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Article

Coastal Land Use: Socio-ecological (D)evolution of Saltscapes in Portugal

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Abstract

Since the mid-1990s, traditional marine salt (TMS) production has seen a renaissance, driven largely by the revaluation of *fleur de sel* (FoS) in the market—a product that previously lacked commercial appeal. Its rise as a premium commodity in global niche markets has encouraged producers to reinvest in this ancient practice, deeply rooted in coastal socio-ecological systems. This study examines not only the diversification of salt-based products but also the emergence of cultural ecosystem services, particularly those related to tourism. By situating TMS and FoS within broader transformations in land use and socio-ecological system dynamics, the research highlights their role in sustaining traditional knowledge, local economies, and the integrity of the coastal landscape.

Keywords: cultural tourism; innovation; flower of salt (FoS); land use and land cover change (LULCC); social–ecological systems (SES); traditional marine salt (TMS)

1. Introduction

Salt production has kept pace with the evolution of humanity [1]. Salt is used in a multitude of applications in people's daily lives. Among the uses of salt for people, it can be highlighted, for example, in direct use as a condiment in food, or as salts for application on the skin in health and wellness treatments (e.g. [2,3]).

In terms of salt production, with the evolution of machinery in the middle of the last century, salt extraction became very mechanized, and the market value of raw material reduced considerably [4,5]. This phenomenon has meant that only large producers have been able to persist in the market [6]. It also happened that smaller landowners who could not remain competitive due to the scale of their production, joined or sold their salt pan areas to larger producers [7].

However, with the appearance of the valued flower of salt (a.k.a., *fleur de sel* in French or *flor de sal* in Portuguese), until then consigned to oblivion, there was a change in the production paradigm [8]. From that moment on, regeneration of the artisanal salt production sector began, thanks to a new and promising market [9]. In the meantime, several small producers have reappeared.

Traditional marine salt (TMS) production, particularly prominent in southern European regions, represents more than a climatic advantage for salt crystallization [10–12]; it is embedded within a long-standing social–ecological system (SES) [13,14]. While environmental conditions—such as high summer temperatures, minimal rainfall, and low atmospheric humidity—create an ideal setting for salt formation, the sustainability of TMS depends equally on the adaptive practices and knowledge systems of salt producers [15]. These producers draw on generations of local ecological knowledge (LEK) to manage tidal flows, evaporation cycles, and seasonal climate variability [16]. Their ability to read ecological cues and adjust management practices accordingly—such as optimizing pond preparation and timing the harvest of *fleur de sel*—demonstrates a co-evolved relationship between humans and the landscape [9]. Furthermore, traditional forms of social organization, including informal institutions and cooperative labor arrangements, play a crucial role in regulating access, coordinating maintenance, and preserving collective knowledge. As such, TMS production systems

exemplify how cultural practices, ecological processes, and local governance intertwine to maintain a dynamic and resilient coastal land-use tradition [17].

However, this intricate social–ecological balance is increasingly challenged by shifting land-use dynamics, including coastal development, aquaculture expansion, and abandonment of traditional practices [14]. Such transformations not only alter the physical landscape but also disrupt the institutional memory and ecological feedback that have historically sustained TMS systems [18]. Understanding traditional salt production through the lens of SES and land-use change allows to examine how cultural heritage, environmental knowledge, and governance interact under conditions of socio-economic and climatic uncertainty. This perspective is essential for assessing the resilience and adaptive capacity of TMS landscapes in the face of global change [19]. In the last decade, it has been observed that there has been a growing interest in activities in salt pans associated with tourism, which increases the resilience of the socio-ecological system [9,16].

This study aims to assess recent land use and land cover changes in traditional salt pan areas in mainland Portugal, focusing on signs of ecological regeneration or abandonment. By integrating official statistics, satellite imagery, fieldwork, and literature, the research examines how these coastal landscapes function within broader social-ecological systems. The goal is to inform about habitat restoration and sustainable land use near urban coastal zones in line with European environmental policy.

2. Literature Review

2.1. Saltern Land Use and Land Cover Change in Portugal

In Portugal, traditional sea salt production has shaped coastal land use across key wetland systems such as the Ria de Aveiro, the Mondego and Tagus estuaries, and the Ria Formosa in the Algarve. While regions like the Sado estuary—once the nation’s leading salt producer—have seen a shift to alternative land uses such as rice cultivation, others are witnessing a partial revival of saltpan landscapes (or saltscapes) [20–24].

This regeneration reflects a broader land-use change, as abandoned saltpans are repurposed not only for salt extraction but also for cultural and ecological services, including tourism, habitat provision, and recreation [6,25,26]. The spatial demands of traditional salt production—requiring extensive evaporative basins—alter land cover yet often restore valuable ecological functions [27,28]. These managed environments reestablish food webs (e.g., *Dunaliella spp.*, *Artemia spp.*, waterfowl), reinforcing the multifunctionality of these anthropogenic but biodiverse landscapes [29,30].

The EU's commitment and responsibility to reverse biodiversity loss is currently underway. By 2030 there is a commitment to restore at least 1/5 of terrestrial and marine habitats [31]. By 2050 in Europe, it is supposed to rehabilitate up to 90% of all these marine and terrestrial habitats [32].

In addition to being scarce, most of the literature on the characterization of salterns is related to waterfowl [25,33,34]. These articles usually refer not only to the abundance and description of the species present, but also to which wetlands are important for nesting, feeding habits or wintering areas [35]. On the production of other studies of a socio-economic nature, literature is also scarce [36].

