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Networking, partnerships and tools to enhance *in situ* conservation of European plant genetic resources

Landrace hotspots identification in Europe

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https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/10/D1.4_Landrace_hotspots_identification_in_Europe.pdf

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Contents

Summary

A variety of heterogeneous materials, which can be regarded as landraces in a broad sense, are still grown in different European countries even if their cultivation decreased strongly in the last decade. Indeed, different factors, such as high population density, widespread industrial and agricultural activities and the effects of climate change, are negatively affecting European Plant Genetic Resources for Food and Agriculture (PGRFA) diversity. This is true for both its components: cultivated (i.e. landraces) and wild (i.e. crop wild relatives) plants. Only limited and scattered information exists about where in situ maintained landraces are grown, which species they belong to and where hotspots of cultivated diversity are. In this scenario, and in order to put in place conservation actions able to efficiently safeguard PGRFA, it is particularly urgent to identify areas characterised by a high level of landrace diversity holding and at the same time CWR diversity. Farmer's Pride aims to identify such areas across Europe.

In this document we identify 100 diversity hotspots to be included in a European network for *in situ* conservation and sustainable use of plant genetic resources based on the available data relative to 19,335 landrace *in situ* records from 14 different European countries (see Deliverable 1.2 *In situ* plant genetic resources in Europe: crop wild relatives of the Farmer's Pride project available at www.farmerspride.eu) (Raggi et al., 2020). To this purpose, we initially identified a grid of cells with a side of 25 km (625 km^2 area) containing at least one landrace, then, using a percentile analysis of distribution of the average number of species per cell, selected the cells with the highest number of different species grown as landraces and, finally, located them in different ecogeographic regions of Europe. Additionally, in order to consider the European breadth of diversity for each country, we listed sites with the highest number of species cultivated as landraces. We initially identified 1,261 cells containing at least one landrace covering all 14 countries and distributed over seven different biogeographical areas: Alpine, Atlantic, Boreal, Continental, Macaronesia, Mediterranean, and Steppic. With more than 500 cells characterised by landrace cultivation, the Mediterranean area is the largest area, followed by the Continental and Boreal.

The percentile analysis of distribution of average number of species cultivated as landraces in the 1,261 cells allowed the identification of 100 hotspots of landrace diversity. These hotspots are mainly located in Greece (45 hotspots), Portugal (29), Italy (16) and Austria (8); one hotspot was noted in the United Kingdom and one also in Spain. Interestingly, 53 of the 100 hotspots occur within Natura 2000 network sites: 31 out of 45 (69%, Greece), 9 out of 16 (56%, Italy), 4 out of 8 (50%, Austria) and 9 out of 29 (31%, Portugal). With a total of 75 diversity hotspots scattered over four different countries (Greece, Portugal, Italy and Spain), the Mediterranean area is the richest in terms of number of hotspots, followed by the Continental and the Alpine, respectively. Besides the 100 hotspots, additional sites containing a relatively high number of landraces of different cultivated species were also identified in each of the other eight countries that provided data: they also deserve attention in conservation planning. Knowledge on diversity hotspots detailed this document can certainly be useful to identify sites to be targeted for future conservation efforts, as well as to be included in the costituenda European network for *in situ* conservation and sustainable use of plant genetic resources.

1. Introduction

With the term Plant Genetic Resources for Food and Agriculture (PGRFA) we generally refer to the portion of between- and within-species plant diversity that is used by humans in agriculture. They include the wild progenitors of cultivated species – also commonly named crop wild relatives (CWR) – and crop landraces also known as local varieties. Both CWR and landraces are important source of genes to adapt crops to ever-changing conditions and to overcome the constraints caused by pests, diseases and abiotic stresses. They are consequently essential for sustainable agricultural production and food security, especially in the actual scenario of climate change and unpredictability. For their intrinsic and actual value, and because they are at risk of extinction, both CWR and landraces are in urgent need of protection (Kell et al., 2012; Veteläinen et al., 2009).

Regarding PGRFA conservation, the *ex situ* approach has historically been regarded as the most practicable due to its relatively easy application and easy access to the conserved germplasm. However, PGRFA conservation in gene banks literally "freezes" their evolutionary and adaptive potential (Brush, 2004; De Haan et al., 2013; Wang et al., 2016). While the *in situ* approach is based on the conservation of the resources where they evolved their distinctive characteristics over time (CBD, 1992). Indeed, *in situ* conservation is seen as a means of capturing the evolutionary adaptation of resources that are exposed to a changing environment, thereby providing a valuable reservoir of adaptive traits (Gepts, 2006; Tiranti and Negri, 2007; Vigouroux 2011). When farmers apply *in situ* conservation to cultivated PGRFA (i.e. landraces) it is commonly referred as on-farm. Due to different peculiar aspects that generally characterise on-farm conserved materials, on-farm conservation can also contribute to support farmer's income, especially in marginal areas and when the production is carried out under organic or low input conditions (Caproni et al., 2020).

Although cultivation of landraces has strongly declined in recent decades, such resources – together with obsolete cultivars and a variety of other heterogeneous materials that can be regarded as landraces in a broad sense, as formalised into the ECPGR Concept for on-farm conservation and management of PGRFA by the European Cooperative Programme for Plant Genetic Resources (ECPGR, 2017) – are still grown in different European countries. However, several factors are still associated with landrace loss including their replacement with modern cultivars, the effects of seed certification legislation, simplification of production processes, breakdown of knowledge and of material transmission from a generation to the next together with the fact that in most countries, no formal government agency has direct responsibility for landrace conservation. Finally, with very few exceptions (e.g. Negri, 2003; Camacho Villa et al., 2005; Heinonen and Veteläinen, 2009), no country has an ample inventory of extant landrace diversity.

Different factors including the high human population density, the widespread industrial and agricultural activities and the effects of climate change make European PGRFA diversity vulnerable; so that a specific agro-biodiversity conservation plan is needed for the continent. This is particularly urgent in the Mediterranean basin, partially covered by European countries, as it is one of the most important biodiversity hotspot (Myers et al., 2000), where high diversity of both landraces (Vavilov, 1927; Pacicco et al., 2018) and CWR (Vavilov, 1927; Vincent et al., 2013; 2019; Castañeda Alvarez et al., 2016) are present. In order to efficiently plan and implement conservation actions able to safeguard the two key components of PGRFA at the same time, it is particularly urgent to identify areas characterised by a high level of landrace and CWR diversity. However, a complete European inventory of *in situ* maintained landraces is still lacking and only limited and scattered information exists on where they are grown, which species they belong to and where hotspots of cultivated diversity are located. Farmer's Pride aims to fill in these gaps as far as possible.

Taking advantage of data produced within the framework of the Farmer's Pride project WP1 Task 1.2 Knowledge of *in situ* resources/sites (Raggi et al., 2020), this document aims to provide information on landrace diversity hotspots across Europe with a special focus on those occurring on Natura 2000 network protected areas where CWR are also conserved.

2. Materials and methods

2.1 Data collection

One of the objectives of the Farmer's Pride Project is to collect information on *in situ* (i.e. on-farm) maintained landraces across Europe and to identify diversity hotspots. To achieve such an objective, an ad hoc template was initially developed by UNIPG and circulated to the Farmer's Pride Consortium Members, Farmer's Pride Ambassadors and ECPGR National Coordinators of all European countries asking for records of known sites of cultivations (records) of broad sense landraces (including true landraces, conservation and amateur varieties, populations and old cultivars) conserved on-farm in their respective countries. The template was prepared by using a subset of the descriptors for web-enabled national *in situ* landrace inventories document (Negri et al., 2012) originally established to facilitate the development of national inventories of *in situ* maintained landraces. Among others, selected fields allowed the collection of information on: landraces name, genus, species, location of cultivation (including geographic coordinates, where available) and country. More information about the template structure and specific fields are available in Raggi and colleagues (2020).

2.2. Data format standardisation and spatial consistency verification

All the information collected was initially organised in a database to allow successive analyses. Since, latitude (LAT) and longitude (LONG) were provided by partners using different formats, as a first step all data were converted to Decimal Degrees (DD) – the standard used to implement the subsequent analysis – through appropriate techniques. Standardized data were subsequently imported into GIS software specifying the geographic reference system WGS84 (EPSG: 4326), compliant with the LAT / LONG DD format.

As a second step, a consistency analysis was carried out to verify that the LAT / LONG DD fields of all the records were correctly filled in and that records fell within the census territory (i.e. within the borders of the declared country). The administrative borders of the EU countries from the Eurostat database – Administrative Units, with update date of 03/14/2019 (scale of 1: 1000000), with reference system EPSG: 4326 (https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statisticalunits/nuts#nuts16) was used as the national borders' layer. At the analysis date, 37 countries were included within European borders (Table 1).

