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Temporal and Spatial Analysis of the Environmental State of the Valencia Plain Aquifer Area Using the Weighted Environmental Index (WEI)

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Abstract

This article analyses the impact of urban sprawl on the Valencia Plain aquifer system from 1990 to 2018, focusing on land use and land cover (LULC) changes and their environmental implications. The study applies the Weighted Environmental Index (WEI), a composite indicator based on a functional landscape perspective, to quantify changes in the environmental value over time. The WEI combines CORINE Land Cover and World Settlement Footprint data to enhance spatial resolution and urban land detection. The results show a significant territorial transformation, with urban surfaces expanding by 70% and rainfed agricultural areas declining by over 59%. Consequently, the WEI decreased from 44.80 in 1990 to 40.68 in 2018, representing a 9.2% reduction in the environmental value. These changes threaten the sustainability of key ecosystems such as the Albufera Natural Park and indicate a reduced capacity to deliver ecosystem services, including aquifer recharging, biodiversity conservation, and climate regulation. The findings underscore the need for integrated land-use planning, the protection of peri-urban agricultural areas, and the implementation of nature-based solutions to counteract the environmental impacts of urban growth in Mediterranean metropolitan contexts.

Keywords: land use–land change; indicator; environment; Albufera Natural Park

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1. Introduction and Objectives

1.1. Conversion of Agricultural Land into Urban Land

The conversion of agricultural land for urban use is a major driver of territorial change, which is primarily driven by population growth, economic expansion, and accelerated urbanisation [1–3]. This process exerts increasing pressure on fertile land, with significant implications for food security, ecological integrity, and the socio-economic fabric of urban and peri-urban areas [4–6]. D'Amour et al. [7] warn that the projected urban growth could severely impact global farmland, leading to the displacement of agricultural activities and a decline in rural livelihoods. Ayele and Tarekegn [8] similarly note that urban land appropriation is a frequent outcome of economic growth, particularly in rapidly developing contexts. In parallel, rising land-use competition and the fragmentation of agricultural landscapes challenge effective resource management and spatial planning [9]. These

patterns reflect broader territorial decoupling processes, which are influenced by neoliberal models of urban and rural development under contemporary capitalism [10].

In Mediterranean regions, land-use transitions are closely linked to cascading environmental impacts, including deforestation, biodiversity loss, and, ultimately, desertification. The substitution of agricultural mosaics and natural vegetation with artificial surfaces disrupts ecological networks and species habitats [11,12] while also diminishing the land's capacity to retain moisture, regulate microclimates, and control soil erosion [13,14]. This degradation of ecosystem functions increases susceptibility to desertification, particularly under conditions of water scarcity and climatic variability typical of the Mediterranean basin [15,16]. These processes—deforestation, biodiversity decline, and land degradation—are interrelated outcomes of anthropogenic land-cover change, highlighting the necessity for integrated territorial planning and environmental management strategies in the region [17].

Urban sprawl further intensifies agricultural land conversion. Several authors advocate for "smart growth" policies that promote compact urban development and protect agricultural land, emphasizing the role of sustainable land-use planning in mitigating the adverse effects of urban expansion [18]. Other studies underscore that urban encroachment onto farmland is a global challenge, with significant implications for food production and natural resource management [19]. The loss of high-quality agricultural land to urban development undermines local food systems and contributes to broader environmental issues, including deforestation and biodiversity loss [20].

The interplay between urban expansion and agricultural land conversion is further influenced by economic dynamics. As urban areas expand, the demand for residential, commercial, and industrial space increases, frequently encroaching on agricultural land. Pahlevi et al. [21] demonstrate that proximity to urban centres is a key driver of land-use change, with agricultural areas often repurposed for industrial and residential development. This trend poses a growing concern for food security, as urban agricultural land plays a crucial role in sustaining food production for expanding populations [22].

The environmental impacts of this conversion are also substantial. Urban sprawl contributes to land degradation, exacerbates desertification, and intensifies the effects of climate change [20]. Fragmentation of agricultural land not only reduces the arable surface area but also disrupts ecological processes, negatively affecting biodiversity and local ecosystems [23]. Thus, the loss of agricultural land transcends land-use concerns, intersecting with broader environmental and sustainability challenges. As noted by Azadi et al. [24], the ecological consequences of urbanisation are particularly acute in regions experiencing rapid farmland conversion. The reduction in agricultural land—an essential provider of ecosystem services—can diminish the ecological quality and resilience for both urban and rural populations [25].

In addition to environmental impacts, the socio-economic consequences of agricultural land conversion are significant. The displacement of farming communities and the associated loss of livelihoods can intensify poverty and social instability, particularly in developing regions. As urban expansion advances, many farmers are compelled to abandon agricultural activities, leading to shifts in occupation and lifestyle [26]. This transition frequently results in the erosion of traditional agricultural knowledge and cultural heritage, increasing the vulnerability of populations reliant on agriculture.

To mitigate the negative effects of urbanisation, effective land-use planning and policy frameworks that prioritise the preservation of agricultural land are essential. Robinson et al. [27] underscore the importance of growth management strategies to counter urban sprawl, advocating for proactive policies that support both farmland conservation and sustainable urban development. Moreover, the implementation of expansion indices

to monitor and regulate land-use changes can enhance environmental governance and contribute to more informed decision-making processes [28].

Nogueira and Rico [29] report that land-use changes in the Iberian Peninsula between 1990 and 2012 show a marked shift from agricultural to urban land, primarily driven by urban growth and an increasing demand for residential and commercial infrastructure. This pattern is consistent with broader European trends, where land-use-change hotspots reveal that urban sprawl frequently encroaches upon fertile agricultural zones, leading to significant reductions in land productivity [30,31]. Economic factors further intensify these pressures, as agricultural land typically generates lower returns compared with urban uses, prompting landowners to favour more profitable conversions [32]. Jiménez and Campesino [33] examine the case of Extremadura, Spain, where the shift towards an unsustainable urban model illustrates the replacement of traditional productive agricultural systems with less-efficient urban activities. This transformation poses risks to food security and weakens the socio-economic stability of rural communities dependent upon agriculture.

1.2. Urban Pressure in Natural Protected Areas

Urban pressure on protected natural areas has emerged as a critical challenge in contemporary environmental management, particularly as urbanisation increasingly encroaches upon ecologically sensitive zones. A major concern is the expansion of development around protected areas, which threatens their ability to maintain ecological integrity. Gimmi et al. [34] warn that such areas risk becoming isolated ecological "islands" embedded within urban and agricultural matrices, thereby reducing their effectiveness in biodiversity conservation. This issue is evident in the United States, where urban growth rates near protected areas exceed national averages, accelerating the loss in conservation value [35]. Urban encroachment disrupts habitat structure and connectivity, contributing to significant biodiversity loss through habitat reduction and fragmentation.

The proximity of expanding urban areas to protected zones intensifies land-use pressures. Vukomanovic et al. [36] found that both legal protection status and distance from urban boundaries significantly affect land-use intensification, with higher residential densities and landscape transformation occurring closer to national parks. This highlights the vulnerability of buffer zones to secondary pressures, including increased agricultural expansion, infrastructure development, and urban sprawl—all of which contribute to the degradation of ecological functions.

These dynamics are not limited to local or regional contexts. As Guerra et al. [37] emphasize, the global scale of land-cover change within protected areas necessitates strategic spatial planning to ensure that the siting and expansion of conservation zones are resilient to urban encroachment. This is particularly relevant in rapidly urbanising regions, where land competition is intense and regulatory enforcement may be weak. D'Amour et al. [7] further note that the effectiveness of urban containment strategies varies widely, being shaped by local socio-political conditions and the strength of institutional commitments to conservation objectives.

In the Mediterranean region—particularly in Spain—the impacts of urban sprawl on protected natural areas are well documented. Luna et al. [38] report that habitat destruction resulting from urban expansion has contributed significantly to biodiversity loss. Tena and Tellería [39] highlight that this effect is especially severe for species reliant on habitats located within or near protected areas, many of which coincide with ecologically optimal zones. The degradation of these habitats disrupts critical ecological processes, leading to long-term declines in ecosystem functionality. Marull et al. [40], through their analysis of landscape changes in the Barcelona metropolitan region, underscore the im-

portance of traditional rural landscapes in sustaining the ecological quality of non-urban areas. Their findings advocate for a systemic approach to conservation that integrates agroforestry mosaics, cultural landscapes, and protected networks into cohesive biodiversity management strategies.

Urban development in Spain has also exhibited a tendency to occupy high-quality agricultural and natural land. Salvati et al. [41] observe that urban sprawl often targets the most productive soils, creating a dual environmental threat: the reduction in land suitable for food production and the deterioration of ecological buffers essential to the functionality of nearby protected areas. These pressures are further amplified by socio-economic drivers such as speculative real estate investment and deficiencies in territorial planning. Gómez et al. [42] illustrate how the real estate boom has promoted unsustainable land-use patterns that frequently override conservation objectives due to weak regulatory frameworks and limited enforcement capacity.

1.3. Objective of This Research

In this context, the objective of the present study is to conduct a temporal and spatial analysis of the environmental condition of the Valencia Plain aquifer area through the application of the Weighted Environmental Index (WEI) [43]. This index offers a quantitative and spatially explicit framework for assessing the environmental impacts of urban expansion. For the first time, the analysis integrates two globally recognised land-use datasets: CORINE Land Cover (CLC), which provides harmonised European land-cover data, and the World Settlement Footprint (WSF), a high-resolution satellite-derived dataset capable of accurately capturing urban growth patterns [44]. The combined use of CLC and WSF within the WEI framework allows for a robust evaluation of land-cover transformation processes in metropolitan areas experiencing high anthropogenic pressure, such as the Valencia Plain.