2.2. Saltpans as Social–Ecological Systems Undergoing Land-Use Change

Traditional saltpans represent more than an industrial or artisanal heritage—they are embedded within long-standing social–ecological systems that have historically shaped coastal and inland landscapes [37]. Salt production, with its deep historical roots and ecological specificity, embodies both tangible and intangible heritage. In recent decades, the abandonment or transformation of these systems has reflected broader land-use and land-cover changes, driven by shifts in economic priorities, environmental policies, and urban expansion [38].

In response to these dynamics, various local and territorial governance entities have initiated regeneration projects that revalue saltpans not only as historical landmarks but also as multifunctional landscapes. In some areas, these spaces no longer serve extractive purposes but have

been reactivated as educational and cultural infrastructure, preserving social memory while reshaping land use [39]. For instance, the restored salt pans of Junqueira in central Portugal now serve primarily pedagogical roles, highlighting historical techniques and ecological interactions [40].

Elsewhere, hybrid models emerge. The inland salt pans of Rio Maior—located far from the coast—remain in operation while being recognized as national cultural heritage, blending historical continuity with adaptive land use [41]. In coastal regions such as Figueira da Foz, where artisanal salt production has been classified as intangible cultural heritage, regenerated salt pans have become embedded in broader service-based economies, including ecotourism and nature-based recreation [42]. These transformations exemplify how traditional saltscapes are transitioning into multifunctional socio-ecological systems, shaped by heritage values, ecological processes, and emerging demands for sustainable, culturally embedded tourism.

2.3. Entrepreneurial Innovation and Socio-Ecological Transformation in Salt pans

The revalorization of fleur de sel in France during the 1970s catalyzed a broader shift across southern Europe and the Mediterranean, where formerly declining saltscapes began to re-emerge as multifunctional socio-ecological systems [43–45]. In Portugal, this transformation took place in the 1990s, driven by renewed global demand for artisanal salt and an appreciation for heritage food products. What was once an undervalued byproduct of coastal wetlands became a premium commodity, triggering both ecological reinvestment and a restructuring of local economies [46].

A critical innovation in this transformation was the refinement of techniques to harvest fleur de sel—a fragile salt crust that forms on the water surface of crystallizer ponds. Unlike traditional sea salt, which precipitates on the pond bottom, fleur de sel requires careful manual collection to preserve its structure and purity [47–48]. This biophysical specificity has not only shaped harvesting practices but has also reinforced the need for skilled labor, local ecological knowledge, and careful ecological management of the salt pans.

The higher economic returns from fleur de sel production have repositioned salt producers as entrepreneurs and stewards of niche heritage landscapes [49]. This economic reconfiguration has also prompted significant land-use change, as abandoned or underutilized salt pans are reactivated not solely for extraction, but also as cultural and tourism landscapes. Responding to the growing demand for nature-based and heritage-driven tourism, a new class of cultural entrepreneurs has emerged, integrating salt production with experiential tourism, education, and wellness services [50–52]. These innovations demonstrate how socio-ecological regeneration—rooted in both market dynamics and ecological specificity—can drive the adaptive reuse of coastal and peri-urban saltscapes.

2.4. Cultural Tourism as a Driver of Socio-Ecological and Land-Use Transformation in Salt pans

The renewed attention to salt pans—once primarily sites of extractive labor—now reflects their emerging role within dynamic social-ecological systems. The production of salt, a substance integral to human health and daily life, is increasingly attracting visitors who seek meaningful experiences tied to traditional landscapes and ecological processes [53]. The interaction between cultural heritage and ecological distinctiveness has positioned salt pans as appealing destinations for nature-based and heritage-driven tourism.

As tourism infrastructure and visitor services are developed, these landscapes undergo a subtle yet significant land-use shift—from mono-functional production zones to multifunctional areas offering cultural, recreational, and ecological services. This transition is particularly evident where environmental enhancement (e.g., trails, signage, interpretive centers) improves visitor accessibility and comfort, reinforcing the landscape's social value and leading to positive feedback loops of use, investment, and conservation [54].

In response to growing demand, tour operators now include salt pan visits in their portfolios as part of a broader effort to diversify experiential offerings [55]. Simultaneously, cultural entrepreneurs are investing in these traditionally marginal areas—often located at the urban-rural interface—developing activities such as guided tours, wellness services, and artisanal workshops [56]. This

changing pattern of use illustrates a land-cover transition shaped not only by market forces but also by evolving cultural perceptions of landscape value, identity, and function (Table 1).

Table 1. Entrepreneurial Innovation in saltscapes and its socio–ecological and land-use impacts.

Innovation/Practice	Social–Ecological Component	Land-Use / Land-Cover Change Impact
Harvesting techniques for <i>fleur de sel</i>	Requires local ecological knowledge (LEK) for surface collection and ecological timing	Reactivation of abandoned crystallizer ponds for precise micro-management
Revalorization of artisanal salt products	Cultural valuation of traditional foods; reconnection to heritage production systems	Conversion of disused saltpans into heritage-linked productive land use
Higher income from premium products	Economic incentive for producers to remain in or return to traditional livelihoods	Prevents full abandonment; promotes continued or expanded salt production
Tourism and cultural entrepreneurship	Integration of ecosystem services (recreation, education, well-being) with extractive use	Creation of multifunctional landscapes blending production and tourism
Infrastructure for tourism (e.g., trails, spas)	Involvement of new stakeholders; diversification of service-based land use	Physical transformation of saltpan surroundings for public access and services
Cultural recognition (e.g., intangible heritage status)	Institutional support for maintaining traditional practices	Long-term land-use protection; reduced risk of conversion to urban or intensive agriculture

3. Methodology

3.1. Conceptual Framework

As the purpose of this research is to find out to what extent there is land-use change in traditional salt production sites in Portugal, it is important to identify the steps to be taken in order to obtain reliable data and be able to discern the evolution of these spaces. In this sense, an analysis strategy was developed that consists of a multi-step methodology (Figure 1).

