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Effects of Agricultural Use on Endangered Plant Taxa in Spain

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Abstract: Agriculture is one of the most widespread human activities and has the greatest impact on terrestrial ecosystems, as it transforms natural ecosystems into artificial landscapes using, in many cases, large amounts of pesticides as well as overexploiting natural resources. Therefore, for effective biodiversity conservation, it is necessary to include agricultural systems in conservation programs. In this work, the 50 plant taxa described for Spain as threatened by agricultural use were selected. These were divided according to the type of threat into those affected by crop extension, intensification, or abandonment. In addition, information was obtained concerning their conservation status, level of protection and functional traits (life form, pollination, and dispersal). Finally, the evolution of land use, in the areas near the populations of the selected species, was identified. The selected taxa belong to 21 families and present different life forms and modes of dispersal or pollination. Forty-six percent are endangered (EN) and most are included in legal protection lists. Nearly three-quarters are threatened by crop expansion and land use dynamics, reflecting an expansion of cultivated areas, which adds further pressure to these species. In addition to agricultural expansion, taxa are also at risk, due to important rates of agricultural land abandonment, and mention agricultural intensification. Nevertheless, conservation measures do exist to promote biodiversity in agricultural landscapes that may help to reverse the negative effect of land use dynamics on selected species, but few are specific to threatened flora. Therefore, if threatened plants are to be conserved in agricultural areas, it is necessary to promote a profound transformation of our socioecological systems. One of these transformative changes could come from the human-nature reconnection.

Keywords: threatened plant; agriculture; Spain; land use; conservation; human-nature reconnection

1. Introduction

Anthropogenic activities have been altering the natural environment for thousands of years, affecting the structure and functioning of ecosystems [1,2]. Anthropogenic biomes occupy more than 75% of the terrestrial land surface [3], and humans currently appropriate more than one third of global net primary productivity [4]. This has contributed to overcoming several of the planetary boundaries proposed as a safe operating space for humanity [5]. In order to provide resources, food, and contribute to global food security, agriculture has extended during the last decades and actually occupies one-third of the ice-free land surface and almost half of potentially productive land area [2,6]. Thus, it is considered one of the most widespread human activities worldwide [7]. Agriculture transforms natural ecosystems into artificial ones created and managed by humans [8]. This has, in many cases, severe environmental impacts such as soil degradation [9], greenhouse gas emissions [10], depletion and degradation of water resources [11–13], pollution [14,15], or habitat loss [16]. Indeed, agriculture is a major contributor to the transgressing of four planetary boundaries:

biosphere integrity, biogeochemical flows, land-system change, and freshwater use [17]. For example, crop fertilization is the largest anthropogenic perturbation of global N and P cycles [5].

It is estimated that the world population could reach 9.1 billion by 2050 [18]. Increasing population growth, and the continuing development of global trade and the world economy, will increase food demand by 70% [18]. This would imply an increase of 100–110% of the global cultivated land area by 2050 [19]. Within this context of current population growth and increasing food demand, during the 1950s and 1960s, the "Green Revolution" began. This, led to change in the production system that extended for many countries all over the world [20,21] and lead to an increase in world agricultural production mainly by one third in 50 years, with reduced agricultural land expansion (only 12%) [22]. The scientific and technological improvement achieved during the "Green Revolution" was possible because of the intensification of agriculture [23], the use of agrochemicals, the breeding of high-yielding varieties, and innovations in irrigation systems [23–25]. These advances provide us with the possibility to increase productivity by limiting the conversion of natural ecosystems to crops and to prevent the release of huge amounts of greenhouse gases [18].

Traditional agricultural systems or agroecosystems, although less productive than intensive systems developed after the green revolution, had the capacity to preserve natural values [26]. In general, modern intensive agricultural practices cause a simplification and homogenization of the landscape at different scales. For example, at a local scale, the use of agrochemicals and increased mechanization leads to the elimination of trees and shrubs presented in crop fields and a loss or simplification of herbaceous diversity. At a landscape level, the planting of large extensions of monocultures and the elimination of unproductive areas (boundaries, patches of natural vegetation, water points, etc.), leads to the loss of natural habitats and their disconnection. This, together with long-lasting damage to soil and water availability and the large amount of waste generated, is causing an unprecedented loss of global biodiversity [15,25,27–31]. Biodiversity-aggressive practices also lead to a decrease in agroecosystem resilience [32] and the modification of its capacity to provide key ecosystem services [33–38]. One example is the loss of pollinators that affects more than one third of the crops used for food production. Pollinator losses caused by agricultural intensification is not only an emerging risk for ecosystems but also for the economy, as this ecosystem service improves productivity and represents a profit of USD 235–577 billion per year worldwide [39,40]. In Europe, where that local plant diversity co-existed with traditional agriculture over centuries, agricultural intensification is also one of the main causes of biodiversity losses [41–43]. Therefore, one of the current challenges is to find a balance between long-term sustainable agricultural production for the increasing population growth and the effective conservation of biodiversity and its associated ecological processes [44].

Concern about the negative impacts of intensive agriculture on the environment has stimulated interest in alternative agricultural systems, such as those proposed by agroecology and organic farming [23,45–48]. New policy initiatives have also emerged, such as the Agri-Environment Schemes (AES) of the European Union (EU) Common Agricultural Policy (CAP), which provide economic incentives for farmers to undertake agrobiodiversity-friendly practices [49]. The number of scientific studies on biodiversity conservation in agroecosystems has also increased in recent years [27,50–55]. These studies reinforce the idea that with proper management, agricultural areas can be rich in native taxa and key sites for their conservation [44,56,57]. Moreover, according to Storkey et al. [58], the intrinsic ecological value of endangered taxa and their delicate conservation status justify their priority conservation target.

Scientific literature shows agriculture affects some threatened taxa in cultivated areas [41,59,60], either by crop expansion, management change, or agricultural abandonment [58,61,62]. However, not all taxa respond equally to these changes; some are simply not able to adapt to living in cultivation, while for others, agroecosystems are important and sometimes essential for their survival [44,62], being strongly affected by agricultural intensification [58] or by land abandonment [63]. Among all of the different biological groups, plants are a key component of agroecosystems as they provide resources to a wide variety of organisms [64], and also to humans. Plant functional traits, in addition to environmental characteristics, may be responsible for vulnerability to local extinction in agricultural landscapes [65,66] and are frequently used in studies on land-use change or management and their effects [67].

In Spain, as in other Mediterranean countries, major agricultural land transformations have taken place during the last decades. Agriculture has expanded in some areas and the most profitable agricultural areas have intensified while marginal areas have been abandoned [68]. These changes have led to an unfavorable conservation status for part of its biodiversity and a loss of associated ecosystem services [69]. This has happened despite the existence of legal tools for their conservation, and the fact that Spain has an extensive network of protected areas, whose boundaries were established taking into account the presence of endangered species [70]. In order to better understand the conservation status of threatened vascular plants in Spain, since 2000, their conservation status has been evaluated in the Atlas y Libro Rojo de Flora Vascular Amenazada de España (AFA), and its addenda [62,71–74]. However, the effects of different agricultural changes on their populations have never been deeply analyzed. Different types of threats derived from agricultural use and their effects may vary according to the functional traits of the threatened taxa. In addition, the category of threat or the level of legal protection may condition the survival of threatened flora in agricultural environments now or in the future. Thus, we proposed a study aimed at evaluating the state of plant taxa threatened by changes in agricultural practices in Spain. To achieve this, we proposed the following specific objectives: (1) to identify taxa threatened by agricultural activities, and to determine their type of threat and their degree of protection; (2) to analyze the relationship between different threats and key functional traits of plants; (3) to evaluate land use changes in areas close to populations of the endangered taxa in Spain. Finally, we performed an assessment of the current state and expected trend of the endangered taxa threatened by agriculture in Spain and we have drawn up a list of potential actions for conservation.

2. Materials and Methods

2.1. Study Area

In this study, we focused on continental Spain, (the Canary Islands, Balearic Islands, Ceuta and Melilla were not included), which has an extension of 493–486 km^2 [75]. Spain is a European country located in the Mediterranean basin, which is one of the world's main biodiversity hotspots [76] and, therefore, a priority area for conservation [77]. The great diversity of biomes, types of vegetation, relief, climates and microclimates, soil types, and human activity, give it an environmental heterogeneity that confers enormous biodiversity [78,79], with high conservation value. Its flora is remarkable in the European context as it hosts more than 7000 taxa [76] and approximately 80% of the flowering plants living in the European Union [80,81]. Threatened flora represents 17% of the total plant taxa [82].