Table 1. List of European countries for which national borders were elaborated

NUTS_ID[1]	CNTR_CODE[2]	NUTS_NAME	NUTS_ID	CNTR_CODE	NUTS_NAME
AL	AL	ALBANIA	LT	LT	LATVIA
CZ	CZ	CZECH REPUBLIC	LU	LU	LUXEMBOURG
DE	DE	GERMANY	NL	NL	NETHERLANDS
DK	DK	DENMARK	NO	NO	NORWAY
CY	CY	CYPRUS	LV	LV	LATVIA
AT	AT	AUSTRIA	ME	ME	MONTENEGRO
BE	BE	BELGIUM	MT	MT	MALTA
BG	BG	BULGARIA	MK	MK	NORTH MACEDONIA
CH	CH	SWITZERLAND	LI	LI	LIECHTENSTEIN
EE	EE	ESTONIA	PL	PL	POLAND
EL	EL	GREECE	SI	SI	SLOVENIA
ES	ES	SPAIN	SK	SK	SLOVAKIA
FI	FI	FINLAND	TR	TR	TURKEY
FR	FR	FRANCE	UK	UK	UNITED KINGDOM
HR	HR	CROATIA	RS	RS	SERBIA
HU	HU	HUNGARY	SE	SE	SWEDEN
IE	IE	IRELAND	PT	PT	PORTUGAL
IS	IS	ICELAND	RO	RO	ROMANIA
IT	IT	ITALY	-	-	-

[1]Administrative units identity. [2]Country code.

From a first analysis, most of the records fell into the declared nation; other records were located in the sea (very close to the shores) or in neighbouring territories of the declared countries. Information recorded in the field "Farm location" (FARMSECONDADMIN) (i.e. secondary administrative subdivision within the primary administrative subdivision of the country where the farm is located) was used to correctly position the misplaced records within the respective countries, with an average approximation error of about 10 km.

2.3 Density analysis

Georeferenced records and administrative borders (NUTS0 georeferenced in EPSG: 4326) .shp files were used for density analysis. Grids, and the relative cells, were obtained starting from those available at the European Commission website (EEA reference grid – https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2) that are used as the mapping standard. Such grids are characterised by steps of 10 and 100 km, and are georeferenced in EPSG: 3035 (Lambert Azimuthal Equal Area). We selected a grid of cells with a side of 25 km (areas of each identified cell equal to 625 km^2). An analysis of spatial correspondence between the records and the administrative units was carried out that to identify the cells containing at least one landrace. The number of landrace species and cultivation records by cell was also calculated.

2.4 Biogeographical regions

The cartography of the biogeographical regions updated to January 2016, available on the website of the European Environmental Agency (https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe- 3), was initially obtained. The biogeographical regions dataset used contains the official delineations used in the Habitats Directive (92/43 / EEC) and for the EMERALD Network set up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) (Table 2).

Table 2. List of European biogeographical regions

Biogeographical region name	Code	Pre-2012	Biogeographical region name	Code	Pre-2012
Alpine	Alpine	ALP	Continental	Continental	CON
Anatolian	Anatolian	ANA	Macaronesian	Macaronesian	MAC
Arctic	Arctic	ARC	Mediterranean	Mediterranean	MED
Atlantic	Atlantic	ATL	Pannonian	Pannonian	PAN
Black Sea	Blacksea	BLS	Steppic	Steppic	STE
Boreal	Boreal	BOR	-	-	-

2.5 Detection of hotspots

The density analysis file, consisting of all the cells containing ≥ 1 landrace record was initially worked out. “Hotspots” were identified when a single cell (25 × 25 km in size) was characterised by a high number of species cultivated as landraces, as follows: the 90th percentile of the “number of species by cell” was calculated and cell characterised by values ≥ 90th percentile were identified and the top 100 cells were selected. Subsequent GIS analyses allowed to assign each identified cell (hereafter hotspot) to one of the different European biogeographical regions and verify its inclusion, or not, within the Natura 2000 network sites.

In addition to the 100 hotspots, a list of sites characterised by the highest number of landraces was produced for each country for which data were available. Five and three cells were included in the list for those countries characterised by having ≥20 and <20 “cells containing landraces”, respectively. The same GIS analyses were carried out for the sites included in the list. These analyses were not carried out for countries holding most of the hotspots.

3. Results

3.1 Data collection

A total of 19,335 records of landraces (broad sense) cultivation were provided by 17 Institutions from 14 different European countries (Table 3). Unfortunately we got no data from some countries (e.g. France and Poland). A quite different number of records were provided by countries covered by the study. Italy provided the highest number followed by Greece, Austria and Portugal (Figure 1). Results of the analysis of the number of records and crop species by country, and in relationship with different European biogeographic areas, are available in Farmer's Pride Project Deliverable D1.2 by Raggi and colleagues (2020).

Table 3. List of data providers on on-farm maintained landraces.

Institution Name	Institution acronym	Role	Country	Provided records
Arche Noah	ARCN	FP Partner	AUS	4,489
University of Zagreb	-	FP Ambassador	HRV	24
Crop Research Institute	CRI	FP Ambassador	CZE	196
Danish Seed Savers	DSS	FP Partner	DNK	103
Estonian Crop Research Institute	-	FP Ambassador	EST	17
Natural Resources Institute	LUKE	FP Partner	FIN	213
Federal Office for Agriculture and Food	BLE	ECPGR member	DEU	214
Hellenic Agricultural Organisation-DEMETER	DIMITRA	FP Partner	GRC	4,688
Centro Ricerche Produzini Vegetali	CRPV	FP Ambassador	ITA	36
Università degli Studi di Perugia	UNIPG	FP Partner	ITA	5,399
Banco Português de Germoplasma Vegetal	BPGV	FP Partner	PRT	3,050
Banca de Resurse Vegetal "Mihai Cristea" Suceava	SV genebank	ECPGR Member	ROU	128
Universidad Rey Juan Carlos	URJC	FP Partner	ESP	316
Universitat Politècnica de València	UPV	FP Partner	ESP	61
Swedish Board of Agriculture	-	FP Ambassador	SWE	137
University of Birmingham	UOB	FP Coordinator	GBR	254
Independent Researcher and Advisor	-	FP Ambassador	GBR	10

Landrace records belong to 121 different genera – Triticum (2,498 records), Phaseolus (1,870), Solanum (1,175), Malus (1,072), Prunus (958), Cucurbita (942), Secale (780), Fagopyrum (775), Pyrus (748) and Cucumis (723) being the 10 encompassing the largest numbers of records – and 190 cultivated species. Among the identified species, Triticum spelta (1,820 records), Phaseolus vulgaris (1,785), Malus domestica (1,061), Solanum lycopersicum (838), Fagopyrum esculentum (775), Pyrus communis (748), Secale cereale (669), Zea mays (623), Cucumis melo (574), Papaver somniferum (560), Prunus avium (525), Brassica oleracea (461), Cucurbita pepo (457), Capsicum annuum (446) and Vitis vinifera (445) are the 15 accounting for the highest number of records.

The full list of species still cultivated as landraces in Europe, including the number of records by species, is available by Raggi and colleagues 2020.

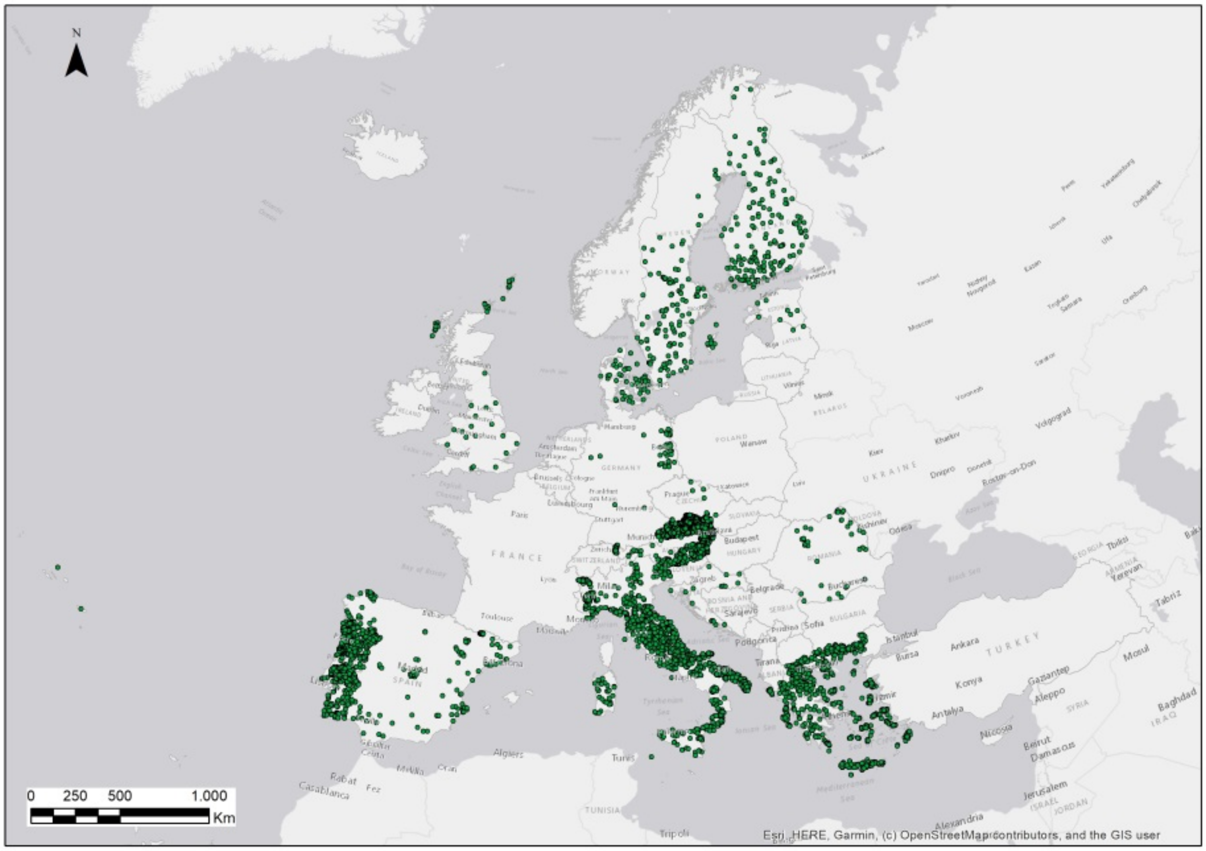

Figure 1. Geographical location of the 19,335 landrace records within their respective countries. It should be noted that multiple records with the same geographic coordinates appear as a single dot due to dots overlapping.