This study contributes to the literature by addressing a key gap: the longitudinal assessment of environmental value in a rapidly urbanising Mediterranean region. Focusing on the Valencia metropolitan area, the analysis examines urban sprawl between 1990 and 2018, with particular attention on the conversion of agricultural land to urban use. The results offer valuable insights into the ecological consequences of land-use change and provide a scientific basis for informed territorial planning and biodiversity conservation strategies.

2. Materials and Methods

2.1. Study Area

The Valencia Plain, located in the Valencian Community on Spain's eastern coast (Figure 1), constitutes a coastal lowland characterised by a complex mosaic of urban, agricultural, and hydrogeological systems that play a central role in the territorial dynamics of the western Mediterranean. This study concentrates on the Valencia Plain aquifer, a key hydrogeological unit that underpins regional water supplies and that mediates critical interactions between urban development, agricultural activity, and natural ecosystem conservation. The study area includes the city of Valencia, a large portion of its metropolitan surroundings, and the Albufera Natural Park—a coastal wetland of high ecological and socio-economic value. This landscape lies within one of the most rapidly transforming Mediterranean corridors, marked by intense urbanisation and dynamic land-use change. The spatial proximity and functional interdependence among the urban core, peri-urban agricultural areas, and the Albufera ecosystem generate considerable environmental pressures. In particular, the Albufera Natural Park, situated immediately south of Valencia, faces increasing threats from urban encroachment, intensive farming, and complex water

resource management challenges that compromise its ecological integrity and long-term sustainability [45,46].

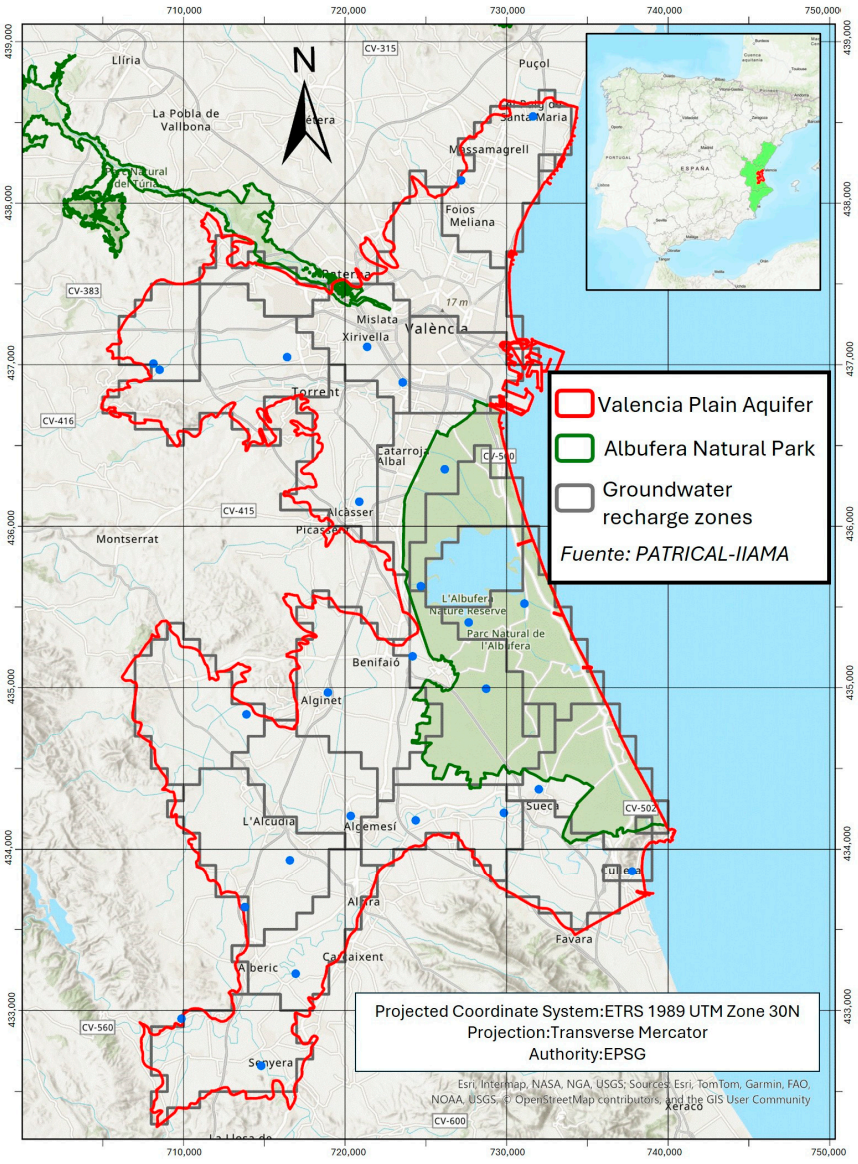


Figure 1. Location of the Valencia Plain aquifer system and the Albufera Natural Park.

The Albufera Natural Park spans approximately 21,000 hectares and includes a coastal freshwater lagoon hydrologically connected to the Mediterranean Sea via a system of gates and canals. Over centuries, this ecosystem has been significantly altered by human activity, especially through the transformation of wetlands into rice cultivation areas.

From the perspective of socio-ecological systems and their historical co-evolution, it is essential to conduct environmental analyses using a bioregional framework [10]. Considering the interlinked territorial components—namely the city of Valencia and its metropolitan region, the Valencia Plain aquifer, and the Albufera Natural Park—this study conceptualises the Valencia Plain as a functional landscape unit. This unit represents a complex territorial system in which diverse elements interact across the urban–rural gradient, delivering essential ecosystem services. For its environmental assessment, the Weighted Environmental Index (WEI) [43] is proposed as the methodological tool, as detailed in the following section.

2.2. The Weighted Environmental Index (WEI) Revisited

The WEI is a comprehensive analytical tool designed to quantitatively assess the environmental quality and land-use change within a defined territorial framework. It integrates heterogeneous data sources—primarily from Geographic Information Systems (GIS)—to deliver detailed spatial analyses of land-use patterns and their ecological implications. The WEI is particularly suited to contexts where land transformation processes exert significant pressure on environmental sustainability and ecosystem integrity. More than a numerical metric, the WEI constitutes a structured methodology that synthesises multiple indicators reflecting the ecological status of a given area [43].

The index supports temporal assessments of land use and land cover (LULC) changes, offering insights into landscape dynamics across various spatial scales. Its effectiveness has been demonstrated in detecting agricultural land-conversion trends and their environmental consequences [43]. Through the integration of GIS databases, the WEI enables a robust evaluation of how urbanisation impacts both agricultural and natural systems. Its applicability has also been confirmed in studies of land-use changes related to solid waste landfills, underscoring the index's adaptability to a range of environmental challenges [43].

The development of the WEI addresses the need for a rigorous and integrative framework capable of managing complex environmental datasets. It has been particularly useful in ecologically sensitive regions such as Doñana (Spain), where it has been applied to track land-cover changes and their consequences for environmental sustainability [47]. By consolidating large and diverse datasets, the WEI facilitates a systemic understanding of how multiple factors converge to shape environmental quality—insights that are essential for informed decision-making in both policy and management contexts.

A key methodological feature of the WEI is its capacity to incorporate weighted environmental indicators, reflecting their relative importance within the overall assessment. This weighting mechanism ensures that the index accurately captures the environmental significance of different land-use dynamics. Rodrigo-Ilarri et al. [43,48] emphasise the critical role of indicator selection and weight assignment, advocating for context-specific approaches that enhance the index's relevance to distinct ecological settings.

Beyond theoretical applications, the WEI has proven to be a practical tool in land-use planning and environmental management. By quantifying the environmental quality associated with different land-use configurations, it enables stakeholders to assess the ecological implications of development scenarios. This is especially pertinent in rapidly urbanising territories, where unchecked expansion frequently results in ecological degradation. The integration of the WEI into planning instruments can support the mitigation of such impacts by offering spatially explicit diagnostics of environmental conditions.

The WEI also contributes to the broader discourse on sustainability and environmental governance. Its structure aligns with the principles of the triple bottom line, incorporating ecological, economic, and social dimensions into sustainability assessments [49]. The significance of weighting strategies in environmental indices has been further explored by [50], who highlight their influence on the effectiveness of conservation programmes—an insight directly applicable to the WEI's implementation.

Moreover, the WEI is well suited for rural environmental-quality assessments, where multiple variables must be simultaneously considered. Xu et al. [51] underscore the importance of integrative indices in evaluating ecological change in rural areas, particularly in the context of agricultural land conversion. The WEI, by structuring such indicators into a coherent index system, offers a robust tool for this purpose.

The index is equally effective in urban contexts. Hu et al. [52] and Zhang et al. [53] applied similar multidimensional approaches to assess the impacts of urbanisation on habitat quality in rapidly developing regions. Their findings demonstrate the utility of

environmental indices like the WEI in linking land-use changes with ecological outcomes, reinforcing its role in supporting conservation strategies.

Rooted in GIS-based analysis, the WEI benefits from high spatial resolution and analytical precision. GIS technology enhances the capacity to detect spatial patterns and monitor temporal changes across heterogeneous landscapes, offering insights often unattainable through traditional assessment methods. This geospatial foundation makes the WEI particularly valuable for evidence-based environmental decision-making.

The reviewed literature confirms the WEI's versatility across a wide range of environmental issues—from waste management and rural land conversion to urban encroachment and habitat degradation. As anthropogenic pressures on land resources intensify, the WEI emerges as a critical instrument for guiding sustainable territorial governance. Its ability to distil complex environmental data into actionable insights positions it as an indispensable tool for researchers, planners, and policymakers engaged in sustainable land and resource management.