2.2. Studied Taxon

For this work, we selected all taxa described for Spain as currently or potentially threatened by agricultural use in the AFA and its addenda [62,71–74]. The selected taxa were then divided into three categories, according to the type of threat from agriculture: (i) crop extension (CE), which represents a threat to taxa that is not typical in agricultural areas, but whose populations inhabit bordering areas or other areas that may change to agricultural use due to the extension of crops; (ii) crop intensification (CI), as a threat to taxa living in agricultural areas where land management practices change, mainly to an intensified production system; and (iii) crop abandonment (CA), which represents a threat to taxa whose survival depends on agricultural activities (i.e., taxa well specialized to coexist with crops in agricultural areas). All scientific names listed in AFA have been revised and some have been updated according to bibliography [83–87]. For each taxon, we explored the conservation status and level of legal protection and we obtained information with reference to several plant functional traits related to the tolerance of threatened taxa to agricultural changes. Finally, for each of the identified species, we collected occurrence records from the Global Biodiversity Information Facility (GBIF). Before using the spatial data, we cleaned the dataset to minimize common errors in GBIF occurrence data [88]. From the preliminary list, wrong records (e.g., records whose coordinates were outside the possible range values or those in which latitude or longitude were equal to 0), records whose presence was outside the study area, and those outside their known distribution were removed.

2.2.1. Conservation Status

We retrieved the threat level of each specie according to IUCN classes: (i) CR, critically endangered; (ii) EN, endangered; and (iii) VU, vulnerable. In addition, we identified the level of legal protection of each taxon. For this purpose, we used the information related to the legal protection and threat level collected in the AFA and its addenda [62,71–74], and in the Dríada database (https://www.conservacionvegetal.org/drtest/, accessed on 1 July 2021).

2.2.2. Trait Data

For each of the taxon studied, a search was carried out in the AFA and its addenda [62,71–74], on plant functional traits related to the tolerance of threatened taxa to agricultural changes [89]. The life form was selected as a taxon's response to disturbances [67], whereas the type of pollination and dispersal mode are indicators of the dispersal capacity and recruitment success of the plants [67]. According to Raunkiaer [90], we classify selected species into six life forms (chamaephytes, geophytes, hemicryptophytes, hydrophytes, phanerophytes, and therophytes). This classification has been used to determine the response of some taxa to different intensities of agricultural management [65,66]. Given the diversity of pollination type and mode of dispersal of plant taxa threatened by agriculture, they have been classified into three categories: abiotic, biotic, and unknown. Pollination was classified as abiotic when autogamous or anemophilous taxa were involved, and as biotic if the mode of pollination was by zoogamy (entomophilous). The dispersal and pollination mechanism was not determined for the identified threatened taxa. In these cases, as well as in the cases not presenting obvious adaptations, the pollination mechanism was classified as unknown. In the case of the mode of dispersal, it was included in the abiotic category when the mode of dispersal of the taxon was autochory, baricory, anemochory, or hydrochory, and as biotic, if the mode of dispersal was by zoochory (myrmecochory and zoochory without specifying the vector). Again, taxa with unknown mechanisms or with no obvious adaptations were classified as "unknown".

2.3. Agricultural Use Evolution

Using species records obtained from GBIF (Section 2.2), we identified the main land use in a buff area of 500 m radius around each location using Coordination of Information of the Environment (CORINE). To reduce land use complexity, the original legend was reclassified into Urban land, Natural ecosystems and seven agricultural classes: (i) rainfed agriculture; (ii) irrigated lands; (iii) rice plantation; (iv) tree plantation; (v) other crops (including areas with a mix of different crops); (vi) pasture; and (vii) mixed crop-natural (including agroforestry areas and areas occupied by agriculture but with a significant extension of natural lands); see supplementary Table S1 for further details. This process was repeated for the land use classification of 1990 and 2018 and the total change of the different uses in each of the influence areas of each record was calculated as the difference between both dates. Finally, we analyzed, as a reference, the total change of each of the identified classes for the complete study area.

3. Results

3.1. Threatened Plant Taxa and Level of Protection

Of the 1233 plant taxa included in AFA for continental Spain, 591 are in the threatened categories (CR, EN, and VU). Of these taxa, 50 have been classified as threatened by some type of agriculture-related activity (Table 1), Seventy four percent (n = 274) of their populations are threatened for this reason. The total number of taxa belongs to 21 families, although more than 25% belong to two families, Plumbaginaceae (14%) and Compositae (12%). These families, together with Cruciferae (8%), Caryophyllaceae (8%), Leguminosae (6%), Marsileaceae (6%), and Scrophulariaceae (6%), comprise more than 50% of the selected taxa (Table 1). Of these, 24% are classified as vulnerable (VU) (n = 12), 40% as endangered (EN) (n = 20), and 36% as critically endangered (CR) (n = 18). Most of the taxa (90%) are included on legal protection lists (n = 45; 32 at regional level, 5 at regional-national level, 7 at regional-national-supranational level, and 1 at supranational level only). The predominant life form is hemicryptophytes, corresponding to this category 42% (n = 21) of identified taxa; 24 % are therophytes (n = 12); 14 % geophytes (n = 7); 8 % chamaephytes (n = 4); 6 % phanerophytes (n = 3), and 6 % hydrophytes (n = 3). For most, taxa pollination is biotic (82%, n = 41), while dispersal is mainly abiotic (78%, n= 37) (Figure 1).

Table 1. Taxa included in this study. The table shows the taxa studied. Family, specie and subspecies are indicated. The reference is indicated when the taxonomic status has been updated according to the AFA and not implying a change in the number of populations or individuals. In addition, the type of threat that mainly affects the taxa is indicated (CE, crop extension; CI, crop intensification; CA, crop abandonment). The following are also indicated are: P, number of populations; % TP, percentage of threatened populations; threat category in IUCN Red List (CR, critically endangered; EN, endangered; VU, vulnerable); PR, degree of legal protection (-, absent; R, regional; N, national; RN, regional-national; S, supranational; RNS, national, regional, and supranational).

Family	Taxon	Threat	P	% TP	IUCN	PR
Alliaceae	*Allium scaberrimum* M.Serres [84]	CA	16	100	VU	R
Amaryllidaceae	*Narcissus nevadensis* Pugsley subsp. *nevadensis* [83]	CE	2	50	EN	RN
Amaryllidaceae	*Narcissus bujei* (Fern. Casas) Fern. Casas	CI	14	100	VU	R
Caryophyllaceae	*Dianthus inoxianus* Gallego	CE	16	56	EN	R
Caryophyllaceae	*Silene sennenii* Pau	CE	3	67	EN	RN
Caryophyllaceae	*Silene stockenii* Chater	CE	4	100	CR	R
Caryophyllaceae	*Silene diclinis* (Lag.) M. Laínz	CI	5	80	EN	R
Colchicaceae	*Androcymbium europaeum* (Lange) K. Richt.	CE	5	80	VU	RNS
Compositae	*Anthemis bourgaei* Boiss. & Reut.	CE	2	50	EN	R
Compositae	*Centaurea kunkelii* N. García	CE	2	50	CR	R
Compositae	*Centaurea ultreiae* Silva Pando	CE	1	100	CR	R
Compositae	*Jacobaea auricula* (Coss.) Pelser [86]	CE	7	100	VU	R
Compositae	*Leucanthemum gallaecicum* Rodr. Oubiña & S. Ortiz	CE	4	75	EN	R
Compositae	*Pentanema bifrons* (L.) D. Gut. Larr. Santos-Vicente, Anderb., E. Rico & M.M. Mart. Ort. [85]	CE	1	100	CR	R
Cruciferae	*Clypeola eriocarpa* Cav.	CE	2	50	CR	R
Cruciferae	*Coincya longirostra* (Boiss.) Greuter & Burdet	CE	10	100	EN	R
Cruciferae	*Vella pseudocytisus* L. subsp. *pseudocytisus*	CE	2	100	EN	R
Cruciferae	*Isatis aptera* (Boiss. & Heldr.) Al-Shehbaz, Moazzeni & Mumm. [87]	CA	6	100	EN	-
Dipsacaceae	*Succisella carvalhoana* (Mariz) Baksay	CE	4	25	VU	R
Geraniaceae	*Erodium paularense* Fern. Gonz. & Izco	CE	11	9	EN	RNS
Geraniaceae	*Erodium recoderi* Auriault & Guitt.	CE	6	17	VU	-
Gramineae	*Puccinellia pungens* (Pau) Paunero	CE	9	11	EN	RNS
Gramineae	*Enneapogon persicus Boiss.*	CI	2	100	CR	R
Labiatae	*Nepeta hispanica* Boiss. & Reut.	CE	8	62.5	VU	R
Labiatae	*Teucrium edetanum* M.B. Crespo, Mateo & T. Navarro	CE	2	50	VU	R
Leguminosae	*Astragalus oxyglottis* M. Bieb.	CE	10	30	EN	R