3.2 Data format standardisation and spatial consistency verification

From the first analysis, out of a total of 19,335 records, 16,720 correctly fell into the declared nation; other records were located in the sea (very close to the shores) or in neighbouring territories of the declared countries. Results of the second calibration step of the methodology – based on information of the secondary administrative subdivision of the country where the cultivation site was located – allowed the correct positioning of the remaining misplaced records within their respective countries.

3.3 Density analysis

Density analysis allowed the identification of 1,261 cells (25 × 25 km) characterised by the presence of ≥ 1 record (i.e. corresponding to areas where landrace cultivation occurs). For each identified cell, the total number of records and the total number of cultivated species were also retrieved. Summary statistics relative to the 1,261 identified cells are reported in Table 4.

Table 4. Summary statistics of the 1,261 identified cells grouped by country.

Country code	Number of cells	Number of records			Number of species			Estimated number of different landraces*
		Total	Mean	S.D.	Total	Mean	S.D.	
AT	108	4,489	41.6	64.60	23	6.16	3.90	56
CZ	7	196	28.0	22.69	11	3.00	1.63	140
DE	22	214	9.7	8.75	11	2.55	1.44	89
DK	38	103	2.7	3.69	21	1.74	1.67	75
EE	8	17	2.1	1.46	10	1.63	1.06	17
EL	232	4,688	20.2	27.11	93	9.65	8.27	628
ES	87	377	4.3	5.97	45	2.36	2.87	267
FI	130	213	1.6	1.27	20	1.28	0.58	150-
HR	13	24	1.8	1.99	7	1.31	1.11	24
IT	325	5,435	16.7	39.76	107	4.21	4.16	2,256
PT	141	3,050	21.6	28.43	45	7.59	7.02	730
RO	29	128	4.4	6.30	21	2.31	2.32	126
SE	90	137	1.5	1.06	13	1.19	0.49	133
UK	31	264	8.5	18.11	26	2.68	3.03	264

* Based on landraces unique name.

The highest number of cells containing ≥ 1 landrace records was observed in Italy (325 cells) followed by Greece (232), Portugal (141), Finland (130) and Austria (108). As expected, with only the exception of Finland, the same countries were also characterised by the highest total number of records even if they ranked in a slightly different order: Italy (5,435), Greece (4,688), Austria (4,489) and Portugal (3,050). The highest values of mean number of records by cell were also observed in the same countries: Austria (41.6 records, n=108), Portugal (21.6, n=141), Greece (20.2, n= 232) and Italy (16.7, n=325) with the addition of the Czech Republic (28.0, n=7); however, a very low number of cells (seven) were recorded in the latter country. Characterised by the presence of 107 and 93 different species still cultivated as landraces, Italy and Greece are clearly the two countries holding the highest landraces specific diversity followed by Portugal (45) and Spain (45). Finally, the highest mean numbers of species by cell were also recorded in Greece (9.65), Portugal (7.59), Austria (6.16) and Italy (4.21).

As shown in the numbers in Table 4, Greece, Italy and Portugal are also the countries where the largest areas are involved in the conservation process. With regard to this, the low standard deviation of "number of records by cell" observed in Greece (27.11) and Portugal (28.43) also suggest that in these two countries landraces are more evenly distributed in comparison with Italy (39.76).

3.4 Biogeographical regions

The cartographic elaboration of the biogeographical regions' dataset is reported in Figure 2.

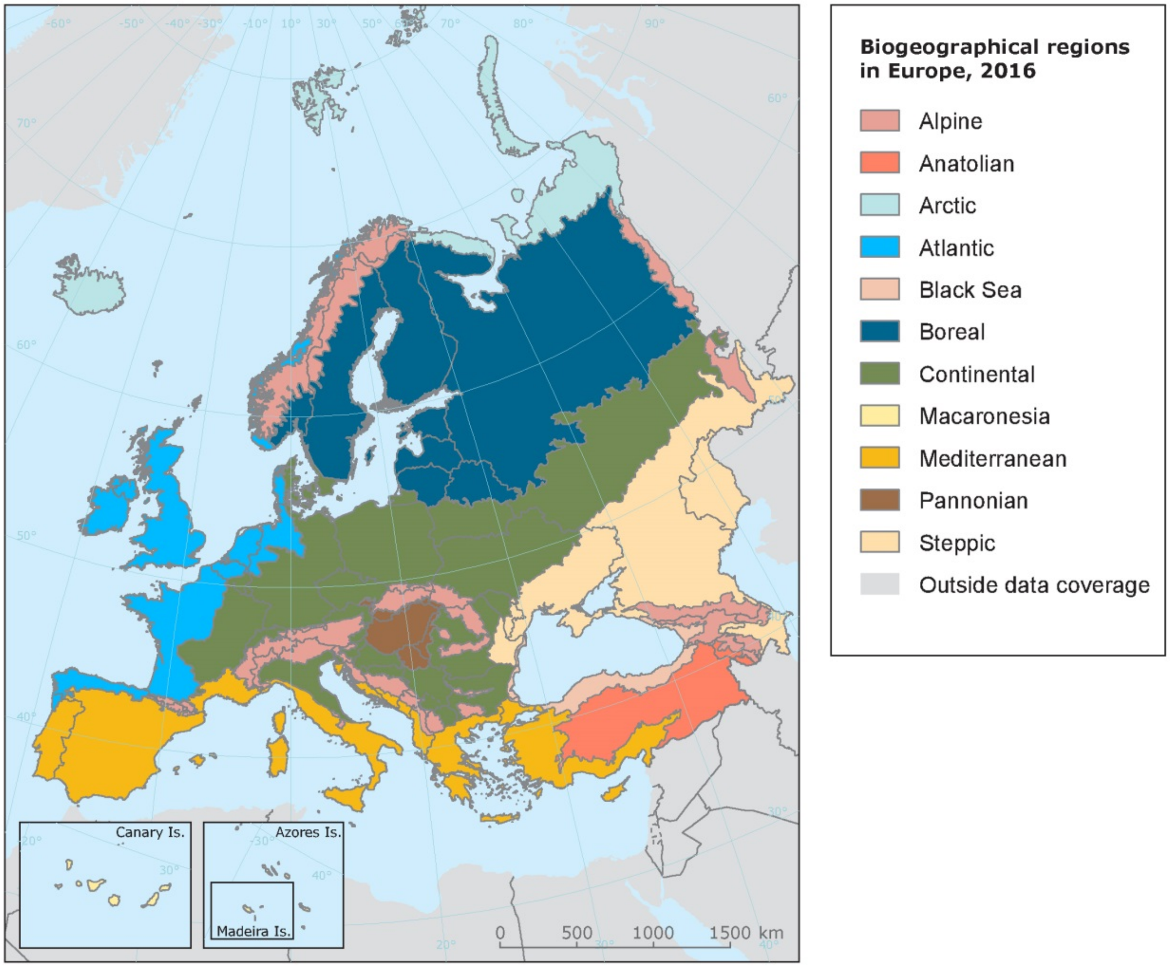

Figure 2. European biogeographical regions.

Table 5 shows the results of the assignment of cells characterised by the presence of ≥1 landrace cultivation sites to the different European biogeographical regions and countries. With a total of 583 cells, scattered over only five different countries, the Mediterranean biogeographical region is the most represented followed by the Continental (231 cells), common to eight countries, the Boreal (217 cells) are almost only present in Finland and Sweden (96.3% of the total cells). With 149 cells scattered in nine countries, the Alpine is the most common biogeographical region, when the number of countries is considered, even if a relative high number of cells is only present in Austria (63) and in Italy (55). Finally, the Macaronesia and the Steppic biogeographical regions are, by far, the least represented ones with only two and three cells of interest, respectively.

Cells in the Continental area of Austria have the highest number of records per cell on average (78.1, n=45) even if, in comparison, the average number of species is fairly low (8.7, n=45) with a records/species ratio of 9.0; the reported numbers indicate that in these situations, few landraces are grown in a high number of fields located in a restricted area. Differently, in Greece, Italy and Portugal – the three countries characterised by the highest number of records – values of the ratio records/species were quite low in almost all the different existing biogeographic areas. With regard to this it is noteworthy that the low (2.0) average value of records/species calculated were for the 211 cells in the Mediterranean area of Greece. In general, in the three above-mentioned countries, the low observed values of this parameter show that several landraces of different species are still grown in relatively small areas scattered all over the countries. Similar low values of the parameter are only typical of cells with an extremely low "number of records"; such cells, where few landraces of few species are cultivated, are present in almost all the biogeographical regions (e.g. Alpine in Czech Republic, Romania and Sweden; Atlantic in Denmark, Boreal and Estonia, Continental in Croatia and Sweden) (Table 5).