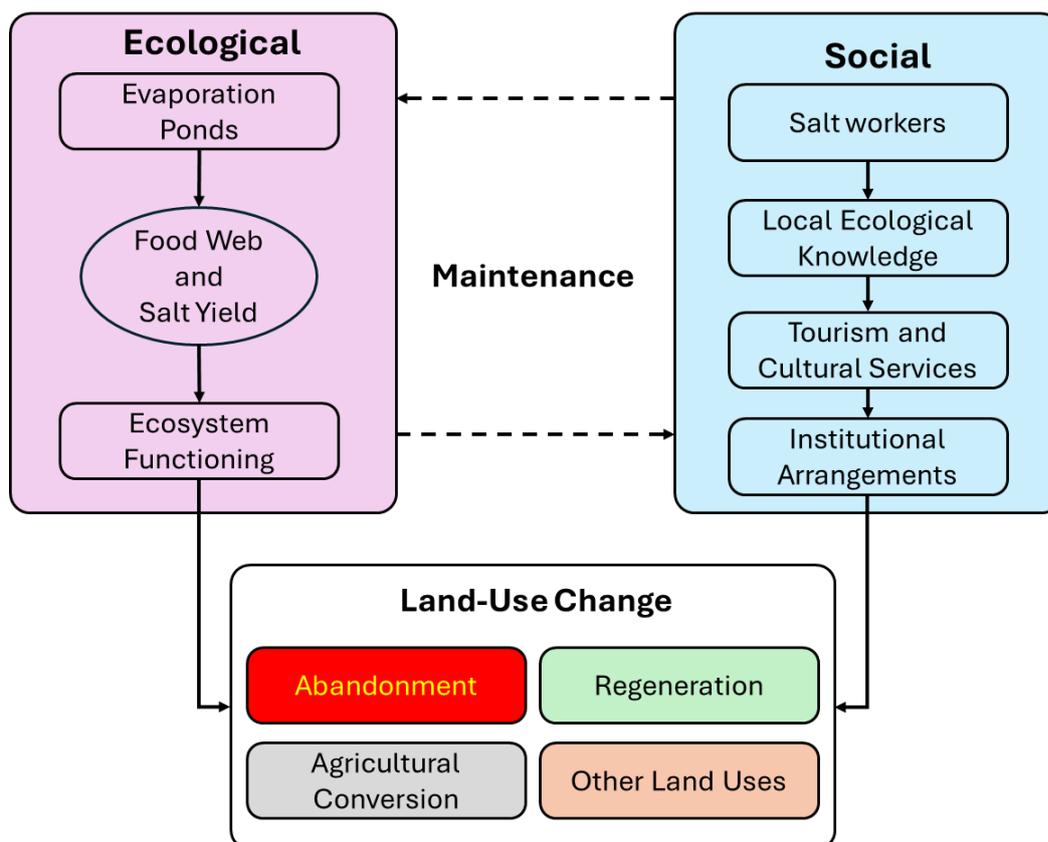


Figure 1. Conceptual framework for analyzing socio-ecological systems (SES) of saltscapes facing land use change.

3.2. Research Question

This study explores whether traditional saltpan areas are experiencing abandonment, regeneration, or transformation, viewed through the lens of social–ecological resilience and land-use dynamics. Rather than focusing solely on production methods, it is assessed how human activities, ecological conditions, and land-use pressures interact to shape the current state of these landscapes.

Field observations and literature review inform the seasonal and physical characteristics of saltpan management, particularly the early-season clearing and preparation of crystallizer ponds. This land preparation serves as a proxy for active socio-ecological engagement and land-use continuity [57]. The central research question asks: **To what extent are traditional saltpan systems being maintained, repurposed, or lost amid shifting social, ecological, and land-cover conditions?**

3.3. Data Collection

To assess the transformation of saltpan landscapes within a social–ecological and land-use change framework, this study draws on multiple data sources. Statistical yearbooks serve as a baseline to track the spatial extent, number of active salt pans, and production volumes of traditional sea salt and *fleur de sel* across Portuguese regions [58–64].

These quantitative records are complemented by qualitative insights from scientific literature and geospatial observations. High-resolution aerial imagery—such as from Google Maps—is used to identify physical signs of abandonment or regeneration (e.g., pond maintenance, infrastructure renewal). These visual data help assess land-cover status and support analysis of socio-ecological engagement in saltpan landscapes [65–67].

3.4. Hypothesis Construction

Salt pans need pond areas designated by evaporators that serve for the graduation of salt (Fig. 2A). With the research question defined and relevant spatial and statistical data gathered, this study constructs a hypothesis framework to assess the condition of saltpan landscapes as indicators of land-use continuity or decline [68,69].

Null hypothesis (H_0): If traditional saltpan landscapes are being regenerated as socio-ecological systems, aerial imagery will show well-defined, maintained infrastructure and active land use.

Alternative hypothesis (H_a): If traditional saltpan landscapes are in decline, aerial evidence will reveal fragmented, deteriorated, or erased saltpan units, indicating abandonment or land-use change.

To evaluate these conditions, it is applied a classification scale with four observable states, reflecting the degree of physical integrity and maintenance visible from aerial imagery (Fig. 2B). These categories serve as proxies for socio-ecological activity and land-cover dynamics—ranging from fully active and maintained to entirely degraded or repurposed.

This framework enables to spatially analyze the transformation of saltpans not merely as production zones but as dynamic landscapes where heritage, ecological function, and human use intersect or unravel.