Table 1. *Cont.*

Family	Taxon	Threat	P	% TP	IUCN	PR
Leguminosae	*Ononis azcaratei* Devesa	CE	4	50	CR	R
Leguminosae	*Astragalus nitidiflorus* Jiménez Mun. & Pau	CI	1	100	CR	RN
Lythraceae	*Lythrum baeticum* Gonz. Albo	CE	24	83	EN	R
Lythraceae	*Lythrum flexuosum* Lag.	CE	57	100	EN	RNS
Malvaceae	*Malvella sherardiana* (L.) Jaub. & Spach	CA	4	100	VU	-
Marsileaceae	*Marsilea batardae* Launert	CE	17	53	EN	RNS
Marsileaceae	*Marsilea strigosa* Willd.	CE	33	97	VU	RNS
Marsileaceae	*Pilularia minuta* Durieu	CE	4	100	CR	RNS
Plantaginaceae	*Plantago notata Lag.*	CI	1	100	CR	R
Plumbaginaceae	*Armeria merinoi* (Bernis) Nieto Fel. & Silva Pando	CE	6	50	CR	R
Plumbaginaceae	*Limonium aragonense* (Debeaux) Font Quer	CE	1	100	CR	R
Plumbaginaceae	*Limonium quesadense* Erben	CE	2	100	EN	R
Plumbaginaceae	*Limonium soboliferum* Erben	CE	1	100	CR	R
Plumbaginaceae	*Limonium squarrosum* Erben	CE	1	100	CR	R
Plumbaginaceae	*Limonium ugijarense* Erben	CE	2	50	EN	-
Plumbaginaceae	*Limonium mansanetianum* M.B. Crespo & Lledó	CI	4	100	CR	R
Polygalaceae	*Polygaloides balansae* (Coss.) O. Schwarz	CE	1	100	CR	-
Ranunculaceae	*Delphinium bolosii* C. Blanché & Molero	CE	2	50	EN	RN
Ranunculaceae	*Ranunculus lingua* L.	CE	1	100	CR	R
Scrophulariaceae	*Scrophularia herminii* Hoffmanns. & Link	CE	31	32	EN	S
Scrophulariaceae	*Linaria nigricans* Lange	CI	6	50	EN	R
Scrophulariaceae	*Verbascum fontqueri* Benedí & J.M. Monts.	CA	8	100	VU	R
Thymelaeaceae	*Thymelaea lythroides* Barratte & Murb.	CE	1	100	CR	RN
Umbelliferae	*Hohenackeria polyodon* Coss. & Durieu	CE	4	100	VU	R

3.2. Current State of Taxa Endangered by Agricultural Threat Categories and Trends

3.2.1. Taxa Endangered by Crop Extension

Almost three-quarters of the total plant taxa classified as threatened by agriculture-related changes in land use (n = 39) are threatened by crop extension (Table 1). Of these, 41.03% (n = 16) have all their populations threatened by crop extension and 43.59% (n = 17) have at least half of their populations affected due to this reason (Table 1). Moreover, 43.6% of the taxa threatened by agricultural extension (n = 17) are endangered (EN), 35.9% (n = 14) are critically endangered (CR), and 20.5% (n = 8) are vulnerable (VU). Most of the selected taxa (92.3%; n = 47) are protected, except *Erodium recoderi* (VU), *Limonium ugijarense* (EN), and *Polygaloides balansae* (CR). However, 61.54% of them (n = 24) are protected only at the regional level, 10.26% (n = 4) are protected at the national-regional level, and 17.95% (n = 7) are also protected at the supranational level (Table 1). One taxon (*Scrophularia herminii)* is protected only at the supranational level by the Habitats Directive (Table 1).

A detailed analysis of the different life forms of the plant taxa threatened by the expansion of agricultural use in Iberian Spain revealed that 43.6 % of them are hemicryptophytes (n = 17), 23% therophytes 23% (n = 9), while the other types (geophytes, chamaephytes, phanerophytes, hydrophytes) account for only about 10% each (n = 3–4). Pollination of plants in this group is mainly biotic (84.62%, n = 33) and the predominant mode of dispersal is abiotic (76.92%, n = 30) (Table 2).

Figure 2 shows the agricultural uses in the areas of influence of the plant taxa classified as threatened by crop extension, as well as the trend of expansion or reduction of agricultural use between 1990 and 2018 according to CORINE land cover. As observed, there is large variability among taxa. Some of them, are located in areas occupied by large extensions of agricultural use (more than 50% of the surface), under both increasing (e.g., *Ononis azcaratei*, *Anthemis bourgaei*, *Pilularia minuta* and *Jacobaea auricula*) and decreasing (e.g., *Limonium aragonense*, *Lythrum flexuosum* and *Vella pseudocytisus*) trends. There are also taxa located in areas with reduced agricultural extension but with a large proportion of intensive practices (irrigated crops) and with a positive trend to increase agricultural extension (e.g., *Delphinium bolosii*). Others, such as *Centaurea kunkelii*, showed the opposite pattern. Finally, regarding several taxa located in heavily cultivated areas (e.g., *Silene sennenii*) or lightly cultivated areas (e.g., *Dianthus inoxianus*), we did not find a significant change in the cultivation extension. However, in most of these cases, there are important changes in the agricultural practices, with a dominant trend toward agricultural intensification or irrigation.

Table 2. Summary of the trial for each of the taxon included in the three threat types (crop extension, crop intensification, and crop abandonment). The trial data included are: life form (C, chamaephytes; G, geophytes; H, hemicryptophytes; Hy, hydrophytes; P, phanerophytes; T, therophytes), pollination (-, unknown; abiotic; biotic) and dispersal mode (-, unknown; abiotic; biotic).

Threat	Taxon	Life Form	Pollination Mode	Dispersal Mode
Crop extension	*Androcymbium europaeum*	G	Biotic	Abiotic
	Anthemis bourgaei	T	Biotic	Abiotic
	Armeria merinoi	H	Biotic	Abiotic
	Astragalus oxyglottis	T	Biotic	Abiotic
	Centaurea kunkelii	H	Biotic	Abiotic
	Centaurea ultreiae	H	Biotic	Biotic
	Clypeola eriocarpa	T	Biotic	Abiotic
	Coincya longirostra	H	Biotic	Abiotic
	Delphinium bolosii	G	Biotic	Abiotic
	Dianthus inoxianus	C	Biotic	Abiotic
	Erodium paularense	C	Biotic	Abiotic
	Erodium recoderi	T	Biotic	Abiotic
	Hohenackeria polyodon	T	Abiotic	Abiotic
	Jacobaea auricula	H	Biotic	Abiotic
	Leucanthemum gallaecicum	H	Biotic	Biotic
	Limonium aragonense	H	Biotic	Abiotic
	Limonium quesadense	H	Biotic	Abiotic
	Limonium soboliferum	H	Abiotic	Biotic
	Limonium squarrosum	H	Biotic	Abiotic
	Limonium ugijarense	H	Biotic	Abiotic
	Lythrum baeticum	T	Biotic	-
	Lythrum flexuosum	T	Biotic	-
	Marsilea batardae	Hy	Abiotic	Abiotic
	Marsilea strigosa	Hy	Abiotic	Biotic
	Narcissus nevadensis nevadensis	G	Biotic	Abiotic
	Nepeta hispanica	G	Biotic	Abiotic
	Ononis azcaratei	T	Biotic	Abiotic
	Pentanema bifrons	H	Biotic	Abiotic
	Pilularia minuta	H	Abiotic	Abiotic
	Polygaloides balansae	P	Biotic	Abiotic
	Puccinellia pungens	H	Abiotic	Abiotic
	Ranunculus lingua	Hy	Biotic	-
	Scrophularia herminii	H	Biotic	-
	Silene sennenii	C	Biotic	Abiotic
	Silene stockenii	T	Biotic	Abiotic
	Succisella carvalhoana	H	Biotic	Abiotic
	Teucrium edetanum	H	Biotic	Abiotic
	Thymelaea lythroides	P	Biotic	Biotic
	Vella pseudocytisus pseudocytisus	P	Biotic	Abiotic
Agricultural intensification	*Astragalus nitidiflorus*	H	Biotic	-
	Enneapogon persicus	G	Abiotic	Abiotic
	Limonium mansanetianum	H	-	-
	Linaria nigricans	T	Biotic	Abiotic
	Narcissus bujei	G	Biotic	Abiotic
	Plantago notata	T	Abiotic	Biotic
	Silene diclinis	C	Biotic	Abiotic
Crop abandonment	*Allium scaberrimum*	G	Biotic	Abiotic
	Isatis aptera	T	Biotic	Abiotic
	Malvella sherardiana	H	Biotic	Abiotic
	Verbascum fontqueri	H	Biotic	Abiotic