According to the definition of the WEI index [43], Table 1 shows the values of the five evaluation factors (F_j) and the value of the WEI index for every land use considered by CORINE (WEI_k) for the current study area:

Table 1. Evaluation factors (F_j) and WEI index values for every land use considered by CORINE (WEI_k).

	Code	Description	F_1	F_2	F_3	F_4	F_5	WEI_k
1. Artificial surfaces	111	Continuous urban fabric	30	30	10	20	10	20
	112	Discontinuous urban fabric	30	30	10	20	10	20
	121	Industrial or commercial units	30	30	10	20	10	20
	122	Road and rail networks and associated land	20	40	20	15	5	20
	123	Port areas	10	10	10	10	10	10
	124	Airports	10	10	10	10	10	10
	131	Mineral extraction sites	10	10	10	10	10	10
	132	Dump sites	0	0	0	0	0	0
	133	Construction sites	30	30	10	20	10	20
	141	Green urban areas	60	65	70	80	75	70
	142	Sport and leisure facilities	20	20	20	20	20	20
2. Agricultural areas	211	Non-irrigated arable land	60	65	40	50	50	53
	212	Permanently irrigated land	60	65	80	75	70	70
	213	Rice fields	60	10	80	45	55	50
	221	Vineyards	60	65	80	75	70	70
	222	Fruit trees and berry plantations	60	65	80	75	70	70
	223	Olive groves	60	65	80	75	70	70
	231	Pastures	80	80	90	100	100	90
	241	Annual crops associated with permanent crops	60	37	80	60	62	60
	242	Complex cultivation patterns	47	59	70	66	57	60
	243	Land principally occupied by agriculture	75	75	75	72	72	74
	244	Agro-forestry areas	90	90	100	100	85	93

Table 1. *Cont.*

	Code	Description	F_1	F_2	F_3	F_4	F_5	WEI_k
3. Forest and semi-natural areas	311	Broad-leaved forest	100	100	100	100	100	100
	312	Coniferous forest	100	100	100	100	100	100
	313	Mixed forest	100	100	100	100	100	100
	321	Natural grasslands	80	80	80	80	80	80
	322	Moors and heathland	100	100	100	100	100	100
	323	Sclerophyllous vegetation	100	100	100	100	100	100
	324	Transitional woodland–shrub	70	70	70	70	70	70
	331	Beaches, dunes, sands	100	100	50	100	100	90
	332	Bare rocks	80	50	30	30	60	50
	333	Sparsely vegetated areas	70	70	70	70	70	70
	334	Burnt areas	0	50	0	0	0	10
	335	Glaciers and perpetual snow	100	100	100	100	100	100
4. Wetlands	411	Inland marshes	90	60	70	90	90	80
	412	Peat bogs	100	100	100	100	100	100
	421	Salt marshes	80	50	30	80	60	60
	422	Saline areas	90	30	40	80	60	60
5. Water bodies	423	Intertidal flats	80	50	30	80	60	60
	511	Water courses	100	100	100	100	100	100
	512	Water bodies	100	100	100	100	100	100
	521	Coastal lagoons	100	100	100	100	100	100
	522	Estuaries	80	50	30	80	60	60
	523	Seas and oceans	100	100	100	100	100	100

F_1: Anthropic or nature of activity developed in the soil.

F_2: Water consumption associated with land use.

F_3: Soil degradation (use of chemicals).

F_4: Environmental sustainability of land use (stability of the ecosystem).

F_5: Landscape value of activity carried out in the analysed area.

The evaluation factors and environmental index values assigned to each land-cover category, as presented in Table 1, were established through an expert-based adaptation process. These values were specifically aligned with the CORINE Land Cover (CLC) classification system by adapting the original weighting criteria developed in [43], a methodology previously validated by the authors of this study. To ensure ecological relevance and methodological consistency, expert consultation was conducted to refine the assignment of environmental weights to the CLC categories. This approach enabled a robust and context-sensitive translation of the original WEI framework into the CLC nomenclature, thereby enhancing its suitability for long-term, spatially explicit environmental assessments in Mediterranean urban–agricultural systems.

2.3. Adaptation of the Use of WEI to CORINE Land Cover (CLC) and World Settlement Footprint (WSF) Data

The WEI has been developed as a tool for environmental assessment based on land occupation, enabling the quantification of the evolution of a territory's ecological value according to various indicators of anthropogenic pressure. Initially, the WEI was applied using the SIOSE database (Sistema de Información sobre Ocupación del Suelo de España—Spanish Land Occupancy Information System) [43], yielding relevant results in studies on landfills in the Valencian Community and land-use changes in the vicinity of the Doñana Natural Park [47].

In this study, a methodological adaptation of the Weighted Environmental Index (WEI) is proposed through the integration of two complementary geospatial datasets:

CORINE Land Cover (CLC) and the World Settlement Footprint (WSF). This combined approach enhances the spatial and temporal resolution of land-occupation-change analysis, particularly in densely urbanised and peri-urban environments where land-cover dynamics are more complex and rapidly evolving.

CORINE Land Cover, a long-standing European initiative, provides harmonised land-use and land-cover data for the period 1990–2018, updated in six-year intervals. Its hierarchical classification system allows for differentiation among the main categories and subcategories of land use, facilitating alignment with the land-cover typologies used in the WEI framework. In this study, CLC datasets from 1990, 2000, 2012, and 2018 were employed. Each CLC class was assigned an environmental index value based on established criteria, including the degree of anthropogenic disturbance, water consumption, soil-degradation potential, ecological stability, and landscape value [47].

To complement the CLC data, the World Settlement Footprint (WSF) database was incorporated to improve the accuracy of urban-area delineation. Specifically, the WSF-Evolution product, which has been based on annual Landsat imagery since 1985 with a spatial resolution of 30 metres, was used to trace urban growth patterns. The inclusion of WSF data is particularly valuable for detecting fine-scale urban changes in fragmented and rapidly transforming peri-urban zones, where moderate-resolution sources such as CLC may be insufficient [44].

The methodological complementarity of the two datasets lies in the structured, widely adopted classification of CLC—supporting consistency and replicability—paired with the high-resolution urban detail provided by WSF. Their integration strengthens the analytical capacity of the WEI to more accurately characterise territorial transformations driven by urbanisation, especially in areas of high ecological and socio-economic relevance.

The study area encompasses the Valencia Plain, including the city of Valencia and its surrounding metropolitan area, as well as the traditional agricultural landscape of orchards (huertas) and rice paddies adjacent to the Albufera Natural Park—a protected wetland of significant environmental value. The adaptation of the WEI using CLC and WSF datasets supports a more robust assessment of the spatial and temporal evolution of anthropogenic pressures in this territory, thereby providing a solid basis for interpreting their ecological implications in subsequent phases of the analysis.

3. Results

The results of this analysis reveal temporal changes in land use and vegetation cover from 1990 to 2018, quantified using the standardised WEI, which reflects variations in anthropogenic pressure and ecological quality over time.

3.1. Soil Dynamics Between 1990 and 2018

Table 2 and Figures 2 and 3 present the dynamics of land use and land cover (LULC) changes in the Valencia Plain during the period 1990–2018. Detailed values for every LULC use are provided in a specific Excel sheet as Supplementary Materials.

Table 2. Temporal dynamics of land use and land cover (LULC) changes.

Description	1990 (km^2)	2000 (km^2)	Variation 1990–2000	2012 (km^2)	Variation 2000–2012	2018 (km^2)	Variation 2012–2018	Variation 1990–2018
Urban	168.97	216.78	+47.81	274.82	+58.04	287.56	+12.74	+118.59
Crops	741.73	697.88	−43.85	628.58	−69.30	618.44	−10.14	−123.29
Trees	4.10	4.08	−0.02	4.90	+0.82	5.04	+0.14	+0.94
Grass	0.33	0.41	+0.08	7.01	+6.60	6.10	−0.91	+5.77
Shrubs and Scrub	15.72	14.39	−1.33	12.07	−2.32	11.18	−0.89	−4.54

Table 2. *Cont.*

Description	1990 (km^2)	2000 (km^2)	Variation 1990–2000	2012 (km^2)	Variation 2000–2012	2018 (km^2)	Variation 2012–2018	Variation 1990–2018
Bare ground	3.11	3.43	+0.32	1.75	−1.68	1.88	+0.13	−1.23
Water	33.69	31.12	−2.57	31.86	+0.74	31.61	−0.25	−2.08

