders while actively involving and gaining support from local and regional authorities. Although our suggestions might be multidimensional and there are interlinkages between the different stakeholders, we highly recommend the implementation of the following suggestions from the perspective of key stakeholders involved in marginal areas for the reactivation/revitalization of a large portion of unused land within the regional territories.

- Politicians: Should work towards political reform of the regional policy to achieve sustainable development and food security in rural areas. This involves transitioning from political commitment to political action and establishing clear guidelines for farming in marginal areas. Good governance plays a key role in this process. Government policies should focus on revitalizing agriculture activities (both for food and non-food products) in marginal areas and prioritize the following actions:
    - Training to all stakeholders. It is important to provide comprehensive training to all stakeholders involved in the development of marginal areas for agricultural purposes. Farmers, researchers, politicians, administrators, producers, and consumers should all receive sufficient training to better comprehend the productive and protective role that marginal areas can play in agriculture.
    - Encourage public investments. Investments are necessary, especially in marginal areas, for food security and environmental reasons, promoting sustainable development.
    - Provide financial support for small/poor family farmers. It is important to provide subsidies for small and poor family farmers who engage in farming activities in marginal areas. These farmers make up a significant portion of regional populations; therefore, improving their productivity should be a top priority for sustainable development. Additionally, it is crucial to compensate these farmers for the environmental services they provide, such as protecting biodiversity, maintaining watershed stability, and sequestering carbon.
    - Establishment of guidelines for the promotion of sustainable practices/strategies to be implemented in farmers located in marginal areas. This is important to conserve local biodiversity and enhance the ecosystem functions in these areas.
- Local communities:
    - Restoring and conserving natural resources that are essential for food security. The degradation of natural resources directly affects the income and food security of rural areas. To address this issue, both community- and national-level interventions are necessary. It is important to secure local ownership, access, and management rights for marginal area farmers.
    - Direct involvement of local residents in regional development processes (bottom-up approach). It is widely accepted that local residents are the best experts to drive the development of their own community. When it comes to revitalizing underdeveloped regions, involving the local community is crucial to maintaining a balanced landscape structure and improving connectivity. This bottom-up approach ensures that the local residents, along with the local players, can help define a development pathway that aligns with their needs, expectations, and plans. Working collectively with delegated decision-making empowers them to take charge of their region's future.
- Farmers: Efforts from farmers and food producers operating in marginal areas should include the following:
    - Willingness to adopt alternative cultivation methods/techniques to promote the use of 'environmentally marginal land'. This includes utilizing treated wastewater, planting salt-resistant cultivars, growing locally adapted genetic varieties, incorporating nitrogen-fixing legumes, using microbial inoculants and mycorrhizas, and implementing strategies like greening and mulching, etc. Proper management of crop residues in marginal areas can also help to maintain land productivity while preventing and mitigating soil degradation, improving biodiversity, and protecting the environment.
    - Encourage the use of local plant resources. One great way to preserve the local ecosystem and support wildlife is to encourage the use of local plant resources. It

is important to support nurseries that specialize in native species and promote the cultivation of plants that are native to the area, which can help preserve the biodiversity of the area.

- Promote the use of multifunctional systems such as the integration of solar panels in crop cultivation. Solar panels can either increase the income of the farmers with the production of green energy or create a better microclimate for the crops.

➢ Regional authorities: Regional authorities should take the initiative to facilitate land use planning for local communities for the sustainable development of the region. This can be achieved by defining what type of marginal lands are better suited for which purpose. This may include:

- Valorization of the touristic aspects of marginal landscapes. When revitalizing marginal areas, it is important to take into account their tourist value. This value should not only be seen as a technical tool but also as an educational instrument for visitors.

➢ Local authorities: Local authorities should work together in the frame of a participatory approach in order to help establish some initiatives for the development of their areas considering the local context. This might include:

- Implement nature-based solutions (NBSs). The NBSs have great potential to address problems associated with environmental challenges, landscape degradation, socio-economic crisis of rural communities, marginal areas, and climate vulnerability.

➢ Industry: The use of materials and raw materials from marginal areas should be properly managed as they are the basis of various products with different market orientations (e.g., cosmetics, food/food additives, drugs, bioproducts, bioenergy). This might include:

- Eco-labelling of the final products. This can ensure its traceability from marginal areas which can add value to the products and encourage producers to maintain good quality products.
- Establish a direct contact with farmers. Industry should ensure direct contact with farmers located in marginal areas to ensure good economic return for farmers.

➢ Landowners: Should be committed and help in the implementation of political development programmes; however, they need to have confidence that the implementation of government programmes and strategies in marginal areas will continue in the long-term and that the government is committed to supporting them. Government programmes should ensure the following aspects:

- Increasing the income of farmers in marginal areas and ensuring fair prices for their products in the market. Properly functioning markets are crucial for farmers to earn a decent income, but they often fail to sell their products at fair prices. Therefore, government policies should aim to make markets work for farmers, especially those who come from marginal areas.
- Support local farms. Purchasing food, feed, and non-food products directly from small local farmers in marginal areas can assist in their survival and maintain productivity during extreme weather events. Additionally, this practice keeps money within the local economy while supporting agricultural efforts to conserve biodiversity.

➢ Research: Research is the basis for the sustainable development of any region, and can fill out the gap of information regarding the role of unused lands in the sustainable development of a region. Research and development in regions with high agricultural potential is of utmost importance as these areas play a crucial role in meeting the food demands of the ever-growing population and livestock. Neglecting these regions can result in an increase in food prices and lead to food scarcity, which can adversely affect the economy and public health. Hence, it is imperative to invest in the research and development of these areas to ensure sustainable agricultural practices and to meet the food requirements of the world's population.

- Investing in targeted research. Focusing on crops and traits that are important to the poor, and on the particular environmental limitations they face, can reduce poverty and marginality on a large scale.
- Promote studies on land suitability and land use planning to define marginal areas according to their suitability for different production purposes. For example, recognizing lands for bioenergy production as an opportunity to foster local development. This brings environmental, social, and economic benefits, such as adding value to marginal land and creating new job and business opportunities.

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