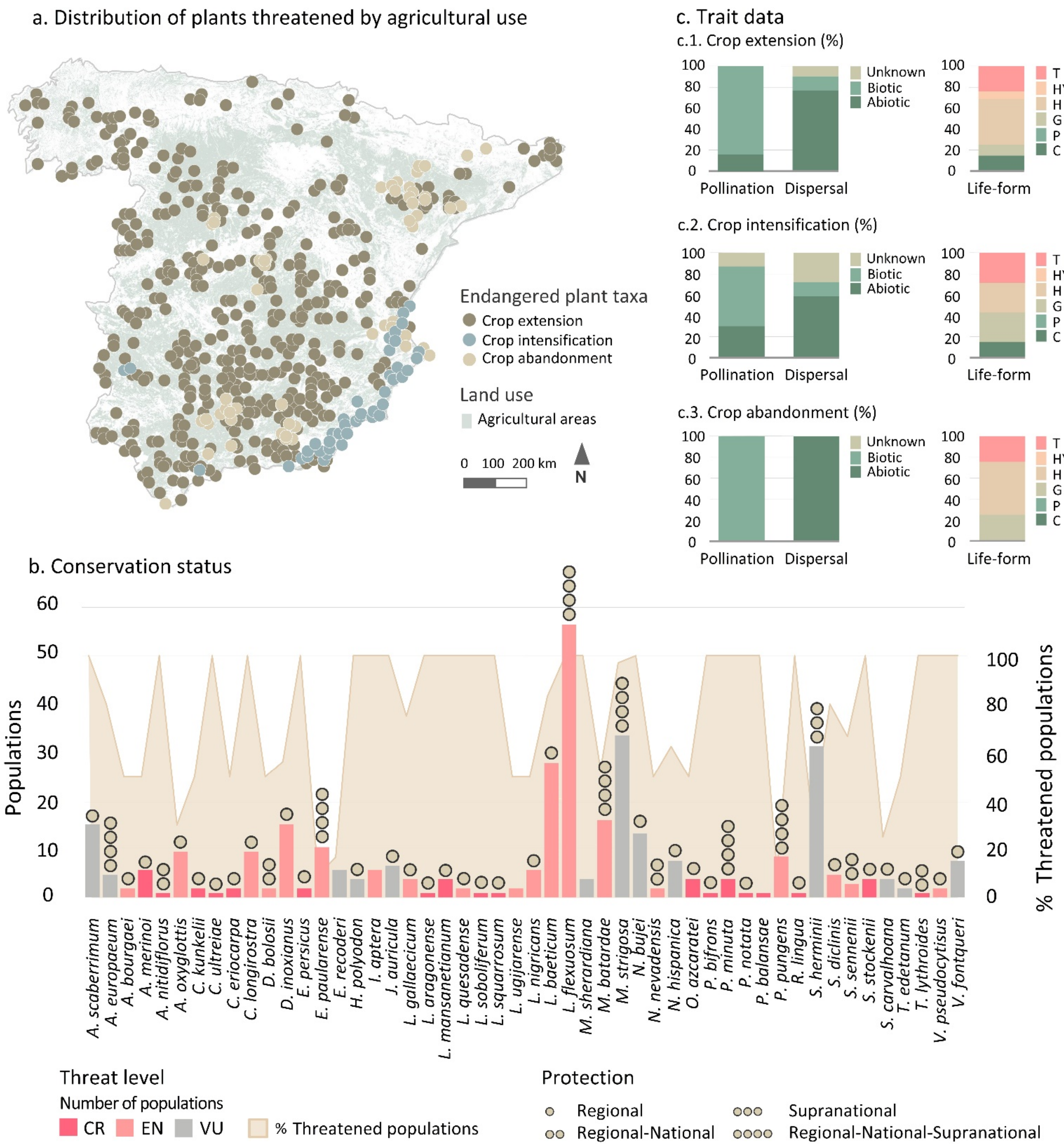

Figure 1. Summary of plants threatened by agricultural use in continental Spain, their conservation status, and functional traits. (**a**) Distribution of plants threatened by agricultural use. Map of the presence of taxa threatened by agriculture included in each category (represented in three different colors) and base map with the area of agricultural use present in the study area. (**b**) Conservation status. The graph shows the taxa identified as threatened by agricultural use; the height of the histogram bar shows the number of populations (values indicated on the left axis), the color of the bar shows the threat category (CR, EN, VU) and the brown area shows the percentage of threatened populations (values indicated on the right axis). In addition, the level of protection is indicated by circles on the histogram bar (1, regional; 2, regional-national; 3, supranational; 4, regional-national-supranational). (**c**) Trait data. Plant trait includes for each threat category (**c1**–**c3**): % pollination mode (unknown; abiotic; biotic); % dispersal mode (unknown; abiotic; biotic); and % life form (C, chamaephytes; G, geophytes; H, hemicryptophytes; Hy, hydrophytes; P, phanerophytes; T, therophytes).

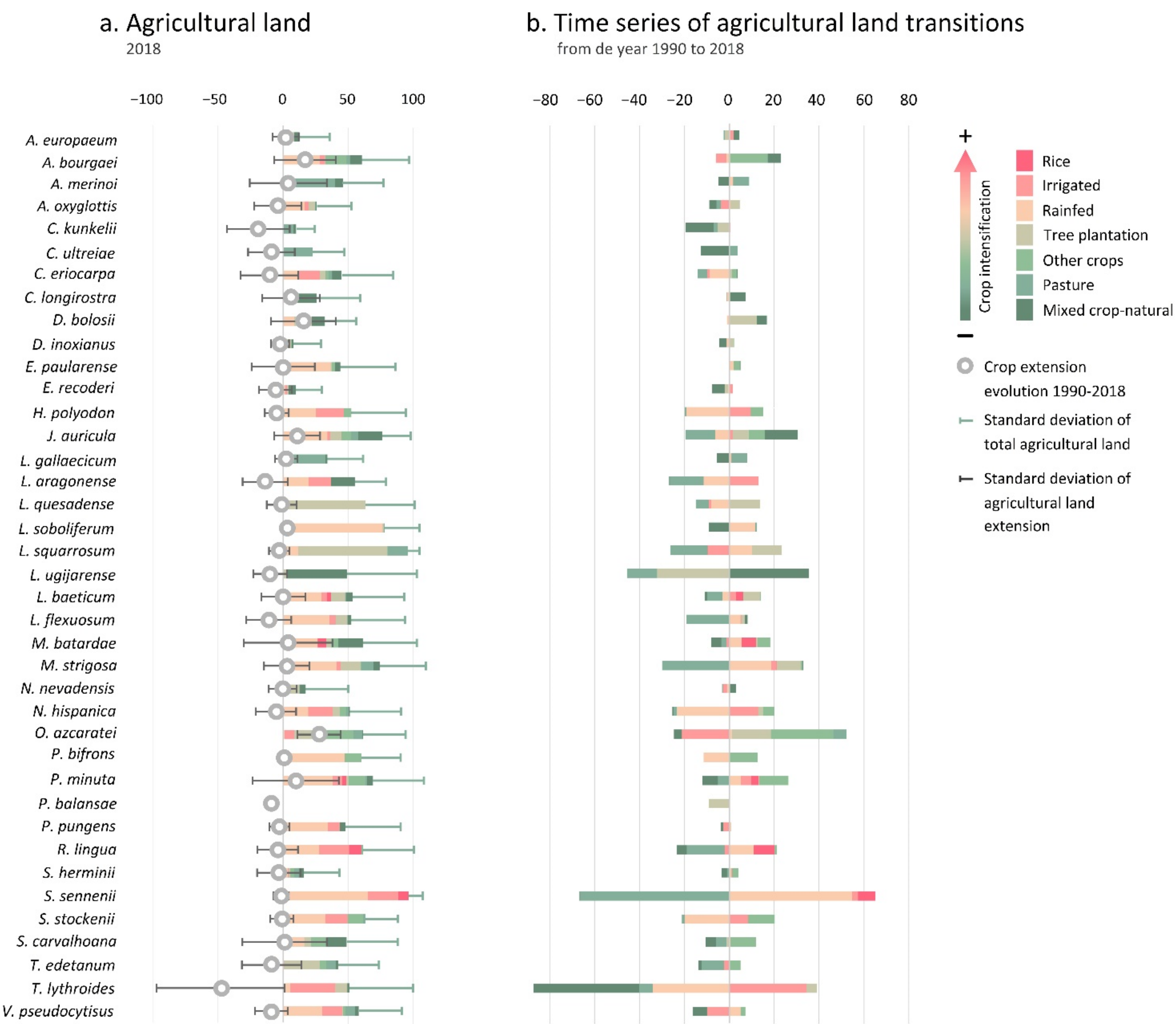

Figure 2. Taxa threatened by the extension of cultivation. (**a**) Agricultural land. The figure shows the total area of agricultural uses, according to CORINE, of the area of influence of taxa threatened by the extension of cultivation in 2008. The dot indicates the evolution of the agricultural land use area for each taxon between 1990 and 2018. (**b**) Time series of agricultural land uses. The figure shows, for each taxon, the trend of expansion or reduction of agricultural use between 1990 and 2018 according to CORINE.

3.2.2. Taxa Endangered by Crop Intensification

Seven plants are threatened by agricultural intensification. Of these, *Astragalus nitidiflorus*, *Enneapogon persicus*, *Limonium mansanetianum*, *Narcissus bujei*, and *Plantago notata*, have all their populations threatened by agricultural intensification, while *Silene diclinis* and *Linaria nigricans* have four (80%) and three (50%) of their populations threatened by agricultural intensification, respectively. Most are critically endangered (CR), except *Linaria nigricans* and *Silene diclinis*, which are listed as endangered (EN), and *Narcissus bujei*, which is, listed as vulnerable (VU). All are protected; *Enneapogon persicus*, *Limonium mansanetianum*, *Linaria nigricans*, *Narcissus bujei*, and *Plantago notata* only at the regional level, while *Astragalus nitidiflorus* is protected at the regional-national level.