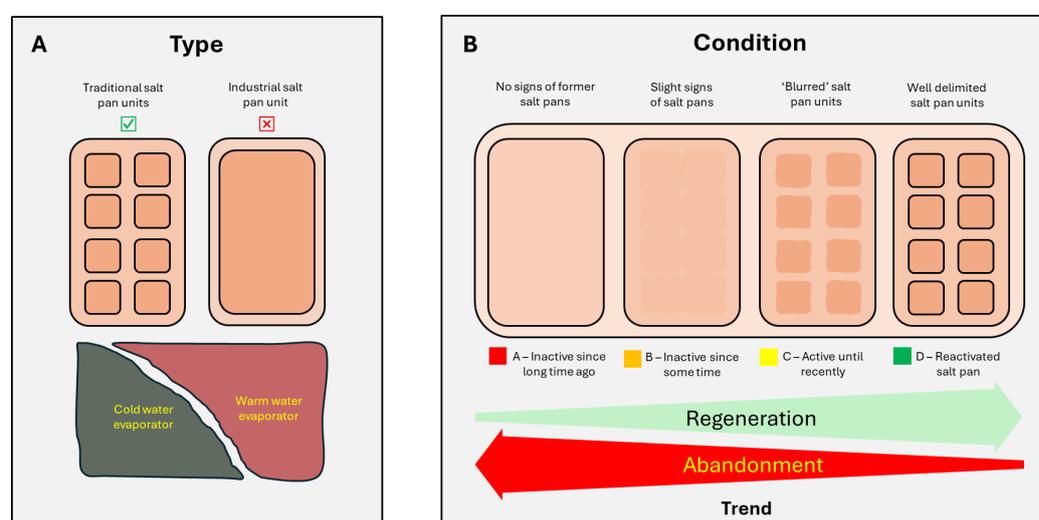


Figure 2. Conceptual representation of salt pan systems as land use units within a dynamic social-ecological landscape. A) Schematic distinction between smaller-scale, historically embedded salt pans and larger-scale industrial salt production units. This study focuses exclusively on the traditional-type salt pans due to their relevance in understanding land use transitions, ecological resilience, and multifunctional value. The coloration of evaporation surfaces was derived from actual Google Maps imagery to reflect spatial legibility and texture in LULCC assessments. B) Categorization of salt pan areas based on visible indicators of ecological or functional regeneration versus abandonment, supporting a spatial typology of land use status across coastal and estuarine zones.

3.5. Testing the Hypothesis

To evaluate the spatial dynamics of saltpan regeneration or abandonment, each site associated with traditional salt production was geolocated using satellite imagery (e.g., Google Maps). The physical condition of the saltpan units—based on visible features such as structural delineation, water presence, and maintenance—was used as a proxy for land use activity and socio-ecological engagement.

Each site was categorized along a gradient from active regeneration to visible abandonment. This classification enabled a comparative assessment of land-use change across regions and provided insight into broader socio-ecological trends, such as the loss or revival of ecosystem services, cultural landscapes, and community stewardship.

A simple spatial index was calculated to estimate the proportion of area under each regeneration condition, informing the selection of representative case studies for further analysis. Below is the generic equation to determine the degree of regeneration that should be applied for each site:

$$A_i = A_t \cdot P_i \quad \text{Eq. 1}$$

Where:

A_i is the area with the degree of regeneration i .

A_t is the total area.

P_i is the proportion of the total area that has the degree of regeneration i (expressed as a value between 0 and 1). From Figure 2 the Condition is according to the following: $0 \leq A < 0.25$ (red), $0.25 \leq B < 0.5$ (orange), $0.5 \leq C < 0.75$ (yellow) and $0.75 \leq D < 1$ (green).

Because there are varying degrees of regeneration, all areas must be added together to ensure that they cover the total area:

$$\sum_{i=1}^n A_i = A_t \quad \text{Eq. 2}$$

3.6. Data Analysis and SES–LULCC Interpretation

Satellite imagery was analyzed with attention to seasonality and recency, as these factors affect the visibility of land-use features. Saltpan conditions were classified along a regeneration–abandonment continuum, serving as a proxy for social–ecological engagement and land-cover change.

These observations were interpreted within the broader SES context—highlighting links between land-use activity, habitat condition, and human presence. The analysis informs whether saltpan landscapes are undergoing ecological revitalization or socio-economic decline, and whether these trends signal resilience, transitions, or opportunities (e.g., eco-tourism, habitat restoration).

4. Findings

4.1. Trends in Saltpan Dynamics and Land Use Transitions

The data indicate a notable contraction in active saltpan areas between 2018 and 2019, reflecting a temporary decline in land use intensity. However, a gradual recovery followed, particularly in the Central and Algarve regions—suggesting regionally differentiated social–ecological resilience (Fig. 3A,B).

In terms of land cover, the Algarve shows consistently larger and more stable production zones, especially for fleur de sel (FoS), signaling a transition from abandonment to multifunctional use (e.g., production + tourism). Meanwhile, central Portugal exhibited fluctuating trends, highlighting sensitivity to socio-economic and environmental pressures (Fig. 3C,D).

The Algarve's dominance in both production area and output—particularly for FoS—suggests a stronger feedback loop between ecological maintenance and market-driven service diversification. The results point to an ongoing but uneven landscape transition, shaped by human investment, ecosystem viability, and evolving land use practices (Fig. 3E,F).