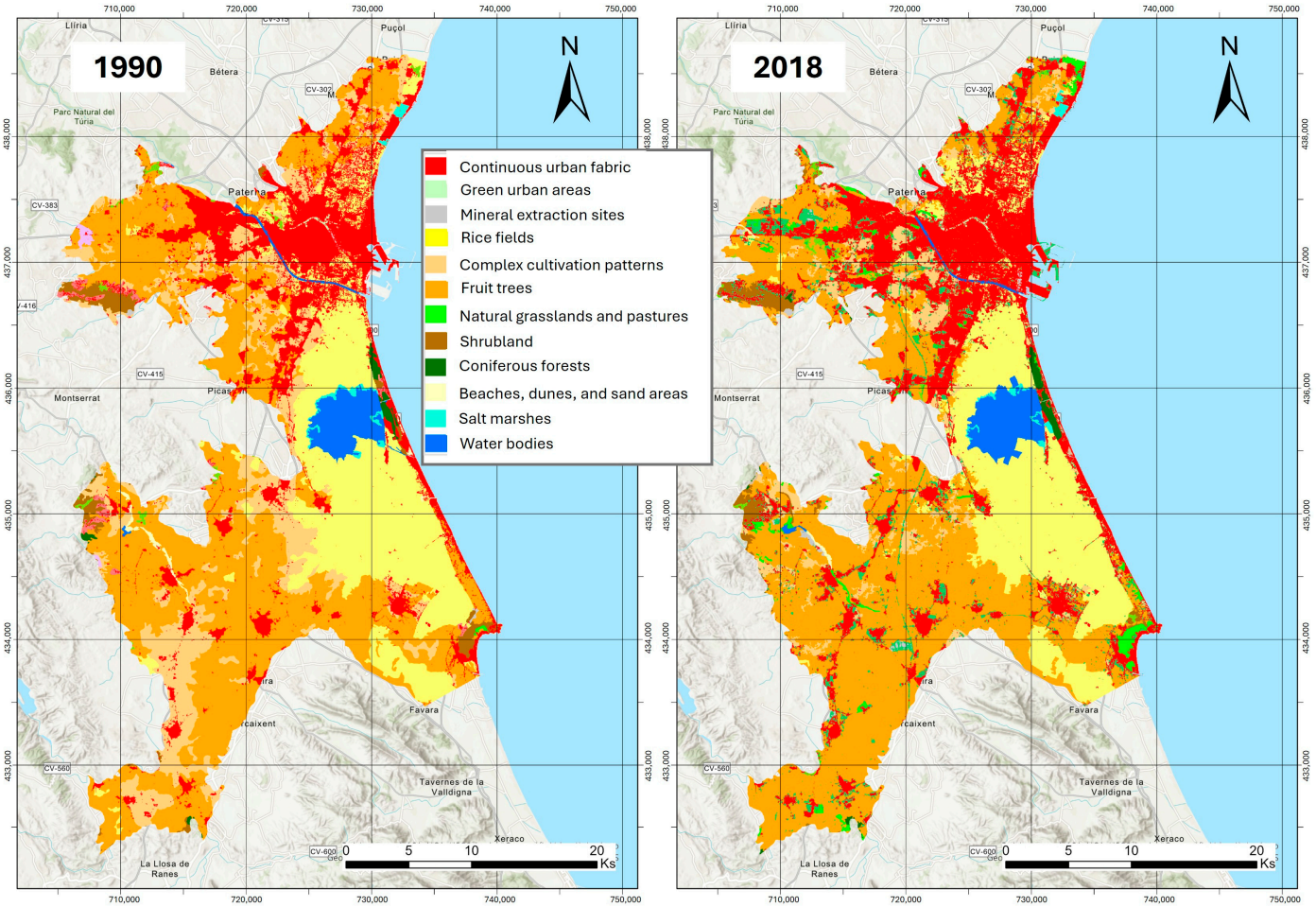


Figure 2. LULC in the Valencia Plain aquifer area in 1990 (**left**) and 2018 (**right**), based on CLC and WSF data.

The analysis indicates substantial territorial transformation in the Valencia Plain, driven by urbanisation processes, economic restructuring, and environmental pressures [45,47]. A key finding is the marked expansion of urban areas, which increased from 168.97 km^2 in 1990 to 287.56 km^2 in 2018—representing a 70% growth over 28 years. The most rapid urban expansion occurred between 2000 and 2012, during which 58.04 km^2 were added. This growth spans multiple urban subcategories, including port facilities, industrial and commercial zones, transportation infrastructure, and construction sites, reflecting the accelerated pace of land occupation by urban uses [45].

Conversely, agricultural land experienced a continuous decline, with a net reduction of 123.29 km^2 over the study period. This trend was most pronounced in rainfed croplands, which decreased by nearly 59%, while irrigated agriculture remained relatively stable, showing only a marginal decrease of approximately 1%.

Grasslands and pasture areas increased significantly—from just 0.33 km^2 in 1990 to 6.10 km^2 in 2018, peaking at 7.01 km^2 in 2012—indicating a notable rise in this land-cover category.

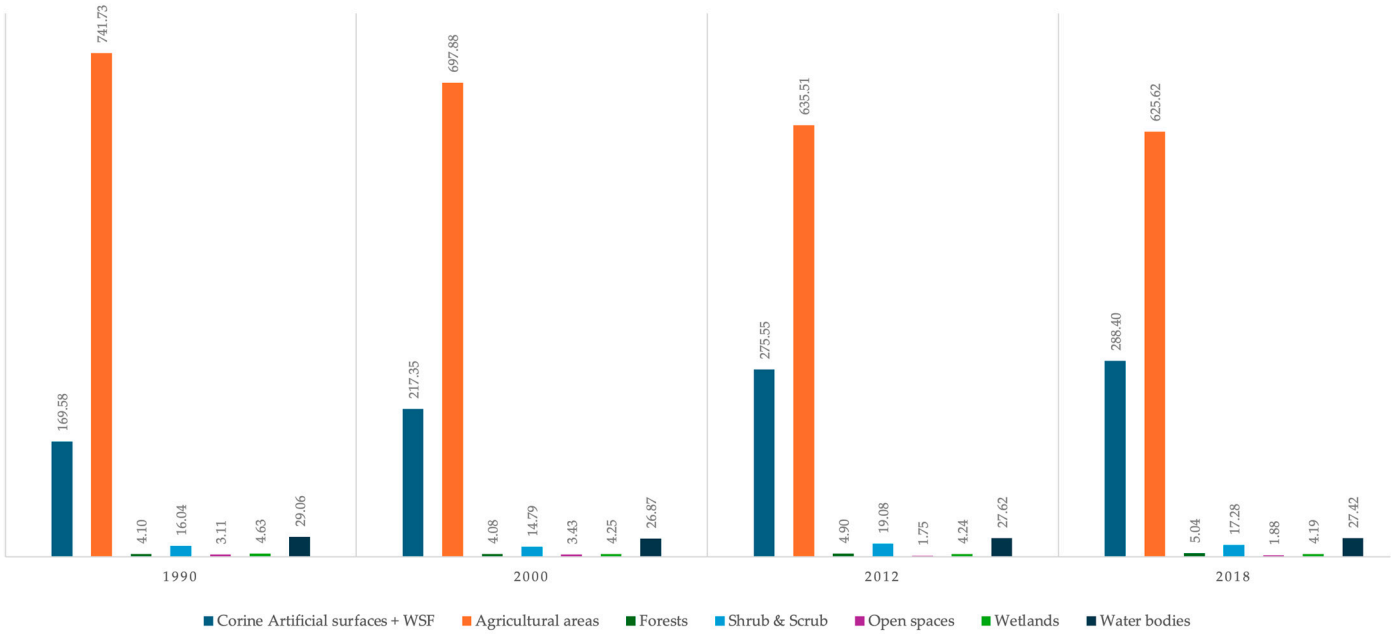


Figure 3. LULC evolution in the Valencia Plain aquifer area between 1990 and 2018, based on CLC and WSF data.

In terms of natural and semi-natural land covers, several recovery trends were observed. Coniferous forests expanded from 4.10 km^2 in 1990 to 5.04 km^2 in 2018 (+23%), with the most substantial growth occurring between 2000 and 2012. Sclerophyllous vegetation exhibited a particularly pronounced increase of 143% over the same period, suggesting processes of natural regeneration, especially during the early 2000s [47].

In contrast, shrubland and scrubland experienced a cumulative loss of 4.54 km^2 between 1990 and 2018. Bare-ground areas also declined, with a net decrease of 1.23 km^2, although they displayed intermediate fluctuations throughout the study period.

Water bodies remained largely stable, with a slight net decrease of 2.08 km^2 (from 33.69 km^2 in 1990 to 31.61 km^2 in 2018), which is potentially linked to climatic variability and shifts in water management practices [45].

These findings reveal clear trends of urban expansion and agricultural contraction, alongside more nuanced changes in natural land-cover categories. These patterns will be further examined in the following sections, which address their ecological implications and relevance for sustainable territorial planning.

3.2. Dynamic of Soil Use Using the WEI Index

The analysis of land use and land cover (LULC) change in the Valencia Plain from 1990 to 2018 reveals significant alterations in territorial configuration, with direct consequences for ecological systems. To evaluate the environmental impact of these transformations, the Weighted Environmental Index (WEI) was applied. This index provides a quantitative and integrative assessment of territorial sustainability by assigning relative environmental values to each land-use category [47].

As shown in Table 3 and Figure 4, the WEI for the study area demonstrates a consistent downward trend over the analysed period, decreasing from 44.80 in 1990 to 40.68 in 2018. This decline reflects the progressive loss of land uses with higher ecological value, primarily

those associated with urban expansion and the reduction of agricultural land, particularly rainfed croplands, which contribute substantially to the environmental balance of the region.

Table 3. WEI historical dynamics.

Year	Total WEI	Area (km^2)					
		Urban	Irrigated Crops	Rainfed Crops	Trees	Natural Pastures	Bare Ground
1990	44.80	168.97	589.87	151.86	4.10	0.33	3.11
2000	43.23	216.78	572.32	125.56	4.08	0.41	3.43
2012	41.15	274.82	566.92	61.66	4.90	7.01	1.75
2018	40.68	287.56	563.69	54.75	5.04	6.10	1.88

Figure 5 presents the spatial distribution of changes in the WEI across the Valencia Plain between 1990 and 2018, delineating zones of environmental degradation, stability, and regeneration. Areas marked in red represent territories where WEI values have declined, indicating environmental-degradation processes. These zones are primarily concentrated in urban and peri-urban areas, where the expansion of the city of Valencia and its metropolitan region has resulted in the conversion of agricultural and semi-natural land into impervious surfaces. This transition has negatively affected key ecological functions, including soil infiltration capacity, local biodiversity, and microclimatic regulation. Furthermore, the fragmentation and degradation of former agricultural corridors have reduced ecological connectivity and diminished the provision of ecosystem services. Coastal areas also exhibit notable degradation, reflecting the impact of tourism-driven development and increased anthropogenic pressure on littoral ecosystems.