This group includes plants with different life forms, such as hemicryptophytes (*Astragalus nitidiflorus* and *Limonium mansanetianum*), geophytes (*Enneapogon persicus* and *Narcissus bujei*), therophytes (*Linaria nigricans* and *Plantago notata*) and chamaephytes (*Silene diclinis*). More than half have biological pollination (*Astragalus nitidiflorus*, *Linaria* *nigricans*, *Narcissus bujei* and *Silene diclinis*) and the mode of dispersal is abiotic in almost all known cases (n = 5) (Table 2).

A detailed analysis of land use evolution in the area of influence of these taxa revealed that most of the taxa included in this category have been found in areas occupied by a large extension of crops, with *Enneapogon persicus* having more than 80% of the surface area dedicated to this use (Figure 3). However, there is no dominance of intensive practices. The taxa located in regions with a higher dominance of intensive agriculture are *Enneapogon persicus*, *Plantago notata* and *Linaria nigricans* with 24.07%, 11.13%, and 6.57% of their areas of influence covered by irrigated crops, respectively.

In most cases, the area of agricultural use has changed minimally between 1990 and 2018, and more traditional and less aggressive uses such as rainfed or mixed crops, have increased. Irrigated crops have only slightly increased around some populations of *Plantago notata* and *Linaria nigricans* (Figure 3).

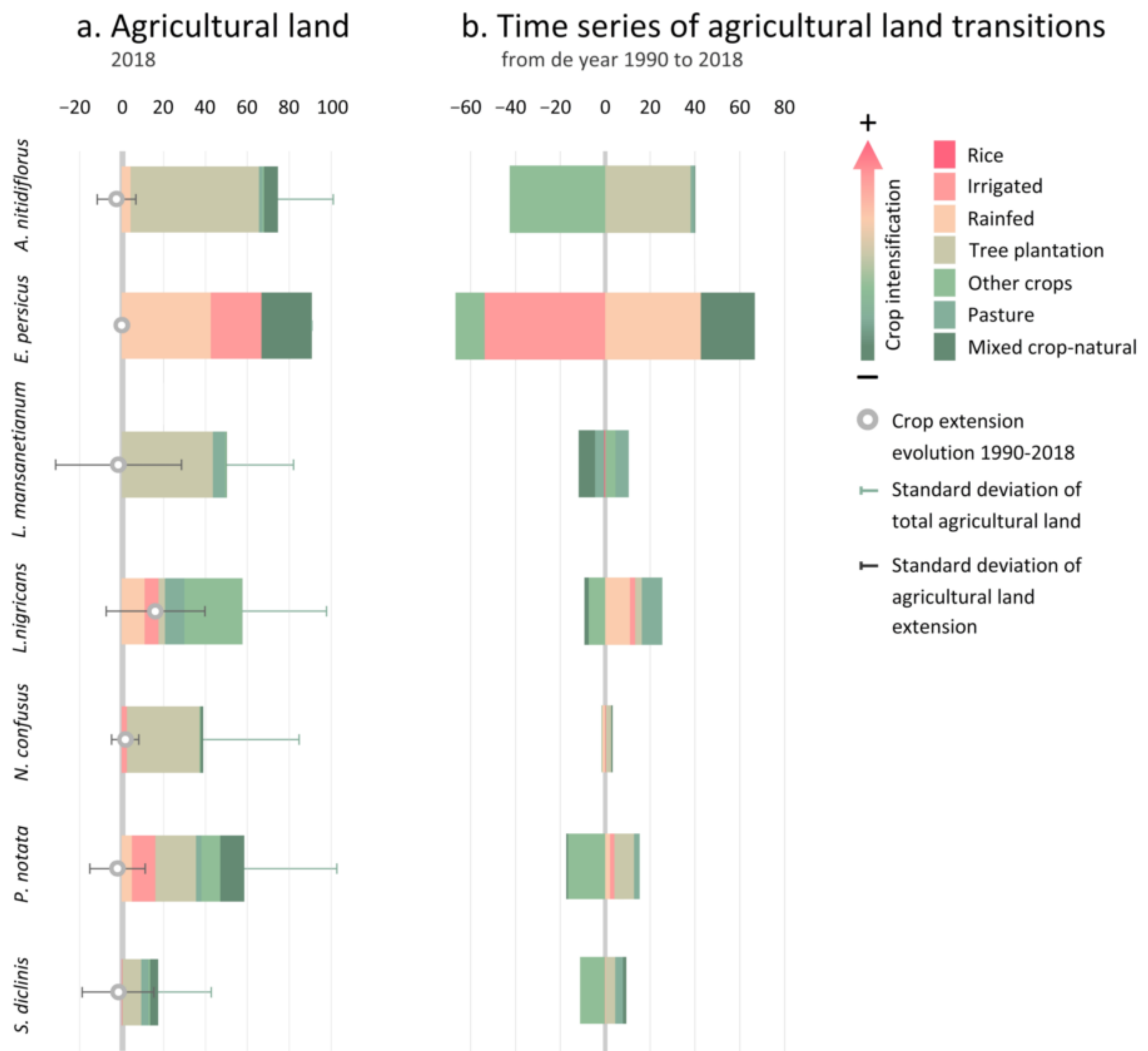

Figure 3. Taxa threatened by crop intensification. (**a**) Agricultural land. The figure shows the total area of agricultural uses according to CORINE of the area of influence of taxa threatened by crop intensification in 2008. The dot indicates the evolution of the area of agricultural use for each taxon between 1990 and 2018. (**b**) Time series of agricultural uses. The figure shows, for each taxon, the trend of expansion or reduction of agricultural use between 1990 and 2018, according to CORINE.

3.2.3. Taxa Endangered by Crop Abandonment

Only four of the identified plant taxa endangered by agricultural practices are threatened by crop abandonment (Table 1). All of them have 100% of their populations threatened for this reason. However, most of the taxa included in this group (*Allium scaberrimum*, *Malvella sherardiana*, and *Verbascum fontqueri*) are listed as vulnerable (VU) and only *Isatis aptera* is listed as endangered. This, as well as *Malvella sherardiana* (VU), have no direct legal protection, whereas *Allium scaberrimum* and *Verbascum fontqueri* are protected by national and supranational regulations. *Malvella sherardiana* and *Verbascum fontqueri* are hemicryptophytes, *Isatis aptera* is a therophyte, and *Allium scaberrimum* is a geophyte. All of them have biotic pollination and abiotic modes of dispersal (Table 2).

According to Figure 4, the four species of this group are located in areas with a large extension of crops, especially *Isatis aptera*, which occupies areas with an average cover of crops of around 80%. The taxon with the lowest representation of agricultural use is *Verbascum fontqueri*, (20%). Net Agriculture extension in the buffer area of the different population of these taxa has changed minimally in most cases with the exception of *Allium scaberrimum*. In this case, a net decrease of about 20% of the agriculture extension has been observed between 1990 and 2018. Though the net area covered by crops did not experience large modifications, there is an important rate of change between different agricultural practices with a clear trend to increase the area dedicated to the most intensive land uses (Figure 4b). This is the case for *Allium scaberrimum*, in the areas close to their populations, rainfed crops, other crops, and pastures have been abandoned and replaced by more intensive crops, such as irrigated crops. Something similar has occurred with *Malvella sherardiana*, although in this case, the pasture area has increased (change identified with the abandonment of agriculture according to CORINE) and there has been a greater fluctuation between the losses and gains of the different types of crops.