Table 5. Number of 25 × 25 km cells assigned to each European biogeographic region followed by mean number of landrace records and of species (in brackets). Cells are grouped by country.

Country code	Alpine	Atlantic	Boreal	Continental	Macaronesia	Mediterranean	Steppic	Total
AT	63 (15.4; 4.4)	-	-	45 (78.1; 8.7)	-	-	-	108
CZ	1 (1.0; 1.0)	-	-	6 (23.7; 3.3)	-	-	-	7
DE	-	2 (10.0; 2.5)	-	20 (9.3; 2.6)	-	-	-	22
DK	-	5 (1.6; 1.2)	-	33 (2.9; 1.8)	-	-	-	38
EE	-	-	8 (2.1; 1.6)	-	-	-	-	8
EL	9 (32.2; 12.9)	-	-	12 (23.7; 8.8)	-	211 (19.5; 9.6)	-	232
ES	8 (6.4; 1.9)	15 (1.9; 1.1)	-	-	-	64 (4.6; 2.7)	-	87
FI	3 (1.3; 1.0)	-	127 (1.6; 1.3)	-	-	-	-	130
HR	3 (1.7; 1.0)	-	-	6 (1.3; 1)	-	4 (2.0; 2.0)	-	13
IT	55 (12.0; 3.5)	-	-	88 (10.9; 3.7)	-	182 (21.0; 4.7)	-	325
PT	-	17 (31.7; 5.9)	-	-	2 (1.5; 1.0)	122 (20.6; 7.9)	-	141
RO	3 (1.0; 1.0)	-	-	23 (5.2; 2.6)	-	-	3 (1.7; 1.3)	29
SE	4 (1.0; 1.0)	-	82 (1.5; 1.2)	4 (1.3; 1.3)	-	-	-	90
UK	-	31 (8.5; 2.7)	-	-	-	-	-	31
Total	**149**	**70**	**217**	**237**	**2**	**583**	**3**	**1,261**

3.5 Detection of hotspots

According to the analysis of the distribution of values "number of species by cell", the first threshold for the diversity hotspot identification was set to ≥ 13 different species grown as landraces per cell (Figure 3). From a total of 1,261 cells containing landraces, the application of the selected threshold resulted in the identification of 128 cells holding a total of 8,362 landrace records (43.3% of the total) belonging to 141 different cultivated species (71.9% of the total).

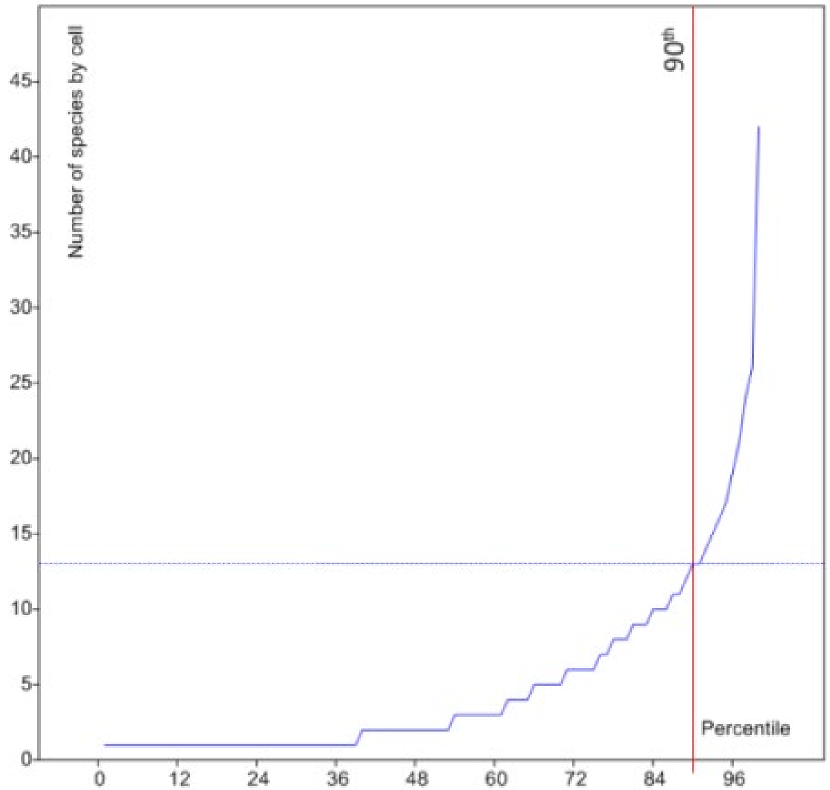

Figure 3. Distribution of increasing values of "number of species by cell". In the plot, the 90th percentile of values distribution (solid red line) and corresponding number of species (blue dotted line) are reported.

Amongst the 128 previously identified cells, the 100 characterised by the highest number of records were selected corresponding to the 100 hotspots of landrace *in situ* diversity in Europe. The comparison of number of records, number of species and derived statistics of the three datasets is reported in Table 6.

Table 6 Comparison of records and species coverage obtained by applying the percentile-based selection method for landrace diversity hotspot identification.

	Total 1,261 cells	128 cells	100 cells
Total records	19,335	8,362	7,732
Total species	196	141	137
Records/cell	15.33	65.33	77.32
Unique species/cell	0.16	1.10	1.37
Records/Species	98.65	59.30	56.44
Included cells in relation to Total (%)	100%	10%	8%
Included records in relation to Total (%)	100%	43%	40%
Included species in relation to Total (%)	100%	72%	70%

The 100 identified hotspots correspond only to the 8% of total cells, but hold a significant percentage of the "total number of records" (40%) and a high percentage of the total number of cultivated species (70%). Both "average number of records" and "average number of species" by cell sharply increased moving from the 1,261 to the 100 cells; it should also be noted that a small reduction of the two percentages occurred shifting the attention from 128 to 100 cells, confirming the appropriateness of the applied procedure (Table 6). Hotspots are located in six different countries: 45 are in Greece, 29 in Portugal, 16 in Italy, eight in Austria, one in the United Kingdom and one in Spain (Figure 4).

A total of 7,732 landraces *in situ* records are present in the 100 hotspots, the highest number have been recorded in Greece (2,737) followed by Portugal (1,767) and Austria (1,570) (Table 7). Greece is also the country where landraces cultivated in the hotspots belong to the highest number of different species (82) followed, in this case, by Italy (73) and Portugal (43). Only a limited number of species (22) are present in the 8 Austrian hotspots (Table 7). Finally, a relevant number of different species are still cultivated as landraces in the single hotspots identified in United Kingdom and Spain (16 and 15, respectively).