Zones shown in yellow correspond to areas where the WEI values remained relatively stable throughout the study period, reflecting minimal changes in environmental quality. These areas include long-standing irrigated agricultural lands—such as rice fields and citrus orchards—that have maintained consistent land use, as well as protected natural areas that have retained their ecological integrity despite being embedded within increasingly transformed surroundings. Consolidated urban areas established prior to 1990 are also included in this category, as they experienced no significant land-use changes during the analysed timeframe. While these zones currently demonstrate environmental stability, they may be subject to future pressures associated with urban expansion and infrastructure development driven by regional economic growth [45].

In contrast, the areas highlighted in green represent territories where WEI values increased, indicating ecological regeneration. These improvements are largely attributable to the abandonment of marginal agricultural lands, which have undergone natural revegetation processes, leading to enhanced ecological quality. Several of these regenerating zones are also associated with land under active conservation management, where restoration efforts have effectively contributed to environmental recovery.

Overall, the spatial patterns depicted in Figure 5 demonstrate the utility of the WEI as a diagnostic and interpretive tool for identifying gradients of environmental degradation, stability, and recovery in landscapes undergoing rapid territorial transformation.

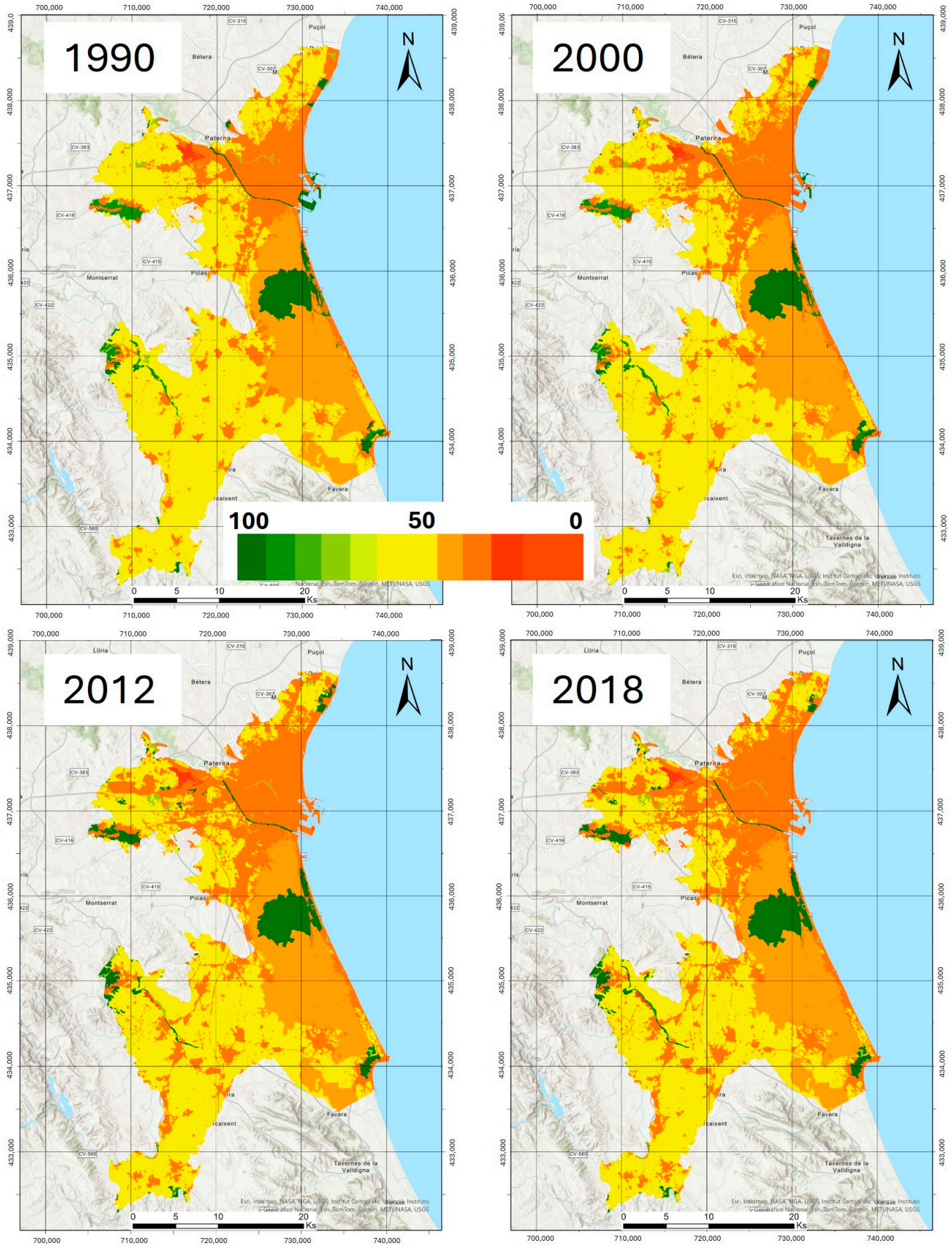


Figure 4. WEI distribution in 1990, 2000, 2012, and 2018 in the study area.

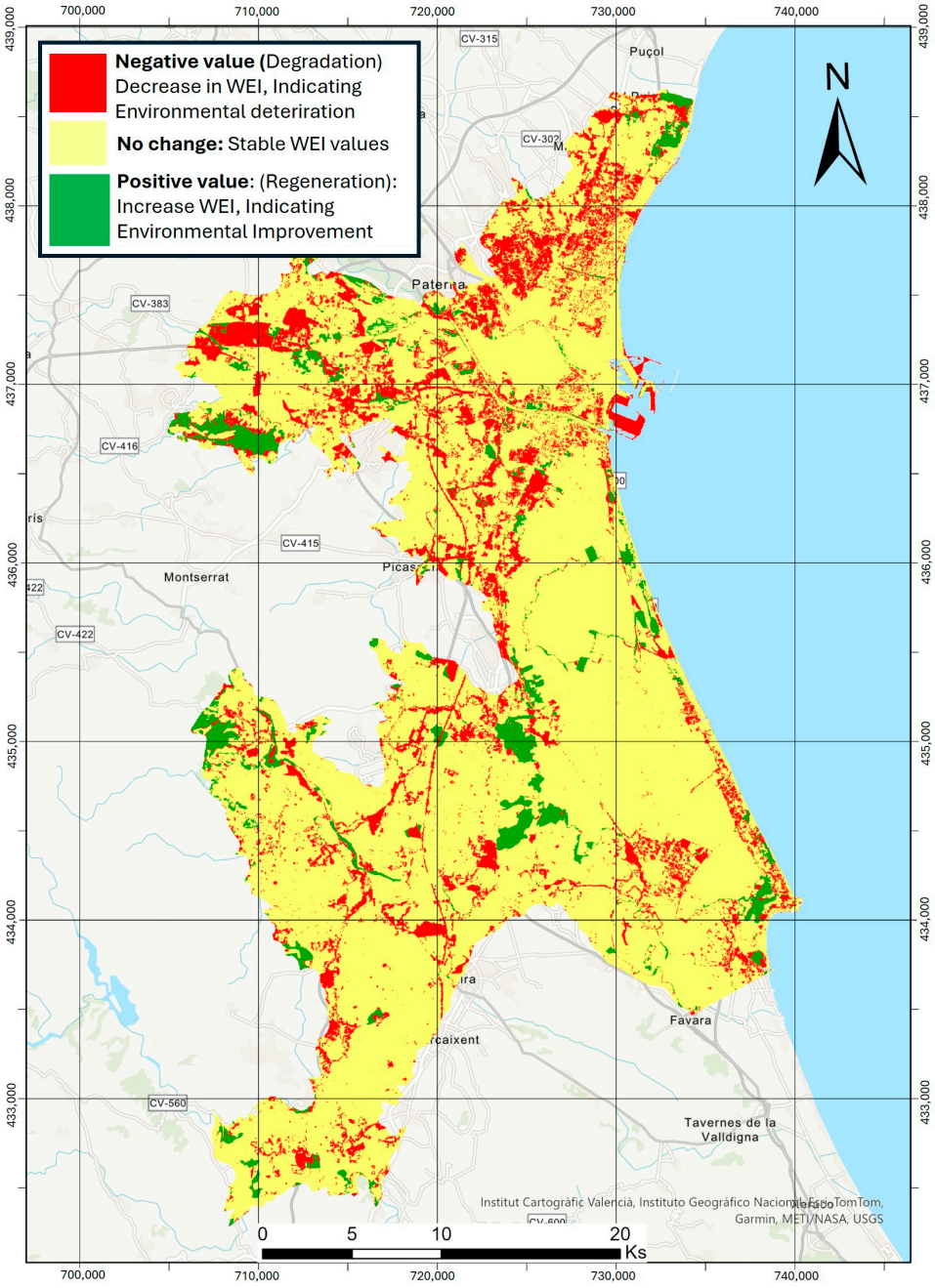


Figure 5. WEI evolution in the study area between 1990 and 2018.

4. Discussion

The analysis of the WEI for the Valencia Plain between 1990 and 2018 reveals a pronounced transformation of the territory, marked by a progressive decline in its environmental value when considered as a functional landscape unit. The conversion of natural and agricultural land into urbanised areas has significantly reduced the capacity of the landscape to sustain key ecosystem services, including climate regulation, wildlife habitat provision, carbon sequestration, and the regulation of hydrological cycles. These services are fundamental not only for mitigating the environmental impacts of urbanisation [10] but also for enhancing the region's resilience to climate change [54].