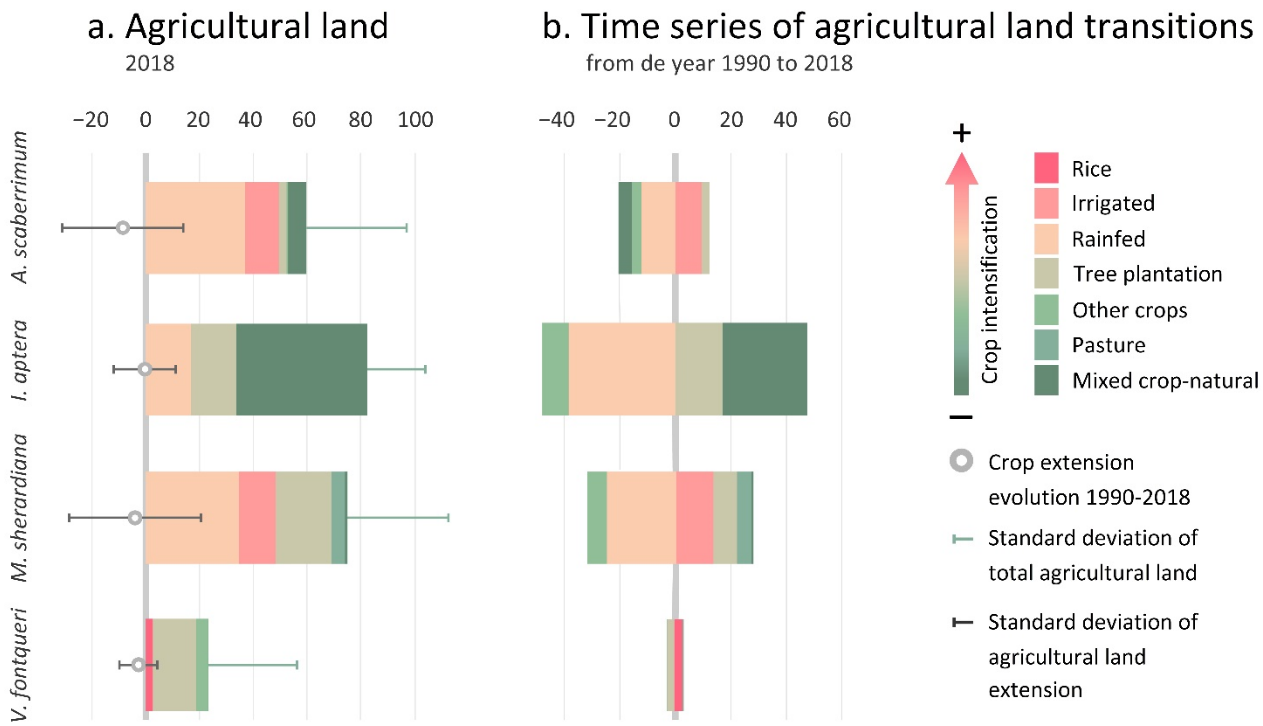

Figure 4. Taxa threatened by Crop abandonment. (**a**) Agricultural land. The figure shows the total area of agricultural use according to CORINE of the area of influence of taxa threatened by crop abandonment in 2008. The dot indicates the evolution of the area of agricultural uses for each taxon between 1990 and 2018. (**b**) Time series of agricultural uses. The figure shows, for each taxon, the trend of expansion or reduction of agricultural use between 1990 and 2018, according to CORINE.

4. Discussion

Agricultural land use changes, such as the conversion of natural areas to agricultural land, crop intensification or abandonment, are considered to be one of the main threats for endangered plant taxa on a global scale [58,61,62,91]. Our review reveals that [92] in continental Spain, there are 50 taxa threatened by any of these land use changes, representing 8.5% of the total number of threatened taxa in Spain. A list has been made based on current knowledge and the number appears to be lower than in other countries [92]. Nonetheless, these numbers may be underestimated as threat assessment efforts frequently focused on endemic and rare taxa and the actual number of plants threatened by agricultural practices may be higher than those provided in the official red list. For example, in Greece, the red data book includes few species threatened by agriculture, but according to [93] numerous widespread species are reducing their populations until levels that do merit a threat status, due to modernization of agricultural practices. Moreover, these numbers may increase in the near future and, as already described by other biological groups, such as steppe birds [91]. This is especially relevant as changes towards higher threat categories in Spain are mostly related to human activities [94]. For these reasons, it is very important to assess the threat status of the native flora of agricultural land, and not focus only on rare and endemic species, which is typically the case in red list assessments.

The probability of persistence of plant taxa in agricultural areas is related, among other plant traits, to those affecting their tolerance to disturbance [95]. As expected, one of the most common life forms among the taxa identified are therophytes, considered as indicators of disturbed ecosystems, regardless of whether they are active or abandoned crops [96]. In addition, there is a predominance of other life forms shown to be highly resistant to disturbance, such as hemicryptophytes and geophytes. These data contrast when compared with the total number of threatened species in Spain, where only hemicryptophytes are well represented (25.2%, n = 149), whereas therophytes and geophytes only represent ~9% (n = 52) and ~8% of the total number of species.

Vegetation capability to disperse and colonize new habitats are also important plant traits for survival in anthropogenic habitats, such as agricultural areas. For example, the reproductive success of plants depends initially on their pollination capacity. As the main pollination vectors of the taxa identified in this study are insects, as is also the case for the total number of threatened species in Spain (88%, n = 488), the loss of pollinators or their efficiency is one of the negative consequences detected in agricultural systems [33,40,97–99]. A clear example is the global commercialization of pollinators for use in crops, due to the absence of wild pollinators [100,101]. Small pollen loads can reduce fruit and seed formation, affecting seed viability, recruitment, progeny and vigor, and the genetic diversity of their populations [102–108]. In addition, identified threatened taxa are also characterized by low numbers and geographically restricted populations. The success of these populations living in fragmented landscapes is strongly dependent on the dispersal rate or the availability of dispersal vectors, as it can be a limiting factor for demographic recruitment, population continuity, and genetic exchange [109,110]. Overall, long-distance dispersal capacity may be key to the survival of populations in fragmented environments [111]. The predominant dispersal strategy in the taxa studied is mainly abiotic with the exception of some taxa (*Centaurea ultreiae*, *Leucanthemum gallaecicum*, *Limonium soboliferum* and *Plantago notata*) whose dispersal is carried out by ants and *Marsilea strigose*, whose vector is unknown. This is consistent with the mode of dispersal of the total number of threatened taxa in Spain, as abiotic dispersal predominates (85.6%, n = 459). Seed dispersal distances, both abiotic and by ants, are small and usually reach shorter distances than when other animals disperse seeds by epi- or endozoochory [112].

The future of plant taxa threatened by agriculture depends on their capability to survive in areas under diverse types of changes related to agriculture, but also on the intensity and direction of land use changes. An overall analysis of crop extension shows a general decrease in the extension of areas under agricultural use during the last three decades (Figure 5). According to this, and taking into account the high level of legal protection of most of the identified taxa (more than 90% of identified taxa are included in official lists; Table 1), one may expect a good conservation status of all taxa threatened by agriculture in Iberian Spain. However, a deeper analysis of land use dynamics shows that there are important changes in the area occupied by the different crops (Figure 5b), which reflects an important rate of crop extension occurring in parallel with agriculture abandonment, and changes to more intensive practices (irrigated crops, rice fields and tree crops have increased, while rainfed crops and other types of crops have decreased; Figure 5b). This could be one of the main reasons explaining why most of the identified populations are endangered, even though they have a high level of legal protection. Thus, it is clear that, although there are already mechanisms to protect them, more effort is needed by policy managers, land owners, and the society in order to ensure biodiversity conservation of plant taxa in areas endangered by agriculture. For example, in the U.S., the U.S. Endangered Species Act (ESA) has succeeded in protecting hundreds of taxa from extinction and improving their recovery over time [113,114]. However, threats to endangered taxa in the U.S. are still persistent and it is estimated that increased funding and continued management will be needed in the future to ensure their survival [114].

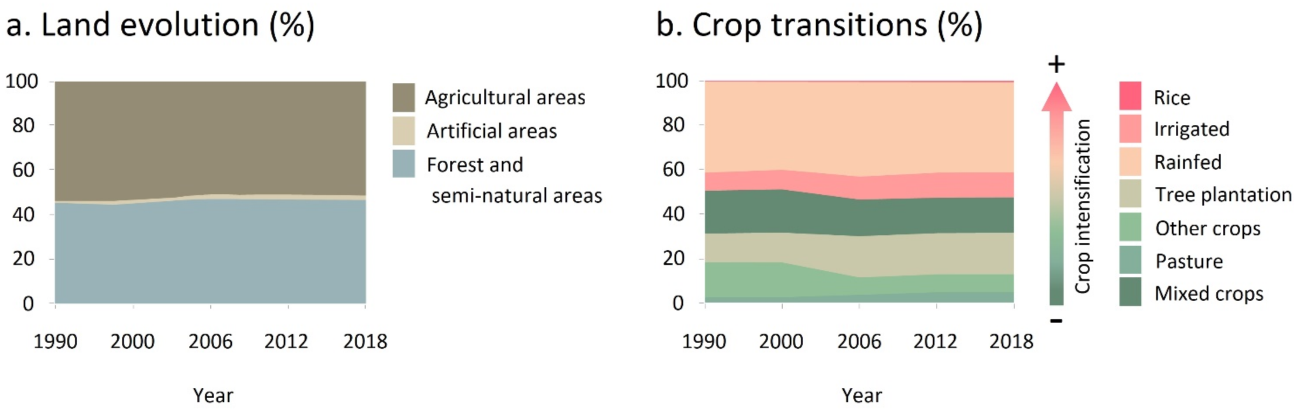

Figure 5. Evolution of changes in use in Spain between 1990 and 2018 according to CORINE. (**a**). Net change in natural and disturbed habitats. (**b**). Net evolution of the different types of agricultural use.

4.1. Crop Extension

The main impact for the plant taxa classified as threatened by agriculture in continental Spain is the loss of natural habitats due to increased agriculture. The extension of crops generates drastic changes in ecosystems in short periods, leading many taxa to immediate local extinction [115]. This also occurs when patches of natural habitat are maintained, because very frequently, they are small and threatened plants are permanently exposed to pressures from the surrounding areas [115]. Moreover, habitat extension reduction related to the expansion of agriculture reduced population size and has other indirect negative effects on plant population survival, such as the reduction of seed banks and the regenerative potential, both being essential for the survival of a large number of plant taxa [116]. All these together, implies that, even if taxa are still present in a favorable zone, local extinction is not avoided but postponed [115]. A clear example of the expansion of crops at the expense of the reduction of natural habitats is the expansion of greenhouses in the southeast of the peninsula [117] that affects, for example, *Androcymbium europaeum* [62].