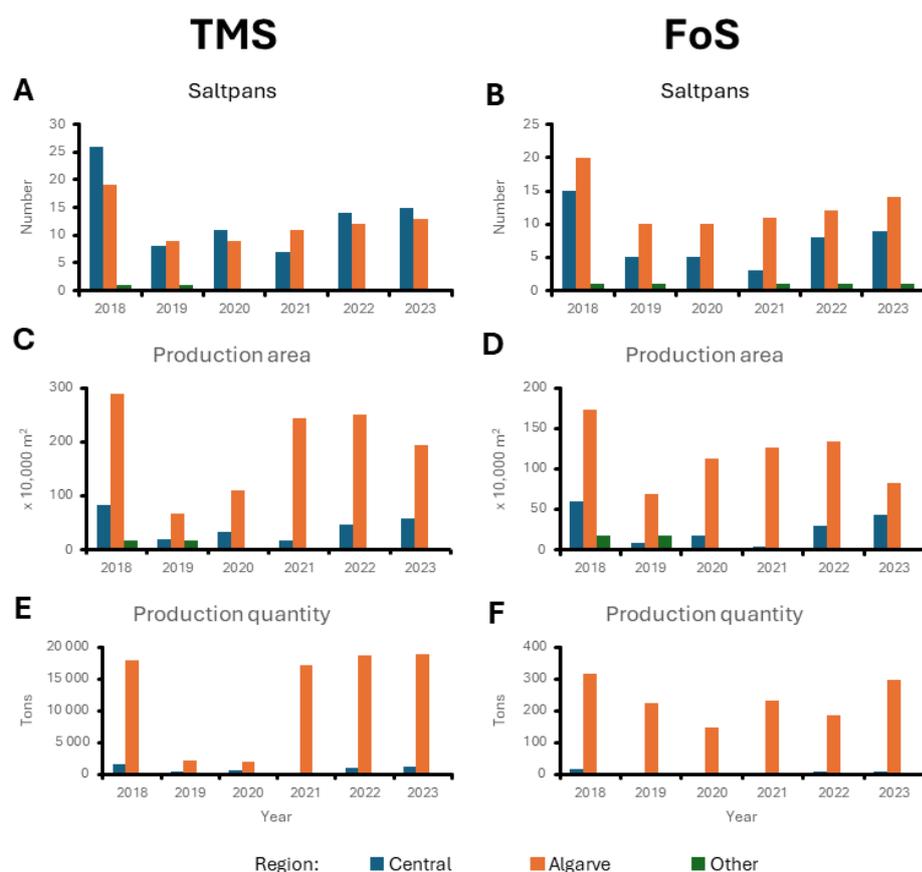


Figure 3. Histograms representing traditional marine salt (TMS) and flower of salt (FoS) data from the official annual statistics yearbook INE (2018-2024) [58–64].

4.2. Main Social–Ecological Saltscapes in Portugal

The spatial distribution of fleur de sel (FoS) and marine salt production in Portugal reveals three major coastal regions. These regions are undergoing dynamic land use and land cover transitions within coupled social–ecological systems (Table 2).

Table 2. Quantitative data related to traditional salt production areas (TSP) in Portugal. Sources: INE [58–64,70]. Note: n.a. stands for non-available data.

Region and municipality	Inhabitants (2021)	Municipality area (km ²)	People density (Pop/km ²)	TSP area (ha)	Estimated TSP jobs (No. workers)
<i>Centre</i>					
+ Aveiro	80,880	198	408	~270	100-150
+ Figueira da Foz	62,125	379	164	~300	n.a.
<i>Lisbon and Tagus</i>					
+ Rio Maior	21,192	273	78	2.7	20-30
+ Alcochete	17,569	128	137	~360	n.a.
<i>Algarve</i>					
+ Faro	60,995	203	300	~200	n.a.
+ Olhão	45,396	131	347	~400	50-70
+ Tavira	26,167	607	43	~290	n.a.
+ Castro Marim	6,747	301	22	~540	200-250

In the central region (e.g., Aveiro, Figueira da Foz), historical saltscapes near urban centers are being reconfigured for tourism and cultural services, often adjacent to restored wetlands. Rio Maior represents an inland exception, where rock salt extraction contributes to a unique socio-environmental niche.

In the Lisbon region, marginal but persistent activity continues in the Alcochete saltmarsh, embedded in a peri-urban landscape. Here, conservation, cultural heritage, and ecosystem service provisioning increasingly shape land-use practices.

The Algarve remains the most active and ecologically resilient zone, driven by favorable climatic conditions (Fig. 4) and entrepreneurial regeneration of saltpans. Land use in this region reflects an adaptive trajectory, where production, tourism, and biodiversity conservation increasingly co-evolve.