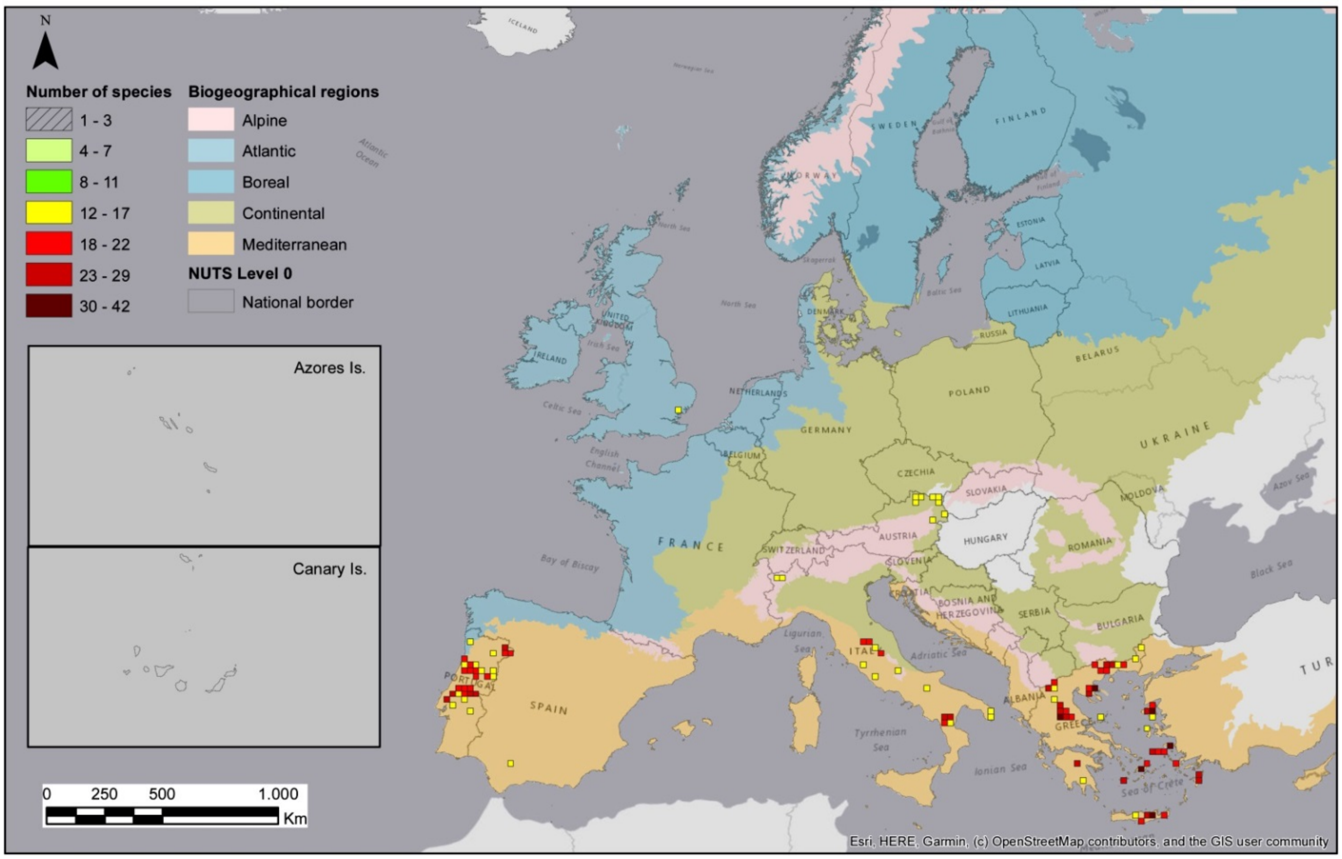

Figure 4. Location of the 100 identified landrace diversity hotspots (coloured cells). Number of species per cell and biogeographic areas colours are according to the legend. Madeira islands are not shown on this map.

Table 7. Number of records and species in the 100 identified hotspots. Data are grouped by country ordered according to the number of identified hotspots.

Country	Number of hotspots	TOTAL number of records	Total number of different species	Mean number of records by cell	Mean number of species by cell
EL	45	2,737	82	60.8	23.1
PT	29	1,767	43	60.9	19.1
IT	16	1,536	73	96.0	16.8
AT	8	1,570	22	196.3	14.1
UK	1	92	16	92.0	16.0
ES	1	30	15	30.0	15.0
Total	**100**	**7,732**	**251**	-	-

Interestingly enough, as much as 53 out of the 100 identified hotspots are part of Natura 2000 sites: 31 out of 45 (69%, Greece), nine out of 16 (56%, Italy), four out of eight (50%, Austria) and 9 out of 29 (31%, Portugal) (Figure 5). The full list of species present in the 100 hotspots is reported in Table 8 and in Table 9 grouped by country.

Table 8. List of species recorded in the 100 identified landrace hotspots.

Landrace species in the 100 identified hotspots			
Abelmoschus esculentus	*Crataegus laevigata*	*Luffa acutangula*	*Prunus persica*
Allium ampeloprasum	*Cucumis melo*	*Luffa cylindrica*	*Punica granatum*
Allium cepa	*Cucumis sativus*	*Lupinus albus*	*Pyrus communis*
Allium porrum	*Cucurbita ficifolia*	*Maclura pomifera*	*Raphanus sativus*
Allium sativum	*Cucurbita maxima*	*Malus baccata*	*Rorippa nasturtium-aquaticum*
Amaranthus retroflexus	*Cucurbita moschata*	*Malus domestica*	*Satureja hortensis*
Anethum graveolens	*Cucurbita pepo*	*Malus pumila*	*Secale cereale*
Apium graveolens	*Cuminum cyminum*	*Matricaria recutita*	*Sesamum indicum*
Arachis hypogaea	*Cynara cardunculus*	*Medicago sativa*	*Setaria italica*
Arbutus unedo	*Cynara scolymus*	*Mentha pulegium*	*Sinapis arvensis*
Avena sativa	*Daucus carota*	*Mentha spicata*	*Solanum lycopersicum*
Beta vulgaris	*Diospyros kaki*	*Mespilus germanica*	*Solanum melongena*
Brassica juncea	*Elettaria cardamomum*	*Morus alba*	*Solanum tuberosum*
Brassica napus	*Eriobotrya japonica*	*Morus nigra*	*Sorbus domestica*
Brassica nigra	*Eruca sativa*	*Nicotiana tabacum*	*Sorghum bicolor*
Brassica oleracea	*Eruca vesicaria*	*Ocimum basilicum*	*Spinacia oleracea*
Brassica rapa	*Ficus carica*	*Olea europaea*	*Trifolium pratense*
Calendula officinalis	*Foeniculum vulgare*	*Origanum majorana*	*Trigonella foenum-graecum*
Capsicum annuum	*Gossypium hirsutum*	*Origanum vulgare*	*Triticum aestivum*
Capsicum chinense	*Helianthus annuus*	*Oryza sativa*	*Triticum spelta*
Capsicum frutescens	*Hordeum vulgare*	*Panicum miliaceum*	*Triticum turgidum*
Castanea sativa	*Hypericum perforatum*	*Petroselinum crispum*	*Vicia ervilia*
Chaenomeles japonica	*Juglans regia*	*Phaseolus coccineus*	*Vicia faba*
Cicer arietinum	*Lablab purpureus*	*Phaseolus vulgaris*	*Vicia sativa*
Cichorium endivia	*Lactuca sativa*	*Pimpinella anisum*	*Vigna unguiculata*
Cichorium intybus	*Lagenaria siceraria*	*Pisum sativum*	*Vitis vinifera*

Citrullus lanatus	*Lathyrus clymenum*	*Prunus armeniaca*	*Zea mays*
Coriandrum sativum	*Lathyrus ochrus*	*Prunus avium*	*Ziziphus jujuba*
Cornus mas	*Lathyrus sativus*	*Prunus cerasus*	-
Corylus avellana	*Lens culinaris*	*Prunus domestica*	-
Crataegus azarolus	*Linum usitatissimum*	*Prunus dulcis*	-

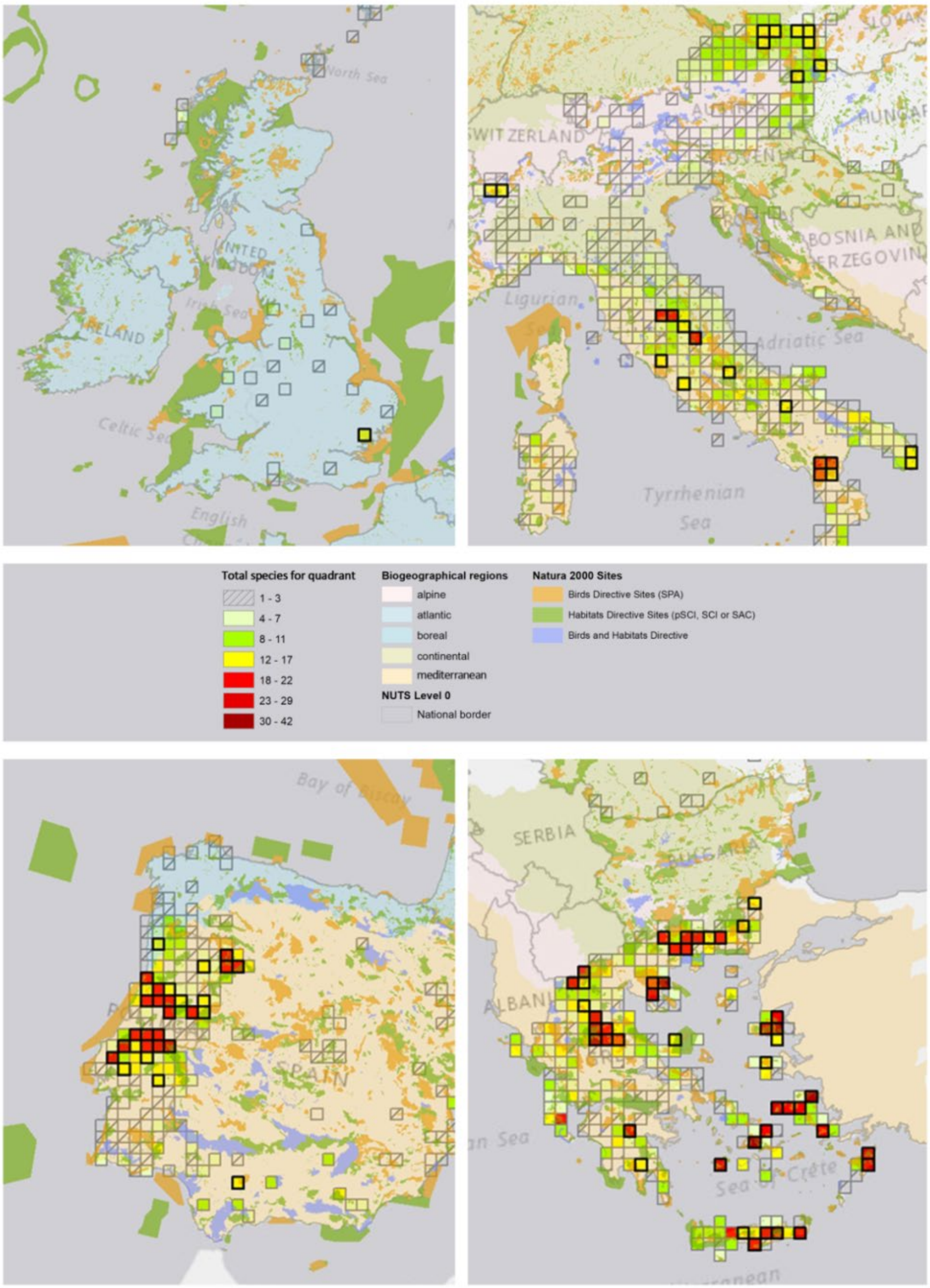

Figure 5. Location of the 100 landrace hotspots (black outline cells) in: United Kingdom (top left), Austria and Italy (top right), Portugal and Spain (bottom left) and Greece (bottom right). Number of species per cell, biogeographical areas and Natura 2000 sites colours are according to the legend (centre).