Attending to the different life forms, there are examples of all of them in the list of species threatened by crop extension, the dominants being hemicryptophytes, phanerophytes, and geophytes. The predominance of these life forms within this category is probably due to their preference for natural areas, thus occupying remnants of natural vegetation close to agricultural fields. The only examples of phanerophytes (*Polygaloides balansae*, *Thymelaea lythroides* and *Vella pseudocytisus* subsp. *pseudocytisus*) and hydrophytes (*Marsilea batardae*, *Marsilea strigose*, and *Ranunculus lingua*) identified in this study are enclosed within this group. The negative effects of the extension of agriculture on phanerophytes are generally because trees and large plants included in this category are frequently removed during preliminary work to prepare the land for the installation of crops (i.e., clearing, leveling, etc., during the preliminary work to prepare the land for the installation of crops (clearing, leveling, etc.) [30]. Hydrophytes are linked to the margins of watercourses, lagoons, or temporary bodies of water. The expansion of crops can directly or indirectly imply the transformation, drainage or drying of the water point, which, together with the low ecological plasticity of some taxa, can cause their disappearance in the short term [62]. In this sense, Spain is one of the countries with the highest rates of groundwater depletion worldwide [118]. In addition, there are aquatic crops that can increase the likelihood of biological invasions. An example is the red swamp crayfish *Procambarus clarkii* (Girard, 1852), which is capable of spreading through rice crops and reaching high densities [119]. This taxon is common in Spain [120,121] and can have negative effects on crops and native biodiversity in invaded areas in a short time [122,123].

The predominant mode of dispersal in plants threatened by crop expansion is abiotic (anemochory, barochory, autochory, and hydrochory), with some exception in which ants (*Centaurea ultreiae*, *Leucanthemum gallaecicum*, *Limonium soboliferum*, and *Thymelaea lythroides*) facilitate seed dispersion. Therefore, the main handicap for this group is not the dispersal capacity, but the availability of suitable habitats for the dispersed seeds to germinate. As shown in Figure 2a, in many cases, the matrix in which threatened taxa are found is highly anthropogenic and remnants of natural vegetation are small and disconnected among them. As abiotic dispersal distances predominant in the taxa of this group are limited [112] even without increased crop cultivation, it is difficult for new populations to thrive. For example, in abiotic modes of dispersal, under optimal conditions (clear soil and morphologically adapted seeds), seeds at most reach distances of 500 m from the mother plant. In the case of dispersal by ants, they are also unable to disperse seeds over long distances, but they minimize predation and facilitate establishment [124].

4.2. Crop Intensification

Traditional farming systems, with low aggressive practices, harbor enormous biodiversity [125], and are key to the conservation of many threatened taxa. However, agricultural intensification is currently significantly decreasing the richness and functional diversity of different biological groups [30,126,127]. Agricultural intensification may cause dominant taxa to become more dominant and rare taxa to become extinct [128]; thus, having a more negative effect over the rare taxa [89,129]. For example, in England, between 1960 and 1997, the loss of rare taxa and the increase of more adaptable common taxa was detected as a consequence of agricultural intensification [129]. Furthermore, even if it is known that a threatened taxon is present in an intensively managed agricultural area, this information should be taken with caution. It is advisable to have good knowledge of the dynamics of its populations, as they may be faced with a gradual depletion of the seed bank [129]. Herbicide use and recurrent plowing have been identified as one of the main factors controlling the seed banks, which may accelerate local extinctions [130–132].

In our study, 14% of the threatened taxa are not affected by crop extension, but by crop intensification. Most of them, such as *Silene diclinis*, *Narcissus bujei*, and *Linaria nigricans*, are flexible taxa able to colonize and survive in some cultivated areas or in the borders of field crops under different levels of disturbance. As observed in Figure 1, the majority of taxa population included in this category are located on the east coast of the Iberian Peninsula, an area identified as a priority for threatened flora in Spain [80]. In most of the areas close to threatened populations, there are no significant net changes in the degree of intensification. However, in taxa, such as *Linaria nigricans*, there has been a greater increase in areas with more intensive agricultural management (Figure 3b). In this case, the fragmentation rate has been increasing over the last decades in some of the most important and largest populations, such as the population of *Linaria nigricans* located in Tabernas (Almeria) [133], where the irrigated olive grove area has increased from 400 ha in 1970 to 4336 ha in 2019 [29]. In addition, there has been a second process of intensification of existing crops [29].

Associated with this type of threat we have found three dominant life forms: hemicryptophytes, geophytes, and therophytes that may favor plant adaptation to survive in agricultural areas. For example, Druckenbrod and Dale [134] relate the increase of geophytes to disturbance by machinery in forested areas. Other authors, however, link the increase of therophytes to tillage, while indicating that geophytes and hemicryptophytes increased in undisturbed soils [66]. Similarly, Tarifa et al. [89] found that hemicryptophytes and therophyte life forms were favored by intensive management in olive orchards. These life forms have the ability to germinate from the seed banks or resprout when disturbances cease and suitable climatic conditions exist [90]. Consequently, they are able to survive and remain in transformed areas, such as agricultural fields. A persistence of seed bank viability has also been related to taxa that are annual or biennial [135], which favors the presence of therophytes. However, the intensification of agriculture and the massive use of agrochemicals may cause them to have adaptive disadvantages compared to other more generalist taxa, as described above. Therefore, all taxa we identified in this category that can colonize and survive in agricultural areas are now threatened by changes in management practices. This situation is aggravated for those taxa that depend on pollinators. As shown in Table 1, more than half of the identified taxa (*Astragalus nitidiflorus*, *Linaria nigricans*, *Narcissus bujei*, and *Silene diclinis)* have generalist entomophilous pollination, which will face an additional threat from agricultural intensification (for example see, Tarifa et al. [89]). This occurs mainly because crop intensification threatens the persistence of wild bee communities and pollination services [99], with important negative implications on the reproductive success of plants. Sometimes what happens is not that the number of bees or dominant taxa decreases, but that intensification reduces foraging success [95,136]. In woody crops, it has been shown that the structure of the pollinator network remains more or less stable under different management regimes (organic and intensive), but the most unique interactions do vary [136]. The risk of extinction of specialized and rare pollinators also affects certain endemic shrubland plants, because the quantity or quality of pollen and the reproductive output may be reduced in the absence of co-evolved pollinators [95,137].

Agricultural intensification also hinders seed dispersal, as it leads to a system characterized by fewer and less interconnected patches of optimal habitats for the threatened taxa. Within crops, at first, the removal of vegetation and the creation of open areas as a consequence of tough plowing, the use of livestock or herbicides, could favor abiotic dispersal plants, such as most of the taxa included in this category (Table 1) [138]. However, this is not usually the case when taking into account soil roughness and slope, factors that are also important for dispersal, as well as for germination and seedling establishment [139]. Recurrent plowing is common in some intensive crops and results in rough soils, which, under certain conditions, can improve the germination capacity of plants [140]. Nevertheless, roughness also increases resistance to movement and decreases seed dispersal distance, preventing colonization of other adjacent favorable agricultural areas. Agricultural intensification has also led to increased soil erosion [141], especially in areas with steep slopes. Soil erosion not only leads to nutrient impoverishment, but also accelerates desiccation and increases the burial depth of seeds [139]. This negatively affects seedling propagation, growth, and survival [139]. Moreover, taxa included in this category are small, which is an additional limitation for wind dispersal (e.g., Watkinson [142]).

4.3. Crop Abandonment

Europe is a continent that has been historically transformed and much of its land area is cultivated. For some threatened taxa, this has meant the loss of their primary habitats and has made their survival almost entirely dependent on the secondary agricultural habitats to which they have adapted [128]. A clear example is the flora and birds of the European steppes [143,144]. As these species have evolved with cultivation, when their preferred habitat (agricultural system) disappears, they are negatively affected [63]. Thus, the abandonment of crops is one of the main threats to most of the taxa included in this group, such as *Allium scaberrimum*, *Isatis aptera*, *Malvella sherardiana,* and *Verbascum fontqueri* (Table 1). Similar results have been observed in other well-studied groups that depend on the agricultural areas they inhabit, such as farmland birds [69,145].

Life forms of the four taxa identified as taxa threatened by land abandonment are hemicryptophytes, therophytes and geophytes. Although it is a very small number of species to draw clear conclusions about trait adaptation, it has been demonstrated that all of these life forms withstand disturbances, can live in crops, and are only displaced by other species when the crops are abandoned. This occurs because land abandonment often leads to interspecific competition for endangered taxa, which, in the end, may promote the increase in the richness and diversity of other more generalist plant species that may sometimes have adaptive advantages over threatened species [146].

Dispersal of taxa included in this group is mainly abiotic. Thus, it seems that revegetation after cultivation could minimize their chances of dispersal as the dispersal rate in open areas should be longer than in more densely vegetated areas [147]. However, as previously stated the number of species is very low to draw clear conclusions about it.