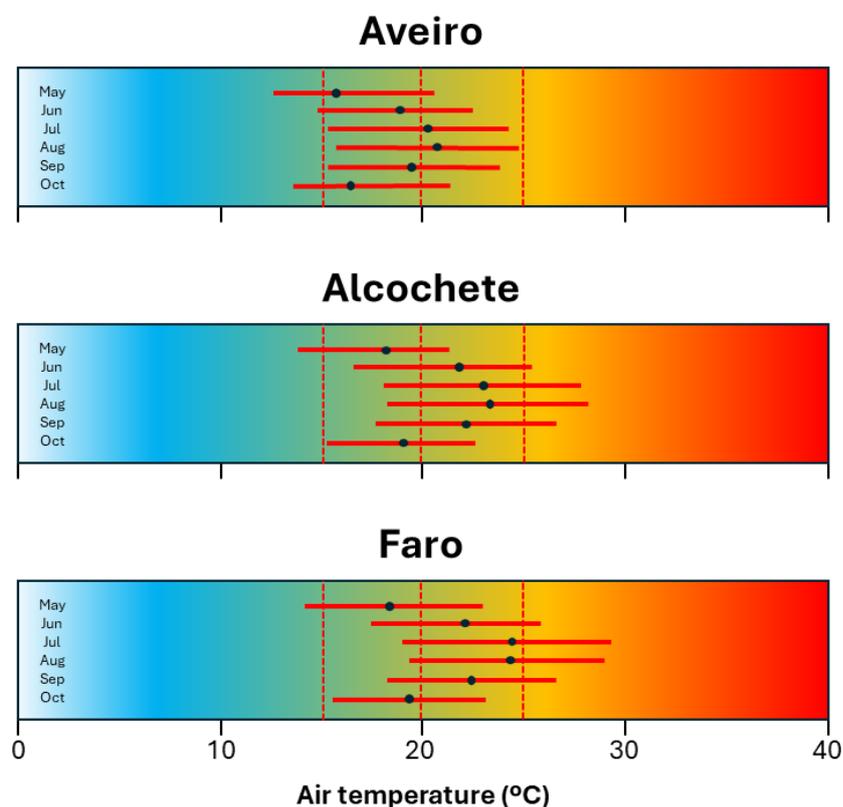


Figure 4. Comparison of the highest average temperatures for some cities located in each of the three traditional sea salt producing regions in Portugal. Source: IPMA [71].

4.3. Assessing Regeneration Through Social–Ecological and Land Use–Land Cover Change Indicators

The hypothesis was evaluated through a spatial cross-analysis of aerial imagery and national statistical datasets on salt production. Results reveal evidence of landscape-scale regeneration in multiple salt-producing areas, with observable changes in land cover configuration and social–ecological function.

In most regions analyzed—particularly in the Central region (e.g., Aveiro, Figueira da Foz) and the Algarve—saltpans show visible signs of maintenance, water management infrastructure, and active crystallization ponds, indicating ongoing or revitalized use (Fig. 5). These land cover patterns, verified against production statistics, suggest not just physical regeneration but reintegration into local economic and ecological systems, including tourism, heritage interpretation, and biodiversity conservation.

Contrastingly, the Alcochete saltmarsh complex, despite being within a protected area and adjacent to urban centers, shows limited regeneration. Only one active saltpan remains, and aerial imagery indicates broader landscape degradation and encroachment by vegetation, suggesting reduced social engagement and declining management effort. This highlights how socio-institutional factors—such as ownership models, proximity to cultural circuits, and tourism investments—play a pivotal role in determining LULCC trajectories in saltpan landscapes.

Overall, the regeneration observed reflects a shift from abandonment toward multifunctional land use: combining niche salt production, cultural ecosystem service delivery, and habitat management. These patterns provide empirical support for interpreting saltpans as evolving social-ecological systems influenced by feedback between governance, land management, and environmental change.