As highlighted in a recent systematic review by [55], the preservation of at least 20–25% of natural or semi-natural habitats is essential for maintaining most of the critical ecosystem services in highly modified landscapes such as urban and agricultural regions.

In this context, the Valencia Plain exhibits a clear trend of territorial imbalance over the historical period analysed. As shown in Table 4, while urban areas maintained a relatively stable balance between 1990 and 2000, the situation deteriorated considerably from 2012 onwards. By 2018, the proportion of natural and semi-natural habitats had fallen below the 20% threshold, indicating a critical loss of ecological function and habitat availability within the landscape. This shift underscores the urgent need for spatial planning strategies that incorporate habitat conservation and ecological restoration as central components of sustainable territorial management.

Table 4. Relationship of natural and semi-natural areas with the landscape unit and with the two anthropogenic landscape elements.

Category (km^2)	1990	2000	2012	2018
Urban areas	168.97	216.78	274.82	287.56
Crops	741.7	697.88	635.51	625.62
Natural and semi-natural	57.56	54.00	58.31	56.65
Natural/Semi-natural vs. Valencia Plain	6.3%	5.9%	6.4%	6.2%
Natural/Semi-natural vs. Urban	34.1%	24.9%	21.2%	19.7%
Natural/Semi-natural vs. Crops	7.8%	7.7%	9.2%	9.1%

The results of the WEI analysis indicate that the transformation of the metropolitan territory in the Valencia Plain has been accompanied by a progressive decline in its environmental value. This trend is largely attributable to the expansion of urban areas at the expense of agricultural land—particularly traditional rainfed systems—which historically played a significant role within the bioregional territorial matrix. The conversion of natural and agricultural soils into urbanised zones has reduced the landscape's capacity to sustain critical ecosystem services, which include climate regulation, habitat provision, and water availability.

Comparative analysis with previous applications of the WEI in other contexts—such as the Doñana region and the broader Valencian Community—reveals a consistent pattern: environmental value tends to decline as a result of urban growth and the intensification of anthropogenic land uses. Nevertheless, the observed increase in the extent of urban green spaces and natural grasslands points to potential avenues for enhancing the environmental quality. These findings suggest that targeted conservation measures and the ecological restoration of degraded areas can contribute to reversing negative trends, reinforcing the importance of integrating ecological planning into urban development strategies.

4.1. Urban Expansion and the Decrease in the Environmental Value

As shown in Tables 2–4, elements associated with the expansion of urban surfaces experienced the most significant growth among all the landscape components. Notably, the continuous urban fabric, mining areas, industrial and commercial zones, transportation infrastructure, and construction sites have been the primary drivers of this transformation. This trend has contributed to the decline in WEI values, primarily due to the replacement of land categories with higher environmental value by more anthropised uses.

The consistently low WEI scores observed in urban areas are attributed to the high degree of land artificialisation, surface impermeabilisation, and biodiversity loss—factors that align with patterns documented in other Spanish regions where the WEI has been applied [47,48]. In addition to the widespread loss of natural and semi-natural habitats, urban expansion has been strongly correlated with the intensification of transportation infrastructure, which imposes a range of ecological impacts. These include habitat degradation, barriers to wildlife movement, edge effects, and increased mortality due to road collisions, all of which are extensively supported by the scientific literature [56].

The evolution of land use and land cover in the region, as illustrated in Figure 2, indicates a clear trajectory of urban growth accompanied by a corresponding reduction in agricultural and natural land. The most pronounced urbanisation occurred between 2000 and 2012, during which the urban surface expanded by 58.2 km^2. This period coincides with a surge in infrastructure development and residential construction, consistent with earlier studies on metropolitan expansion in Valencia. These studies highlight the influence of demographic growth and urban planning policies that favoured the creation of new residential, commercial, and industrial zones [57]. Furthermore, the expansion of the tourism sector has contributed to the increased occupation of coastal areas, intensifying demand for new urban developments and second homes [58].

Despite a nearly 38% increase in urban green spaces, their relative proportion within the total urban area has remained critically low, rising from 0.41% in 1990 to only 0.51% in 2018. This persistent deficit adversely affects urban liveability by limiting the provision of key ecosystem services, including cultural identity, mental and physical health benefits, microclimatic regulation, and biodiversity support [59,60]. Empirical research in the city of Valencia has demonstrated a strong positive correlation between thermal comfort and the availability of green spaces, with larger green areas having a more pronounced effect [61].

While high-value green infrastructure, such as the Turia River linear park, plays an important role, the city must significantly expand its green network to adequately fulfil ecological and social functions [60]. As emphasised by [62], future urban and territorial planning should prioritise (1) the protection and connection of high-value landscapes; (2) the maintenance of agricultural continuity; (3) the integration of infrastructure and peri-urban areas into the broader landscape; (4) the preservation and enhancement of cultural and visual heritage; and (5) the promotion of recreational uses within the Huerta of Valencia.

4.2. The Reduction in Agricultural Areas and Its Environmental Implications

As shown in Table 2, agricultural land in the Valencia Plain has decreased by 15.7%, corresponding to a loss of 123.29 km^2. This decline is attributable to two main drivers: the expansion of urban areas [63] and the abandonment of agricultural practices [64]. These trends reflect the dual pressures of urban–rural land competition and broader national dynamics favouring crop specialisation and intensification. In particular, agricultural production has increasingly shifted towards high-value, market-oriented crops that are typically reliant on irrigation and agrochemical inputs [65].

The expansion of built-up land (118.59 km^2) closely mirrors the contraction of cultivated land (123.29 km^2), with rainfed agriculture experiencing the most significant loss ($-$90.32 km^2), compared with a smaller reduction in irrigated areas ($-$25.79 km^2). Several interrelated factors contribute to this trend. Urbanisation, particularly on the outskirts of Valencia and in adjacent municipalities, has made land conversion more profitable than continued farming [66]. Concurrently, structural changes in the economy—including increasing tertiarisation and declining profitability in agriculture—have accelerated land abandonment, a trend that has been well documented across Mediterranean Europe [58] and Spain as a whole [67].

Abandoned agricultural land has, in many cases, undergone processes of ecological succession, as reported in previous studies of the western Mediterranean [68]. Moreover, the combined effects of climate change and water scarcity have further reduced the viability of rainfed systems, particularly under conditions of prolonged drought and growing inter-annual variability. This is consistent with research highlighting the vulnerability of southeastern Spain to hydric stress [69].

The loss of rainfed agricultural areas, especially those linked to traditional small-scale systems such as the Huerta of Valencia, has played a central role in the observed decline in the WEI. These multifunctional landscapes are recognised for their cultural, ecological, and aesthetic value, and their degradation poses a significant territorial challenge.

Despite this decline, the WEI in agricultural zones has remained above the critical threshold of 30, primarily due to the persistence of productive agricultural land that still maintains certain ecological functions. This intermediate level of environmental value reflects a complex balance: while agricultural activities, particularly those involving agro-livestock systems, exert pressure on ecosystems—such as through nutrient loading and water contamination—agriculture continues to be a key structural and functional component of the territory's environmental matrix.

Nevertheless, the ongoing conversion of agricultural land into urbanised areas has resulted in a notable decline in the provision of key ecosystem services, such as water regulation, carbon sequestration, and ecological connectivity between natural habitats. This loss of functionality reduces the resilience of the territory to the impacts of climate change and undermines the capacity of the landscape to buffer environmental disturbances.

In this context, it is essential to implement selective protection strategies for agricultural land, particularly those areas of high ecological, cultural, and productive value. Moreover, promoting agroecological practices can help restore the multifunctionality of the traditional Huerta of Valencia, enhancing its role not only as a productive landscape but also as green and cultural infrastructure. These measures would contribute to maintaining ecological integrity, improving climate adaptation capacity, and preserving the socio-environmental heritage of the region.

4.3. Evolution of the Environmental Value in the Albufera Natural Park

The metropolitan expansion of Valencia has significantly reshaped the southern territory adjacent to La Albufera, driven by the extension of infrastructure and residential developments over recent decades. This growth has disrupted the wetland's natural hydrological dynamics and intensified land demand for urban and tourism-related uses [46]. Historically agricultural and fishing communities, such as El Palmar and Pinedo, have undergone socio-economic transitions towards gastronomic tourism and recreational activities, progressively diminishing the importance of traditional livelihoods.

Urbanisation has altered the wetland's hydrological regime by disrupting its natural connectivity with the Turia and Júcar rivers, the primary sources of freshwater for the lagoon. The artificial regulation of water levels via hydraulic infrastructure has modified natural flood cycles, leading to degraded water quality and the loss of aquatic biodiversity [45]. Additionally, the expansion of transportation and utility infrastructure has fragmented the landscape, restricted species mobility, and diminished the system's capacity for ecological regeneration.

The prevailing urban development model in the Valencia Plain has exerted direct pressure on both agricultural and natural ecosystems, with the Albufera Natural Park representing one of the most critical cases. This protected wetland faces severe conservation and water management challenges [45,46]. Land sealing and the associated infrastructure have led to increasing landscape fragmentation, contributing to a measurable loss of biological connectivity. Previous studies have documented reductions in both maximum and minimum patch sizes within the park, indicating a trend towards structural homogenisation of the landscape matrix [70].