Table 9. List of species cultivated in the 100 identified landrace hotspots grouped by country.

Austria	Greece	Spain	Italy	Portugal	United Kingdom
Allium cepa	*Abelmoschus esculentus*	*Allium ampeloprasum*	*Allium cepa*	*Allium cepa*	*Allium cepa*
Avena nuda	*Allium cepa*	*Allium cepa*	*Allium sativum*	*Allium porrum*	*Apium graveolens*
Avena strigosa	*Allium porrum*	*Brassica juncea*	*Arbutus unedo*	*Allium sativum*	*Beta vulgaris*
Brassica rapa	*Allium sativum*	*Capsicum annuum*	*Beta vulgaris*	*Avena sativa*	*Brassica oleracea*
Camelina sativa	*Amaranthus retroflexus*	*Citrullus lanatus*	*Brassica napus*	*Beta vulgaris*	*Brassica rapa*
Fagopyrum esculentum	*Anethum graveolens*	*Cucumis melo*	*Brassica oleracea*	*Brassica napus*	*Cucumis sativus*
Hordeum vulgare	*Apium graveolens*	*Cucumis sativus*	*Brassica rapa*	*Brassica oleracea*	*Cucurbita pepo*
Linum usitatissimum	*Arachis hypogaea*	*Cucurbita maxima*	*Capsicum annuum*	*Brassica rapa*	*Daucus carota*
Panicum miliaceum	*Avena sativa*	*Cucurbita pepo*	*Castanea sativa*	*Capsicum annuum*	*Lactuca sativa*
Papaver somniferum	*Beta vulgaris*	*Daucus carota*	*Chaenomeles japonica*	*Capsicum chinense*	*Solanum lycopersicum*
Phaseolus vulgaris	*Brassica napus*	*Lactuca sativa*	*Cicer arietinum*	*Capsicum frutescens*	*Pastinaca sativa*
Secale cereale	*Brassica nigra*	*Phaseolus vulgaris*	*Cichorium intybus*	*Cicer arietinum*	*Petroselinum crispum*
Secale multicaule	*Brassica oleracea*	*Pisum sativum*	*Citrullus lanatus*	*Citrullus lanatus*	*Phaseolus coccineus*
Solanum tuberosum	*Brassica rapa*	*Solanum lycopersicum*	*Cornus mas*	*Coriandrum sativum*	*Pisum sativum*
Sorghum bicolor	*Calendula officinalis*	*Solanum melongena*	*Corylus avellana*	*Cucumis melo*	*Raphanus sativus*
Trifolium pratense	*Capsicum annuum*	-	*Crataegus azarolus*	*Cucumis sativus*	*Vicia faba*
Trigonella caerulea	*Cicer arietinum*	-	*Crataegus laevigata*	*Cucurbita ficifolia*	-
Triticum aestivum	*Cichorium endivia*	-	*Cucumis melo*	*Cucurbita maxima*	-
Triticum dicoccum	*Cichorium intybus*	-	*Cucumis sativus*	*Cucurbita moschata*	-
Triticum monococcum	*Citrullus lanatus*	-	*Cucurbita maxima*	*Cucurbita pepo*	-
Triticum spelta	*Coriandrum sativum*	-	*Cucurbita moschata*	*Daucus carota*	-
Zea mays	*Cucumis melo*	-	*Cucurbita pepo*	*Helianthus annuus*	-

-	*Cucumis sativus*	-	*Cydonia oblonga*	*Hordeum vulgare*	-
-	*Cucurbita maxima*	-	*Cynara scolymus*	*Lactuca sativa*	-
-	*Cucurbita moschata*	-	*Daucus carota*	*Lagenaria siceraria*	-
-	*Cucurbita pepo*	-	*Diospyros kaki*	*Lathyrus sativus*	-
-	*Cuminum cyminum*	-	*Eriobotrya japonica*	*Lens culinaris*	-
-	*Cynara cardunculus*	-	*Eruca vesicaria*	*Linum usitatissimum*	-
-	*Daucus carota*	-	*Ficus carica*	*Lupinus albus*	-
-	*Elettaria cardamomum*	-	*Foeniculum vulgare*	*Oryza sativa*	-
-	*Eruca sativa*	-	*Hordeum vulgare*	*Petroselinum crispum*	-
-	*Foeniculum vulgare*	-	*Juglans regia*	*Phaseolus coccineus*	-
-	*Gossypium hirsutum*	-	*Lathyrus cicera*	*Phaseolus vulgaris*	-
-	*Helianthus annuus*	-	*Lathyrus sativus*	*Pisum sativum*	-
-	*Hordeum vulgare*	-	*Lens culinaris*	*Raphanus sativus*	-
-	*Hypericum perforatum*	-	*Maclura pomifera*	*Rorippa nasturtium-aquaticum*	-
-	*Lablab purpureus*	-	*Malus baccata*	*Secale cereale*	-
-	*Lactuca sativa*	-	*Malus domestica*	*Setaria italica*	-
-	*Lagenaria siceraria*	-	*Medicago sativa*	*Solanum lycopersicum*	-
-	*Lathyrus clymenum*	-	*Mespilus germanica*	*Triticum aestivum*	-
-	*Lathyrus ochrus*	-	*Morus alba*	*Vicia faba*	-
-	*Lathyrus sativus*	-	*Morus nigra*	*Vigna unguiculata*	-
-	*Lens culinaris*	-	*Ocimum basilicum*	*Zea mays*	-
-	*Luffa acutangula*	-	*Olea europaea*	-	-
-	*Luffa cylindrica*	-	*Onobrychis viciifolia*	-	-
-	*Lupinus albus*	-	*Petroselinum crispum*	-	-
-	*Malus pumila*	-	*Phaseolus coccineus*	-	-
-	*Matricaria recutita*	-	*Phaseolus vulgaris*	-	-
-	*Medicago sativa*	-	*Pisum sativum*	-	-
-	*Mentha pulegium*	-	*Prunus armeniaca*	-	-

-	*Mentha spicata*	-	*Prunus avium*	-	-
-	*Nicotiana tabacum*	-	*Prunus cerasifera*	-	-
-	*Ocimum basilicum*	-	*Prunus cerasus*	-	-
-	*Origanum majorana*	-	*Prunus domestica*	-	-
-	*Origanum vulgare*	-	*Prunus dulcis*	-	-
-	*Panicum miliaceum*	-	*Prunus persica*	-	-
-	*Petroselinum crispum*	-	*Punica granatum*	-	-
-	*Phaseolus coccineus*	-	*Pyrus communis*	-	-
-	*Phaseolus vulgaris*	-	*Salsola soda*	-	-
-	*Pimpinella anisum*	-	*Secale cereale*	-	-
-	*Pisum sativum*	-	*Solanum lycopersicum*	-	-
-	*Prunus avium*	-	*Solanum melongena*	-	-
-	*Prunus dulcis*	-	*Solanum tuberosum*	-	-
-	*Raphanus sativus*	-	*Sorbus domestica*	-	-
-	*Satureja hortensis*	-	*Spinacia oleracea*	-	-
-	*Secale cereale*	-	*Trifolium pratense*	-	-
-	*Sesamum indicum*	-	*Triticum aestivum*	-	-
-	*Sinapis arvensis*	-	*Triticum turgidum*	-	-
-	*Solanum lycopersicum*	-	*Vicia faba*	-	-
-	*Solanum melongena*	-	*Vigna unguiculata*	-	-
-	*Solanum tuberosum*	-	*Vitis vinifera*	-	-
-	*Sorghum bicolor*	-	*Zea mays*	-	-
-	*Spinacia oleracea*	-	*Ziziphus jujuba*	-	-
-	*Trigonella foenum-graecum*	-	-	-	-
-	*Triticum aestivum*	-	-	-	-
-	*Triticum spelta*	-	-	-	-
-	*Triticum turgidum*	-	-	-	-
-	*Vicia ervilia*	-	-	-	-
-	*Vicia faba*	-	-	-	-
-	*Vicia sativa*	-	-	-	-

-	*Vigna unguiculata*	-	-	-	-
-	*Zea mays*	-	-	-	-

The 100 hotspots encompass all the major European biogeographical regions: 75 are in the Mediterranean area, 15 in the Continental, eight in the Alpine and two in the Atlantic area. The only exception is the Boreal area where, even if a high number of cells containing landraces have been identified (217), the average number of records/cell and species/cell was always quite low ranging from 1.5 (SE) to 2.1(EE) and from 1.2 (SE) to 1.6 (EE), respectively. Finally, Macaronesia and Steppic areas hold none of the identified hotspots.