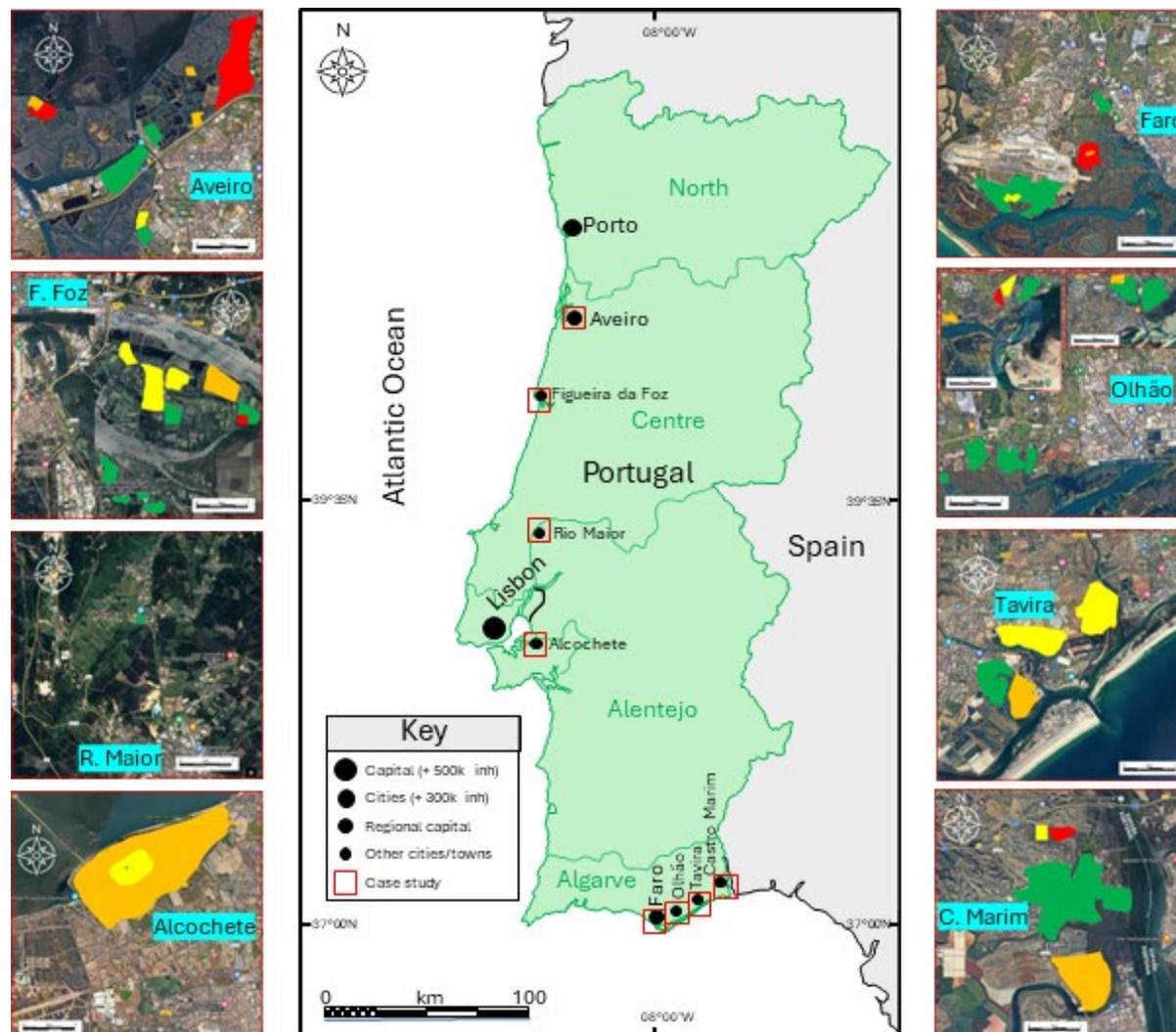


Figure 5. Central map illustrates the spatial distribution of active and formerly active salt pan landscapes across mainland Portugal, identified as part of broader land use–land cover transformations. Surrounding panels provide detailed views of these sites, classified by a four-tiered color code indicating the state of landscape change: green represents ecologically and socially regenerated areas with active land management; red marks complete abandonment with no visible maintenance or use. Yellow and orange indicate transitional stages of partial reactivation or degradation. This classification reflects degrees of social-ecological integration and land use continuity. *Source: Adapted from satellite imagery (Google Maps) and overlaid with field-informed classifications.*

4.4. Data Analysis

The integration of aerial imagery and statistical data reveals varying degrees of land use continuity and regeneration across Portugal's salt pan landscapes. Despite methodological uncertainties inherent to visual classification, a general pattern emerges: several coastal areas show active regeneration, while others reflect stagnation or abandonment (Fig. 6).

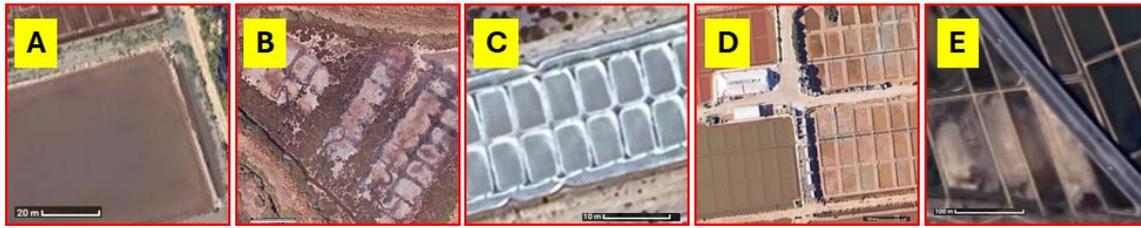


Figure 6. Aerial imagery illustrates varying land use conditions of salt pan landscapes, highlighting different stages of abandonment, regeneration, and reconfiguration. A) Highly degraded salt pans with long-term abandonment alongside recently reactivated units, reflecting land-use transition dynamics. Location: Olhão. B) Persistent inactivity in former saline landscapes, with limited ecological or productive function. Location: Alcochete. C) Salt pans showing signs of recent but discontinued use, suggesting ongoing pressure from social and economic drivers. Location: Castro Marim. D) Seasonally reactivated units indicating adaptive land use based on environmental and economic conditions. Dry, structured pans (right) contrast with flooded ones (left), pointing to spatial variability in management. Location: Olhão. E) Large-scale industrial salt extraction infrastructure, distinguishable by scale and surrounding transport networks (e.g., highway). Location: Alcochete. Source: The aerial images were adapted from Google Maps.

Classifying salt pan conditions from aerial imagery involves uncertainties, particularly in distinguishing between active, abandoned, and repurposed uses. For example, industrial salt or aquaculture sites can resemble traditional pans without careful interpretation. Visible indicators such as aeration systems in aquaculture help differentiate these land uses, but classification errors remain possible.

Despite these challenges, aerial data confirm that Castro Marim hosts the largest concentration of salt pan landscapes in Portugal. In this low-population municipality, the extensive saline infrastructure appears to function as a key socio-economic and ecological asset, contributing significantly to local land use dynamics and identity (Table 3).

Table 3. Spatial distribution of key salt pan landscapes by region and municipality across mainland Portugal. The table presents an assessment of land use conditions based on aerial imagery (Google Maps) and a simplified classification system (from Equations 1 and 2), estimating the proportion of salt pan areas in different stages of ecological regeneration (Categories P_A to P_D). This evaluation reflects broader patterns of landscape transformation, abandonment, and reactivation within coastal social-ecological systems.

Region/municipality	TSP area (ha)*	Condition			
		P _A	P _B	P _C	P _D
<i>Centre</i>					
+ Aveiro	~270	0.5	0.15	0.05	0.3
+ Figueira da Foz	~300	0.05	0.25	0.4	0.3
<i>Lisbon and Tagus</i>					
+ Rio Maior**	2.7	0	0	0	1
+ Alcochete	~360	0	0.9	0.09	0.01
<i>Algarve</i>					
+ Faro	~200	0.19	0.01	0.05	0.75
+ Olhão	~400	0.05	0.05	0.1	0.8
+ Tavira	~290	0	0.25	0.5	0.25
+ Castro Marim	~540	0.05	0	0.05	0.9

*TSP area includes not only the crystallizers, but also evaporators and water reservoirs. **The salt produced is not TMS but salt from mine. The salt pans are not fed by marine water.

In Aveiro, approximately one-third of former salt pans show renewed activity, likely linked to eco-tourism and heritage valorization, as seen in lagoon tours and saline spas (Fig. 7A).

In Figueira da Foz, another third of the pans are regenerating, situated at the transitional freshwater–saltwater interface. Rio Maior, although not coastal, represents an inland regeneration effort motivated by cultural heritage preservation, indicating a different social driver.