Currently, the Albufera is in a state of advanced eutrophication, with high concentrations of nitrogen and phosphorus primarily resulting from agricultural runoff and urban wastewater discharges. These nutrient inputs promote phytoplankton blooms, which

reduce water transparency and impair aquatic ecosystems [45]. The lagoon, once dominated by submerged macrophyte communities, has undergone a regime shift towards phytoplankton-dominated conditions, significantly altering its ecological structure. Although rice cultivation remains a dominant land use—covering approximately 73% of the park's surface—it also acts as a significant environmental pressure due to the widespread use of agrochemicals that degrade the water quality [45].

While environmental management efforts have aimed to mitigate these impacts through regulatory measures and conservation programmes, public policy has largely prioritised the development of the Huerta of Valencia and the intensification of agricultural production. This policy orientation has often come at the expense of an integrated management strategy for La Albufera and its associated aquatic ecosystems, undermining the long-term ecological sustainability of the park [46].

4.4. The WEI: Between the Visible and Invisible Dimensions of the Water Cycle

Consistent with the trend of environmental degradation identified through the WEI analysis, the expansion of urban areas and the contraction of agricultural land—particularly traditional rainfed systems—are linked to a series of environmental impacts corroborated by official monitoring data and prior studies.

Urban growth has led to increased pressure on domestic water consumption, contributing to heightened demand across the metropolitan area. Parallel to this, the transformation of the Huerta of Valencia has shifted predominantly towards irrigated agriculture, further intensifying water resource use. Analysis of piezometric level records within the Valencia Plain aquifer system suggests that this rising demand has been primarily met through the increased utilisation of surface water sources. This is evidenced by a general recovery of groundwater levels in much of the aquifer system, with some localised exceptions, as illustrated in Figure 6. These dynamics point to a reconfiguration of water resource management in response to changing land-use patterns and reinforce the need for integrated planning that accounts for both quantitative and qualitative aspects of water sustainability.

From a qualitative perspective, both surface and groundwater resources in the Valencia Plain exhibit clear signs of degradation linked to agricultural and urban pollution. Nitrate monitoring conducted under Royal Decree 47/2022 reveals that nitrate concentrations in several monitoring wells significantly exceed the threshold of 35 mg/L established to prevent adverse effects on human health and ecosystems. Specifically, seven wells in the northern sector and four in the southern sector of the Valencia Plain show average concentrations ranging from 47–114 mg/L in the north and 42–144 mg/L in the south, confirming a widespread problem of nitrate contamination.

In lentic systems, three water bodies—Ullales de l'Albufera, Albufera de Valencia, and Marjal de Rafalell y Vistabella—have been identified as having been impacted by nitrates, with the latter two already exhibiting eutrophic conditions. These are driven by the combined effects of diffuse agricultural inputs and urban wastewater discharges. In lotic systems, 14 monitoring stations have recorded nitrate levels exceeding the 25 mg/L threshold for surface waters, as defined by the same regulatory framework. These points are distributed along the Júcar, Turia, Sellent, Verde, and Albaida rivers, as well as along the barrancos of Poyo and Picassent. Additionally, previous research has identified the presence of emerging contaminants—such as illicit drugs (e.g., cocaine and its metabolite benzoylecgonine) and pharmaceutical compounds (including carbamazepine, ibuprofen, acetaminophen, and sulfamethoxazole)—in effluents discharged into the Albufera [71], further signalling the anthropogenic degradation of the water quality.

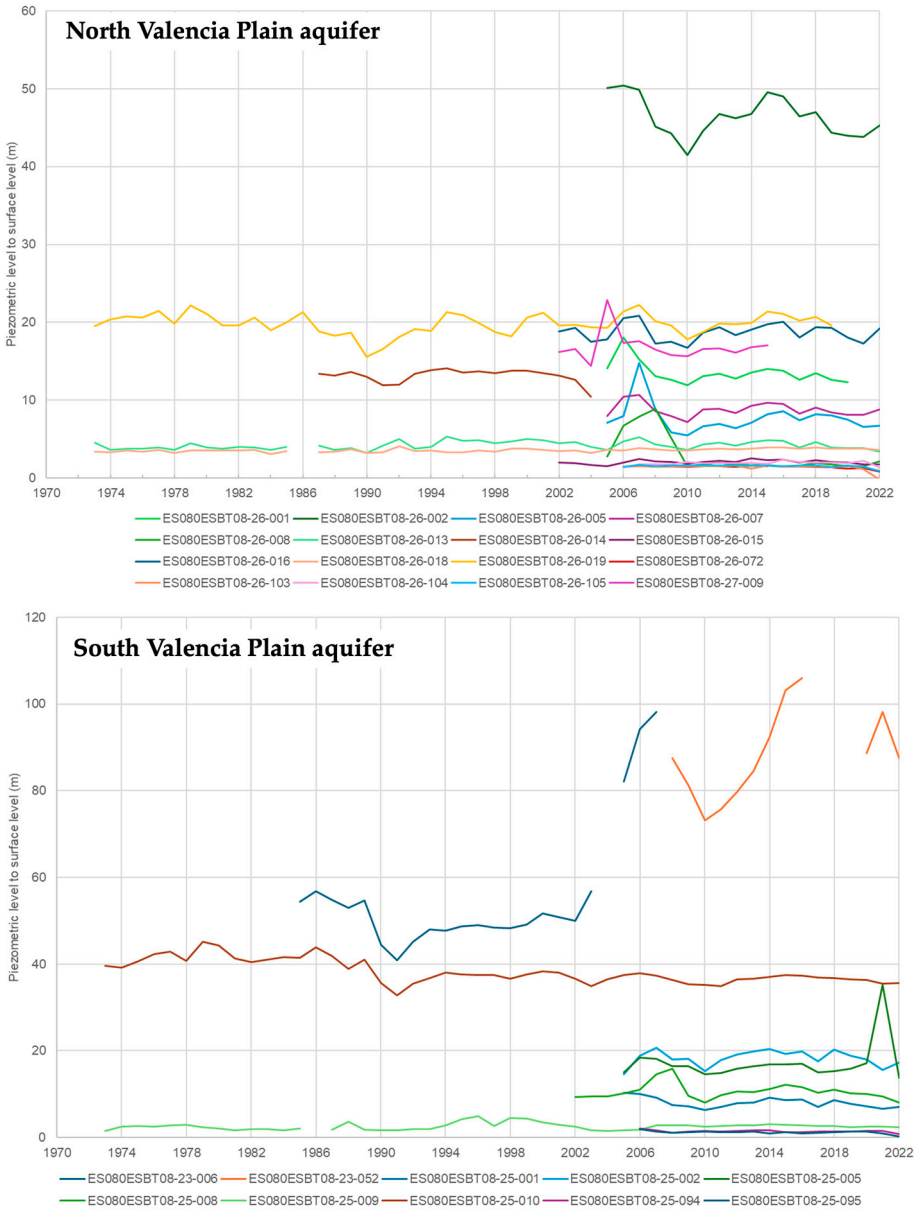


Figure 6. Piezometric levels of the Valencia Plain aquifer.

Soil sealing and the artificialisation of the drainage network represent another critical dimension of the environmental impact. These processes have increased the magnitude and velocity of surface runoff, intensifying flood risk—particularly in areas where urban development has encroached upon natural floodplains and ephemeral drainage systems such as ramblas and barrancos. This has elevated the exposure and vulnerability to extreme hydrometeorological events. A stark example is the flood event of 29 October 2024, triggered by a DANA (isolated high-altitude depression), which caused severe rainfall in the southern metropolitan area of Valencia. The resulting overflow of rivers and ravines led to the loss of over 220 lives in an area previously identified as flood-prone [72–74]—a risk that had been flagged in earlier studies but inadequately addressed in local urban planning decisions.

This situation highlights the urgent need for improved urban planning and comprehensive flood-risk management [75,76], including the implementation of nature-based solutions to mitigate runoff and to restore hydrological connectivity [77]. Figure 7 presents the official flood hazard map from the Territorial Action Plan on Flood Risk in the Valencian Community (PATRICOVA) [78], providing further evidence of the overlap between declining environmental quality—reflected in decreasing WEI values—and hydrological

vulnerability. These findings reinforce the conclusion that unregulated urban expansion not only accelerates ecological degradation but also amplifies the risk to human populations in the face of extreme climate-related events.