4.4. Conservation Implications

There is growing concern about how to reduce the impact of agricultural use on biodiversity and the scientific community considers the application of biodiversity conservation measures in these areas a key step to achieve effective biodiversity conservation at a global level [44]. For this reason, agri-environmental plans have been implemented in many regions to improve biodiversity in these areas. Some examples are, the Agri-Environment Schemes (AES) of the European Union (EU) Common Agricultural Policy (CAP). However, the measures have not been very effective [148–150] and sound scientific evaluations of the conservation status of taxa and the existing knowledge gaps are needed in order to support policy decisions and to prioritize conservation actions focused on the most threatened taxa [115]. By performing an overall evaluation of the state and potential evolution of the plant taxa threatened by changes in agricultural practices in Spain, we have found that there is an overall decrease in the extension of agricultural areas during the last three decades (Figure 5a). According to this, and considering the high level of legal protection of most of the identified taxa (more than 90% of identified taxa are included in official lists; Table 1), one may expect a good conservation status of all identified taxa. However, a deeper analysis of land use dynamics showed that there are important changes in the area occupied by the different crops (Figure 5b), which reflect an important rate of crop extension occurring in parallel with agriculture abandonment and changes to more intensive practices (irrigated crops, rice fields, and tree crops have increased, while rainfed crops and other types of crops have decreased; Figure 5b), all of these actions having important negative impacts on the plants considered in this study, as well as in all other plants that may not be well recognized as threatened taxa. Thus, although legal mechanisms do exist to protect them, more effort is needed by policy managers, landowners, and society to promote biodiversity conservation of plant taxa in areas endangered by agriculture.

Traditionally, there are two main approaches when facing the difficult and challenging task of reconciling biodiversity conservation with agriculture: (i) to implement measures to achieve sustainable and wildlife-friendly agriculture [91]; and (ii) to increase agriculture intensification in some areas and to minimize new conversions of natural habitats to cultivated areas in others [91]. The first approach proposes the implementation of measures to enhance biodiversity in already existing crops and mainly favors taxa threatened by crop intensification and abandonment. The main problems for its implementation may be the over-cost of the measures and a decrease in crop yields, which could imply an increase in natural habitat conversion rates, being detrimental to taxa affected by crop expansion. Increased intensification, on the other hand is expected to reduce pressure for taxa threatened by crop expansion and to avoid new taxa being included in this category due to the expansion of agriculture in non-altered territories. Nevertheless, it does increase pressure for plants that coexist in agro-ecosystems.

Most of the taxa identified as threatened by agricultural use in continental Spain are threatened by agriculture extension, as there are many plants unable to adapt to any type of agricultural management [59]. For these taxa, respectful and less productive agriculture that implies a greater conversion to cultivation may suppose an additional risk and a sustainable and well-managed intensification, in which natural habitats are conserved and with regulated abandonment of some areas with a proper plan for restoration, could be appropriate [91]. The proposed solution for taxa threatened by crop extension may be to the detriment of those threatened for other reasons (i.e., crop intensification and abandonment). In these cases, it is necessary to implement measures aimed at improving biodiversity in intensified landscapes or in areas where abandonment of cultivation is a threat to plants. For intensified crops, some of the measures to promote biodiversity proposed in scientific literature are: the reduction of the intensification level [151], to promote complexity and heterogeneity of the area by diversifying the agricultural landscape [27,152,153], to increase crop heterogeneity [154], to conserve remnants of natural vegetation [155], to preserve the margins of cultivated fields [156], to conserve riparian vegetation [157], to maintain or create ecological corridors [109], to perform actions to maintain and to improve vegetation cover and diversity within the crops [27], to reduce the use of agrochemicals [130], to identify and conserve key taxa and ecosystem functions [136], and to create green infrastructures such as ponds, hedges or buffer strips [128,158,159]. In the case of those taxa whose threat is crop abandonment [160], general measures could be the identification and maintenance of agricultural landscapes with a high conservation value.

All of the listed measures can benefit threatened taxa, but sometimes they are not sufficient, and additional specific actions are needed [128,151]. Spanish legislation makes the development of recovery plans for endangered taxa mandatory that include measures designed for threatened taxa. However, these plans have rarely been implemented and in others they are developed too late [161]. Thus, more effort is needed in order to implement long-term monitoring programs and warning systems able to detect new impacts, the rarefaction of populations or to evaluate the conservation measures implemented at an early stage. In extreme cases (very small and isolated populations, under great pressure), it is also necessary to develop ex situ conservation programs [162]. With these programs, rescue populations can be established, with which to reintroduce or reinforce populations in the future and conserve genetic viability [162]. Scientific collections preserved in natural history museums and academic institutions play an important role in their ex situ conservation programs for threatened taxa [163] and are responsible for preserving specimens and seeds. Herbaria have been documented as useful resources for improving the genetic diversity of threatened flora as they contain viable seeds and sometimes unique alleles not present in current taxa [164]. In addition, historical records can be obtained almost exclusively from specimens preserved in herbaria, so herbaria are important when making extinction risk assessments of plants [165–167]. However, despite their usefulness, their contributions are widely underestimated by both society and administrations [168] and are in crisis due to the reduction of resources [169]. As an additional recommendation, seeds of threatened species need to be conserved in germplasm banks and natural history collections should continue to be supported with funds and personnel.

In summary, conservation measures exist to promote biodiversity in agricultural landscapes, although few are specific for threatened flora. Moreover, it has been demonstrated that in most situations the adoption of these sustainable practices by farmers depends on incentives that provide a short-term economic benefit [170], which signifies a big effort for the different administrations and frequently only retard biodiversity loss [171]. Indeed, despite all global efforts for preserving global biodiversity, the sustainability gap is growing rather than closing [172], and many new species are threatened every year by the increase in agricultural land to guarantee food security for the global [173] population. Paradoxically, only two-thirds of the food produced in the world is consumed, and 14% of the losses occur in the post-harvest stages [174]. An illustrative example is that 114 kt of fruits and vegetables were discarded in Spain in 2009 [175]. Therefore, if biodiversity conservation, responsible consuming and the achievement of a sustainable production system is the goal, it is timely to promote a deep transformation of our social–ecological systems.

One such transformative shift could come through the reconnection with nature [176]. In recent years, there has been a significant increase in research that supports the need to strengthen human–nature connections (HNC) in agroecosystems to foster environmental and socio-cultural sustainability in agricultural landscapes [177–179]. This promotes the establishment of belonging, stewardship, and connections to nature [179]; thus, providing the social support that is needed to make agriculture and the protection of endangered flora compatible. Indeed, it has been demonstrated that links between nature and people may be more important for biodiversity conservation than indirect links based on incentive payments [143]. Even so, there is a general problem: at the societal level, little empathy has been detected for plants in relation to other biological groups, such as animals, a phenomenon known as "plant blindness" [180]. According to the leverage point hypothesis, the HNC can be approached from five dimensions [181]: material connections, experiential connections, cognitive connections, emotional attachments and philosophical perspectives. Most previous experiences in this line are focused on providing extra income to farmers and in to increase experience of population in agroecosystems, mainly achieving material and experiential connections. However, in order to achieve a real transformation to improve the emotional attachments, and the perspective that society has about what nature is, why it matters, and how humans ought to interact with it (philosophical perspective) would be more efficient. To deepen these connections, environmental education can be an important tool [182]. With environmental education, society can be made aware of the threatened taxa present in agricultural landscapes, their importance, and their threats. With experiences such as agrotourism, supported by environmental education, it is also possible to deepen the emotional and philosophical reconnection, and get consumers to decide to pay a little more for products grown in production systems that respect the environment and threatened plant species [175].

Regardless of the type of measure that we can implement for biodiversity conservation in agricultural areas, it should be a priority for society to be aware of the added value of biodiversity and the presence of endangered species in agricultural environments, and to promote their conservation. Therefore, reconnecting society with nature through agriculture is a challenge today and can be an effective tool to achieve better protection of threatened taxa in cultivated landscapes. This reconversion process must be accompanied by conservation support from the competent administrations and institutions. Moreover these institutions should promote the application of transdisciplinary and collaborative processes in which science, policy making, and society should work together to promote evidence-based biodiversity conservation practices [183]. For example, when developing land use policies, it is advisable to carry out exploratory studies involving different social actors working together in order to discuss potential solutions for the biodiversity crisis and to contribute toward improving the efficiency of policy instruments that will be reflected in later phases [184].

5. Conclusions

Agriculture-related activity causes negative impacts on threatened flora in continental Spain, mainly due to the crops extension, but also to the crop intensification or crop abandonment.

In Spain, the global extension of crops shows a generalized decrease during the last three decades. Nevertheless, when studied in detail, there are significant changes in the areas occupied by the different crops, which reflects an important pace of crop extension that occurs in parallel to the abandonment of agriculture and the shift towards more intensive practices.

The agricultural use of the territory and the biodiversity conservation are possible. For these, it is necessary to reduce and change consumption habits, to carry out rational land planning in which natural habitats are maintained, and to achieve a sustainable production system, in which specific measures for endangered flora are applied. These measurements may benefit from data within scientific collections, as these allow for the assessment of the loss of populations of threatened plant taxa and, in turn, facilitate the sustainable planning of the territory in which they are found.

Finally, to favor the conservation of flora threatened by agricultural use, it is necessary to promote a profound transformation of our socio-ecological systems. The most effective way to achieve it is the human-nature reconnection.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/agriculture11111097/s1, Table S1. Reclassification of land uses from CORINE land cover.

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