Alcochete, in contrast, exhibits widespread abandonment post-urban infrastructure development (e.g., Vasco da Gama Bridge), with minimal regeneration efforts maintained by an environmental foundation.

The Algarve region—i.e., Castro Marim, Olhão, Tavira, and Faro—shows the most robust regeneration, where salt pans have been revitalized for both production and nature-based tourism (Fig. 7B,C). These areas benefit from favorable hydrological conditions (e.g., Ria Formosa’s multiple tidal inlets) and a growing interest in integrating economic activity with habitat conservation. Castro Marim stands out with the largest extent of active salt pans, where regeneration appears closely tied to local livelihoods and ecological function, reflecting a strong social-ecological dependency.

These patterns reflect broader land use–land cover changes shaped by intersecting environmental, cultural, and economic dynamics.



Figure 7. Tourism and recreational activities as emerging land use practices in regenerated salt pan areas, reflecting broader social-ecological transformations. A) Salt pan-based wellness facility (saline spa) in Aveiro, representing adaptive reuse of historical landscapes. Source: Frame from a report aired on national public television. B) Eco-tourism infrastructure integrated into a reactivated salt landscape in Olhão. Source: Photo courtesy of Veronika Rosová. C) Educational and interpretative visit to a salt pan site, illustrating community engagement with multifunctional land use. Source: Photo by the author.

5. Discussion

5.1. Salt Pan Landscapes as Social-Ecological Systems

Salt production areas—especially salt marshes and salt pans—extend beyond their economic function as extraction sites. Though industrial sea salt accounts for the vast majority of production in Portugal (83%) [64], the spatial context of saltscapes makes them increasingly relevant in land use transitions. These areas are often embedded in ecologically rich and protected zones such as wetlands, estuaries, and natural parks, creating unique intersections between ecological integrity, cultural value, and land use demand.

Despite low labor intensity in industrial salt operations, salt pan landscapes are under growing pressure and opportunity for alternative uses. Their ecological setting supports diverse biodiversity and ecosystem services, including bird habitats and carbon sequestration, while also offering potential for low-impact recreational and educational uses. As such, they represent evolving social-ecological systems where traditional extractive practices are being complemented—or replaced—by multifunctional land uses that integrate conservation, tourism, and environmental education.

5.2. *Reactivation and Adaptive Reuse of Saltscapes*

The regeneration of abandoned or underused salt pan areas is part of broader land use and ecological restoration dynamics in coastal Portugal [72]. While abandonment can lead to habitat degradation or spontaneous rewilding, reactivation—especially when ecologically sensitive—can enhance ecosystem function and social value [73]. These transformations are increasingly influenced by public discourse, spatial planning, and environmental regulation [74,75].

Field observations from this study reveal distinct regional patterns of land cover change, with some areas—particularly in the Algarve and Central regions—undergoing ecological or functional regeneration. These processes are often supported by hybrid models of use, such as eco-tourism, environmental education, and small-scale artisanal production. In these cases, reactivated salt pans are not merely production landscapes but become platforms for integrated ecosystem services and sustainable local economies.

5.3. *Cultural-Ecological Value and the Role of Tourism*

Regenerated saltscapes are often embedded with cultural heritage and environmental narratives that increase their attractiveness to visitors and planners alike [76,77]. Unlike industrial sites, which generally lack aesthetic and historical appeal, traditional salt pans—especially those situated in scenic or historically rich regions—offer experiences tied to both nature and culture. This makes them points of interest for local tourism and cultural interpretation [50,78].

Tourism-oriented reuse of salt pans—such as saline spas, nature trails, and educational programs—has emerged as a viable strategy to support multifunctional land uses [79]. These activities not only enhance visitor engagement but also contribute to the conservation of traditional practices and local identity. When planned carefully, they serve as catalysts for socio-economic revitalization while maintaining or even improving ecosystem function.

6. Conclusions

This study examined whether the landscapes historically associated with traditional salt production in mainland Portugal are showing signs of abandonment or regeneration, within a broader framework of social-ecological transformation and land use–land cover change (LULCC).

Using a combination of official statistical sources and spatial analysis through Google Maps imagery, it was possible to assess the condition of salt pan areas and categorize their trajectories across the country. Despite some limitations related to aerial image interpretation, this approach proved effective for identifying patterns of use, disuse, and reactivation.

Findings indicate a heterogeneous picture across regions, with notable evidence of regeneration, particularly in coastal areas with favorable climate and ecological value. In these contexts, salt pan areas are transitioning from single-function production zones to multifunctional landscapes. These shifts are driven by an interplay of environmental, economic, and social factors—such as protected area designation, tourism interest, cultural heritage value, and changing land use demands.

Key insights include:

- Saltscapes represent dynamic social-ecological systems, often situated at the intersection of natural conservation, heritage preservation, and land-based livelihoods.
- Their reactivation is frequently supported by multifunctional uses—including eco-tourism, environmental education, and artisanal salt production—which contribute to rural resilience and adaptive land management.
- Spatial and seasonal dependencies are important to consider because in more temperate northern latitudes, reactivation efforts are often constrained by climatic limitations, while southern regions show more consistent regeneration linked to tourism flows and environmental planning.

Overall, salt pans in Portugal are increasingly becoming sites of ecological and cultural revalorization, rather than strictly production-oriented spaces. Their evolving land use reflects broader LULCC processes where environmental, heritage, and socio-economic dimensions converge.

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Abbreviations

The following abbreviations are used in this manuscript:

FoS	Fower of salt
TMS	Traditional marine salt
TSPs	Traditional salt production areas

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