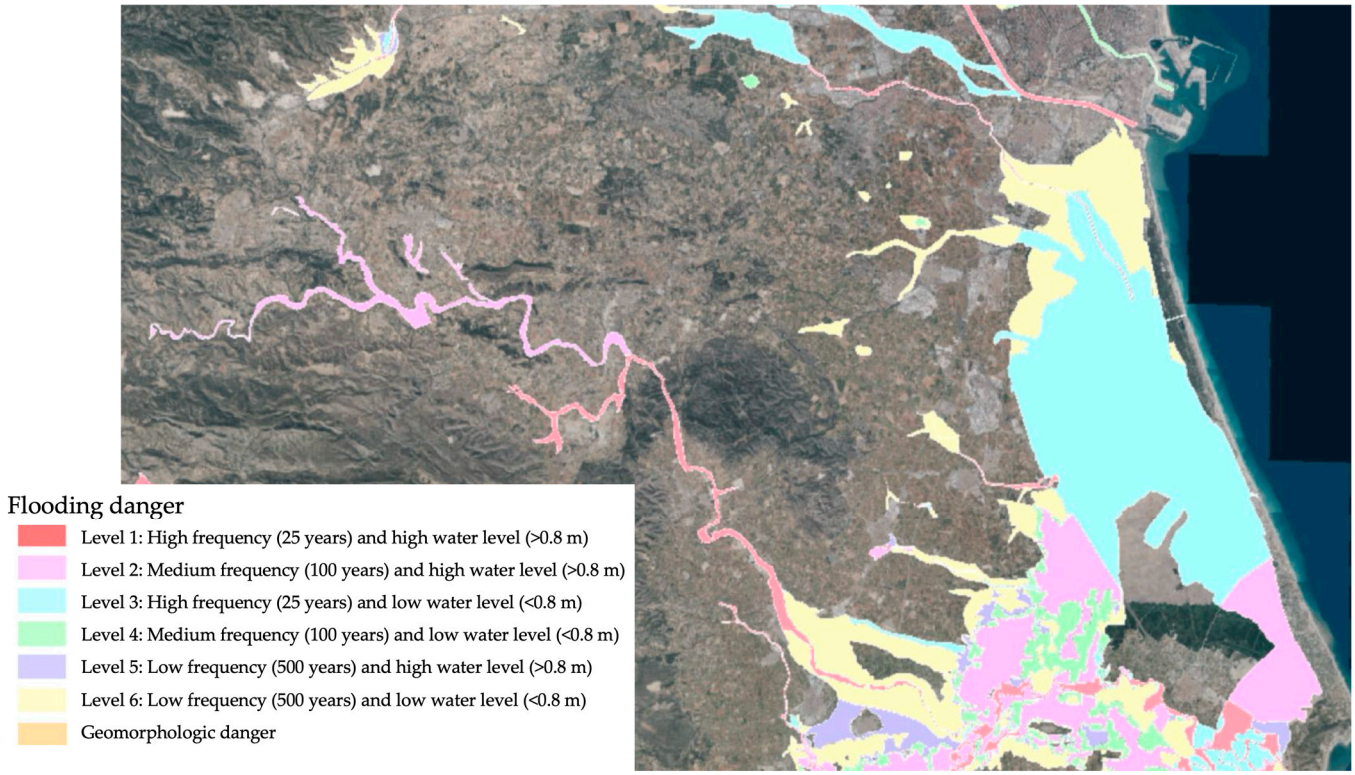


Figure 7. Flooding danger in the study area, according to PATRICOVA [78].

Table 5 summarises the variations in effective groundwater recharge across the Valencia Plain between 1990 and 2018 as derived from observed land use and land cover (LULC) changes. The results reveal a general decline in recharge rates, which correlates strongly with the expansion of urban land and the associated increase in impervious surfaces. As natural and agricultural areas have been progressively replaced by built-up environments, the soil's capacity for rainfall infiltration has diminished significantly. This transformation has led to greater surface runoff and a substantial reduction in groundwater recharge, particularly in the most urbanised zones of the study area.

The implications of this decline are hydrogeologically significant. A reduced infiltration capacity undermines the sustainability of the aquifer system, which is already under considerable stress due to competing demands from urban, agricultural, and industrial sectors. Moreover, the combined effects of soil sealing and the artificial modification of drainage networks exacerbate the decline in recharging, threatening both the quantity and quality of groundwater resources over the long term.

These findings align with the broader environmental degradation trends identified by the Weighted Environmental Index (WEI), reinforcing the conclusion that urban expansion not only contributes to landscape transformation and ecological decline but also impairs key hydrological functions critical to territorial resilience and water resource sustainability.

Table 5. Effective recharge variations between 1990 and 2018.

Zone	Urban (km^2)	Irrigated Crops (km^2)	Rainfed Crops (km^2)	Recharge (m)
8135010	2.28	−2.94	0.2	−0.06
8135022	6.3	−3.15	−4.21	−0.01
8135026	13.57	−10.03	−3.4	−0.05
8135040	7.28	−5.72	−1.69	−0.04
8135050	6.45	−4.93	−1.98	−0.05
8135060	7.49	−0.5	−7.17	−0.01
8135070	4.47	−4.25	0.47	−0.04
8135080	7.02	−3.73	−3.12	−0.04
8135090	10.19	−5.72	−6.04	−0.05
8135094	−0.01	−0.61	−0.01	−0.03
8135504	0.42	−1.26	0.33	−0.04
8135510	4.34	8.76	−13.84	−0.27
8135520	3.01	−3.97	−0.28	−0.21
8135522	5.75	15.42	−21.17	−0.25
8135526	4.54	−2.44	−2.47	−0.31
8135530	3.82	2.4	−6.55	−0.37
8135540	7.53	6.25	−13.79	−0.27
8135550	3.02	−2.39	−0.63	−0.33
8135560	2.08	1.11	−3.45	−0.08
8135570	2.52	−0.27	−2.27	−0.17
8135580	5.78	−5.16	−1.28	−0.11

4.5. Opportunities for the Recovery and/or Maintenance of Ecosystem Functions

Despite the overall trend of environmental degradation in the Valencia Plain, the analysis identifies certain opportunities for ecological regeneration. In particular, the observed increase in grassland cover in some areas may reflect natural recovery processes following agricultural abandonment. These zones have shown modest improvements in the WEI, suggesting partial restoration of ecological function; however, these gains are insufficient to counterbalance the broader decline in environmental value driven by urban expansion.

Of particular concern is the reduction in water bodies, which, although limited in surface area, represent ecosystems of high ecological value (WEI score: 96.67). Their decline may be attributed to hydrological alterations and intensified water extraction for urban and industrial purposes. Given their critical role in biodiversity support, hydrological regulation, and ecosystem connectivity, the loss of these systems poses a significant threat to regional environmental sustainability.

Comparison with previous WEI-based studies conducted in Doñana and the broader Valencian Community confirms a consistent trend of environmental value loss due to the intensification of anthropogenic land uses. Nonetheless, the parallel increase in urban green areas and naturally regenerating grasslands suggests that opportunities exist for reversing degradation through targeted conservation and ecological restoration strategies.

These findings highlight the urgent need for integrated territorial planning policies that promote sustainable urban development, protect high-value agricultural and natural land, and prioritise ecological integrity. Key measures include the adoption of compact urban growth models, the restoration and reconnection of floodplains, and the promotion of climate-resilient agricultural practices. Collectively, these strategies could help reconcile urban development with long-term landscape conservation and environmental resilience in the Valencia Plain.

5. Conclusions

The analysis of the Weighted Environmental Index (WEI) in the Valencia Plain from 1990 to 2018 reveals an accelerated process of territorial transformation, characterised by urban expansion occurring at the expense of agricultural and natural land. This pattern of urbanisation has significantly reduced the environmental value of the territory, compromising the provision of essential ecosystem services, including climate regulation, groundwater recharge, carbon sequestration, habitat availability, and biodiversity conservation.

The integration of the World Settlement Footprint (WSF) dataset with CORINE Land Cover (CLC) data enhanced the spatial resolution of built-up area detection. While the official CLC dataset for Spain offers harmonised land-cover data at a resolution of 100 m, the WSF dataset—derived from satellite imagery at 30 m resolution—allowed for a more detailed identification of both dense and dispersed urban development, which may be underrepresented in the CLC data. Furthermore, the temporal span of WSF (1985–2019) complemented the CLC dataset (1990–2018), enabling a more complete and consistent assessment of urban land-use change over time.

Nevertheless, the annual resolution of the WSF dataset limits its ability to detect intra-annual land-use dynamics or abrupt urban transformations. Accordingly, differences in spatial and temporal resolution between the two datasets were carefully addressed to minimise analytical bias and to ensure consistency in interpreting the results.

The findings confirm that urbanisation was particularly intense between 2000 and 2012, during which the urban surface increased by 58.2 km^2. This expansion was driven by sustained development pressure, the growth of the tourism sector, and structural shifts in the regional economy, which collectively contributed to the conversion of agricultural land into built-up areas. Over the entire study period, cultivated land decreased by 15.6%, reflecting the gradual erosion of a historically important agrarian landscape.

The impacts of this urban growth model extend beyond environmental degradation. Urban expansion into hydrologically sensitive areas—such as the floodplain of the Turia River—has significantly increased the flood risk, as exemplified by the DANA event of October 2024. This episode, which resulted in substantial material damage and over 220 fatalities, occurred in areas previously identified as flood-prone, underscoring the urgent need to incorporate climate resilience criteria into spatial planning and disaster risk-reduction frameworks.

Despite the general trend of degradation, the modest expansion of certain urban green spaces and natural grasslands points to potential opportunities for environmental regeneration. However, these improvements have not been sufficient to offset the overall decline in environmental value. This highlights the necessity of adopting land-use planning strategies that prioritise sustainability, ecological connectivity, and the conservation of strategic land resources.

In this context, promoting a more sustainable urban development model—based on compact growth, floodplain restoration, and the protection of high-value agricultural soils—is essential. The implementation of climate-resilient agricultural practices could also help mitigate biodiversity loss and support ecological functionality across the region.

These findings are consistent with similar trends observed in other Mediterranean landscapes, such as Doñana and the broader Valencian Community, where WEI applications have also documented environmental degradation linked to the intensification of anthropogenic land uses. This reinforces the importance of tools like the WEI for assessing the long-term impacts of land-use change on territorial sustainability and ecosystem service provision.

In parallel, a complementary line of research is currently under development by the authors, which is aimed at empirically validating WEI-based trends. This initiative involves

comparing WEI outputs with observed environmental indicators such as groundwater nitrate concentrations, biodiversity metrics, and land surface temperature. A research proposal addressing this topic has recently been submitted to the Spanish Ministry for Science, Innovation and Universities. If approved, the project will support the integration of multi-source environmental datasets and facilitate systematic cross-validation of the WEI across Mediterranean land systems, thereby enhancing its methodological robustness and policy relevance.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17135921/s1. WEI values and detailed distribution of areas for every specific LULC use for 1990, 200, 2012 and 2018.

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