The eight hotspots in the **Alpine biogeographic area** are located in Austria, Greece and Italy. In particular: four hotspots are located in Greece, close to the borders with the Republic of North Macedonia (2) and Bulgaria (2); three are located in Italy, one in the province of Frosinone and two near the border between Italy and Switzerland (near the cities of Biella and Aosta, respectively); one hotspot is located in North-Eastern Austria, in the belt of the cities of Liezen and Ternitz (Figure 6). Among those identified, hotspots 1,774 and 2,324 (both located in Greece) are characterised by the highest number of different cultivated species, 26 and 22, respectively, while hotspot 5,484, located in Austria, has the highest number of records of 13 species only (Table 10).

Table 10. Main characteristics of the 8 Alpine hotpots.

Cell number	Number of records	Number of species	Records/ species	Country	Biogeographic area	Rank, by number of species	Rank, by number of records	Natura 2K site
5484	123	13	9.5	AT	Alpine	91	13	Yes
1774	72	26	2.8	EL	Alpine	13	32	No
1902	48	22	2.2	EL	Alpine	28	67	Yes
2321	53	21	2.5	EL	Alpine	38	58	No
2324	65	24	2.7	EL	Alpine	18	45	No
2155	52	13	4.0	IT	Alpine	93	60	Yes
4416	82	14	5.9	IT	Alpine	82	23	No
4417	57	13	4.4	IT	Alpine	92	53	No

The 100%, 25% and 33% of hotspots in Austria, Greece and Italy occur in Natura 2000 sites respectively. Landraces of 68 different species are cultivated in the eight Alpine hotspots (Table 11).

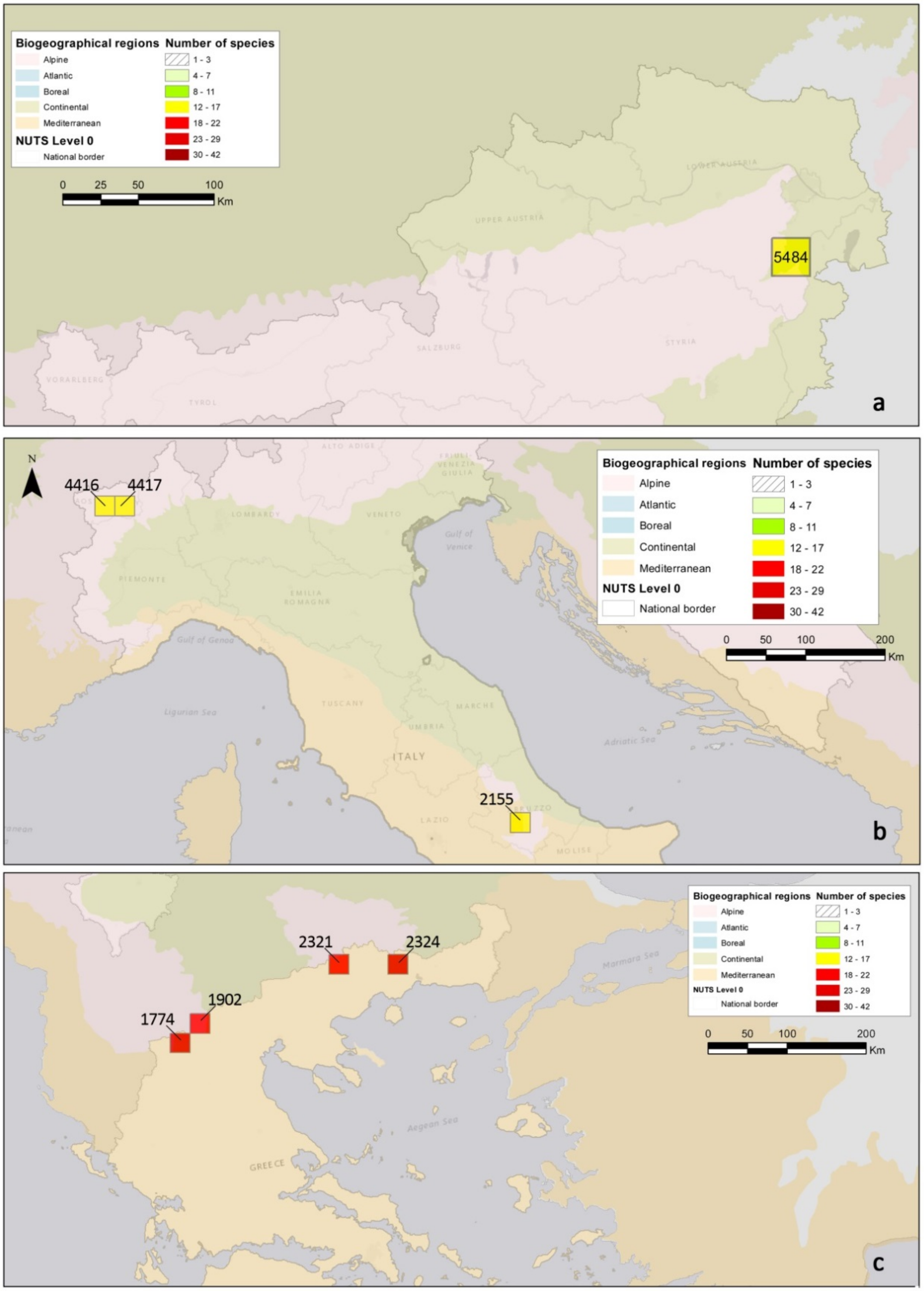

Figure 6. Geographical distribution of landrace diversity hotspots in the Alpine biogeographical region in Austria (a), Italy (b) and Greece (c). Biogeographical regions and hotspot colours are according to the legend. For each hotspot, the unique ID (i.e. cell number) is also reported.

Table 11. List of landrace species cultivated in the eight Alpine hotspots.

Species	Species	Species	Species
Allium cepa	*Cucumis melo*	*Medicago sativa*	*Prunus persica*
Allium porrum	*Cucumis sativus*	*Mespilus germanica*	*Pyrus communis*
Allium sativum	*Cucurbita maxima*	*Morus alba*	*Secale cereale*
Anethum graveolens	*Cucurbita moschata*	*Nicotiana tabacum*	*Sesamum indicum*
Apium graveolens	*Cucurbita pepo*	*Ocimum basilicum*	*Solanum lycopersicum*
Arachis hypogaea	*Cydonia oblonga*	*Panicum miliaceum*	*Solanum melongena*
Avena nuda	*Elettaria cardamomum*	*Papaver somniferum*	*Solanum tuberosum*
Avena sativa	*Fagopyrum esculentum*	*Petroselinum crispum*	*Sorghum bicolor*
Beta vulgaris	*Ficus carica*	*Phaseolus coccineus*	*Spinacia oleracea*
Brassica oleracea	*Helianthus annuus*	*Phaseolus vulgaris*	*Trifolium pratense*
Brassica rapa	*Hordeum vulgare*	*Pisum sativum*	*Triticum aestivum*
Camelina sativa	*Juglans regia*	*Prunus armeniaca*	*Triticum monococcum*
Capsicum annuum	*Lactuca sativa*	*Prunus avium*	*Triticum spelta*
Cicer arietinum	*Lagenaria siceraria*	*Prunus cerasifera*	*Triticum turgidum*
Cichorium endivia	*Lathyrus sativus*	*Prunus cerasus*	*Vicia faba*
Citrullus lanatus	*Lens culinaris*	*Prunus domestica*	*Vigna unguiculata*
Coriandrum sativum	*Malus domestica*	*Prunus dulcis*	*Zea mays*

The two hotspots in the Atlantic biogeographic area are located in Portugal, in the area from Porto to Braga and Bragança cities (in northern Portugal close to the border with Spain, hotspot 2,826), and in the United Kingdom in Colchester, South East England (hotspot 6,983). The two hotspots hold a quite similar number of species while records in the hotspots in United Kingdom are almost two times in number when compared to those in the Portuguese one (Table 12). None of the two hotspots occur in Natura 2000 sites.

Table 12. Main characteristics of the 2 Atlantic hotpots.

Cell number	Number of records	Number of species	Records/ species	Country	Biogeographic area	Rank, by number of species	Rank, by number of records	Natura 2K site
2,826	44	13	3.4	PT	Atlantic	94	72	No
6,983	92	16	5.8	UK	Atlantic	67	19	No

Landraces of 24 different species are cultivated in the two Atlantic hotspots (Table 13).

Table 13. List of landrace species cultivated in the two Atlantic hotspots.

Species	Species	Species	Species
Allium cepa	*Brassica rapa*	*Daucus carota*	*Phaseolus vulgaris*
Allium sativum	*Coriandrum sativum*	*Lactuca sativa*	*Pisum sativum*

Apium graveolens	*Cucumis melo*	*Solanum lycopersicum*	*Raphanus sativus*
Avena sativa	*Cucumis sativus*	*Pastinaca sativa*	*Secale cereale*
Beta vulgaris	*Cucurbita maxima*	*Petroselinum crispum*	*Vicia faba*
Brassica oleracea	*Cucurbita pepo*	*Phaseolus coccineus*	*Vigna unguiculata*

The 15 hotspots in the Continental biogeographic region are located in Austria (7), Italy (4) and Greece (4) (Figure 7). In Austria the identified hotspots belong to two areas: the first is a quite large area close to the Czech border (between Linz in the West and Hollabrunnin the East) that includes cells 5775, 5779, 5873, 5874, 5876, 5877; the second area, between Bruck and der Leitha (Southern Vienna) and Gyor, is smaller only including cell 5585 (Figure 7a). In contrast to the Alpine regions of Austria, mainly covered by grasslands, the North and East regions of the country are characterised by the highest extent of arable farmland where different types of field and vegetable crops can be successfully grown due to the favourable climate. Peculiar characteristics of these areas justify the presence of the hotspot where many different field plots of landraces and conservation varieties are counted (H. Maierhofer personal communication).

The Continental hotspots identified in Italy are mainly located in the Umbria region near the Trasimeno lake (cells 2877, 2878), in the area between Perugia and Foligno (2727) and between Norcia and Spoleto cities (2581) (Figure 7b). Finally, the Continental hotspots detected in Greece are all located in the Eastern part of the country with hotspots 2470 and 2763 close to the border with Turkey (Figure 7c). 43%, 50% and 66% of the hotspots in the Continental part of Austria, Greece and Italy belong to Natura 2000 protected areas, respectively (Table 14).

Table 14. Main characteristics of the Continental hotpots.

Cell number	Number of records	Number of species	Records/ species	Country	Biogeographic area	Rank, by number of species	Rank, by number of records	Natura 2000 site
5585	162	14	11.6	AT	Continental	84	8	Yes
5775	386	14	27.6	AT	Continental	83	1	Yes
5779	93	14	6.6	AT	Continental	85	18	No
5873	382	17	22.5	AT	Continental	60	2	No
5874	246	13	18.9	AT	Continental	95	5	Yes
5876	79	15	5.3	AT	Continental	75	25	No
5877	99	13	7.6	AT	Continental	96	16	No
2325	28	14	2.0	EL	Continental	86	98	No
2326	38	20	1.9	EL	Continental	43	77	No
2470	123	17	7.2	EL	Continental	61	14	Yes
2763	28	13	2.2	EL	Continental	97	96	Yes
2581	66	18	3.7	IT	Continental	57	38	Yes
2727	74	17	4.4	IT	Continental	62	30	No
2877	48	19	2.5	IT	Continental	49	66	Yes
2878	53	21	2.5	IT	Continental	39	57	Yes

All the identified hotspots are characterised by a relatively low number of species with the one with the highest number ranking only 39th when all the hotspots are considered (hotspot 2878, Italy). Differently, a high number of records is common to all the hotspots in Austria with hotspots 5775, 5873 and 5874 ranking 1st, 2nd and 5th according to this parameter. Landraces of a total of 68 different species are cultivated in the 15 identified Continental hotspots (Table 15).

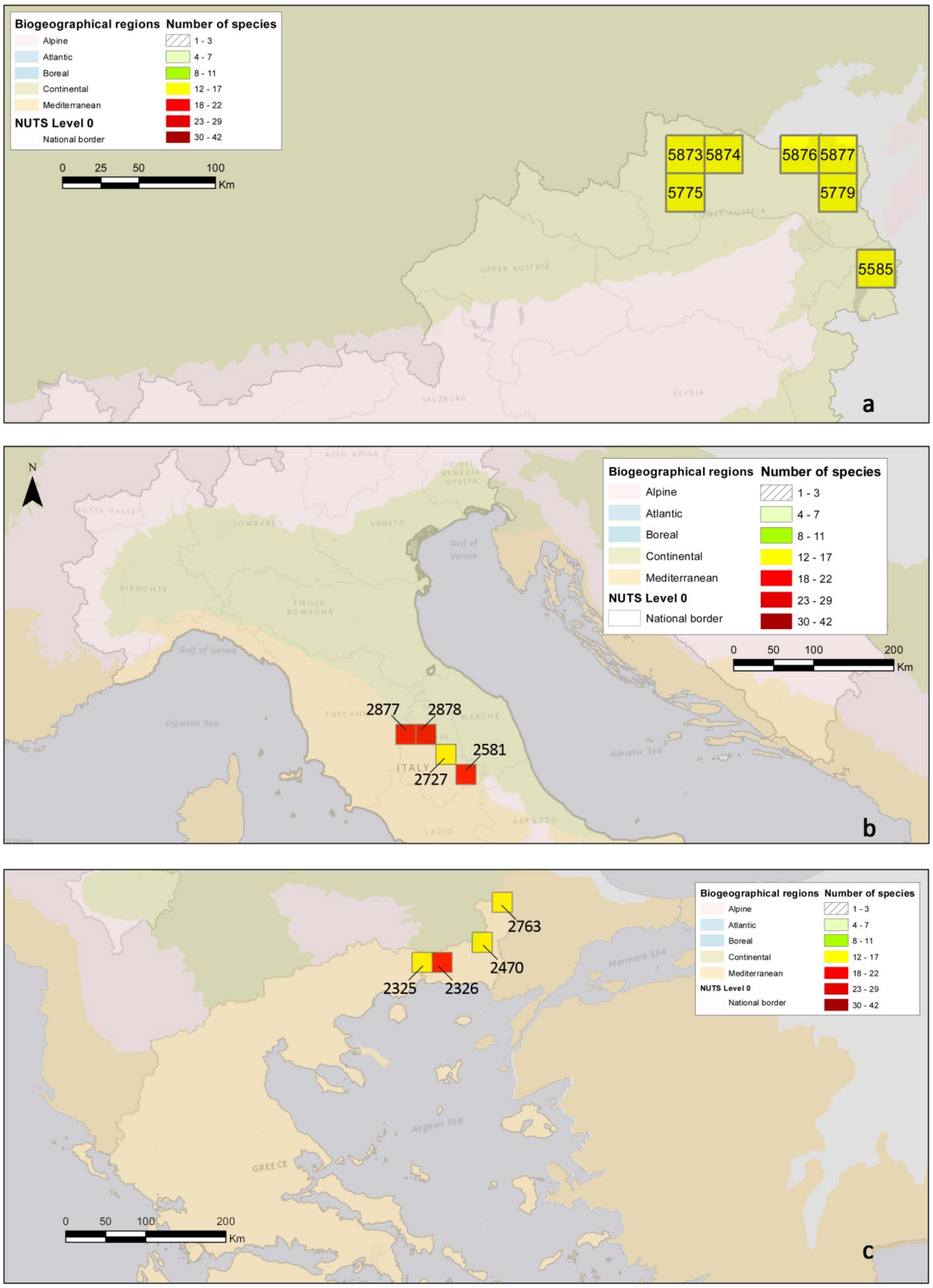

Figure 7. Geographical distribution of landrace diversity hotspots in the Continental biogeographical region in Austria (a), Italy (b) and Greece (c). Biogeographical regions and hotspot colours are according to the legend. For each hotspot, the unique ID (i.e. cell number) is also reported.

Table 15. List of landrace species cultivated in the 15 Continental hotspots.

Species	Species	Species	Species
Abelmoschus esculentus	*Cucurbita maxima*	*Onobrychis viciifolia*	*Sesamum indicum*
Allium cepa	*Cucurbita moschata*	*Origanum vulgare*	*Solanum lycopersicum*
Allium porrum	*Cucurbita pepo*	*Panicum miliaceum*	*Solanum melongena*
Allium sativum	*Fagopyrum esculentum*	*Papaver somniferum*	*Solanum tuberosum*
Avena nuda	*Ficus carica*	*Petroselinum crispum*	*Sorghum bicolor*
Avena strigosa	*Helianthus annuus*	*Phaseolus coccineus*	*Spinacia oleracea*
Beta vulgaris	*Hordeum vulgare*	*Phaseolus vulgaris*	*Trifolium pratense*
Brassica napus	*Juglans regia*	*Pisum sativum*	*Trigonella caerulea*
Brassica oleracea	*Lactuca sativa*	*Prunus avium*	*Triticum aestivum*
Brassica rapa	*Lathyrus cicera*	*Prunus domestica*	*Triticum dicoccum*
Camelina sativa	*Lathyrus sativus*	*Prunus dulcis*	*Triticum monococcum*
Capsicum annuum	*Lens culinaris*	*Prunus persica*	*Triticum spelta*
Castanea sativa	*Linum usitatissimum*	*Pyrus communis*	*Triticum turgidum*
Cicer arietinum	*Malus domestica*	*Raphanus sativus*	*Vicia faba*
Citrullus lanatus	*Medicago sativa*	*Salsola soda*	*Vigna unguiculata*
Cucumis melo	*Ocimum basilicum*	*Secale cereale*	*Vitis vinifera*
Cucumis sativus	*Olea europaea*	*Secale multicaule*	*Zea mays*

The 75 hotspots in the **Mediterranean biogeographic area** are located in Greece (37) Portugal (27), Italy (9) and Spain (1). It is noteworthy that as many as 76% of hotspots in Greece are part of the Natura 2000 network; the percentage declines to 56% and 33% in Italy and Portugal respectively, while the single site identified in Spain is not part of the network. In Greece, hotspots are distributed quite evenly between the continental part of the country (16 hotspots) and the islands (21 hotspots); Crete and Lesvos are the two islands where the highest number of hotspots have been recorded (5 and 4, respectively) (Figure 8).

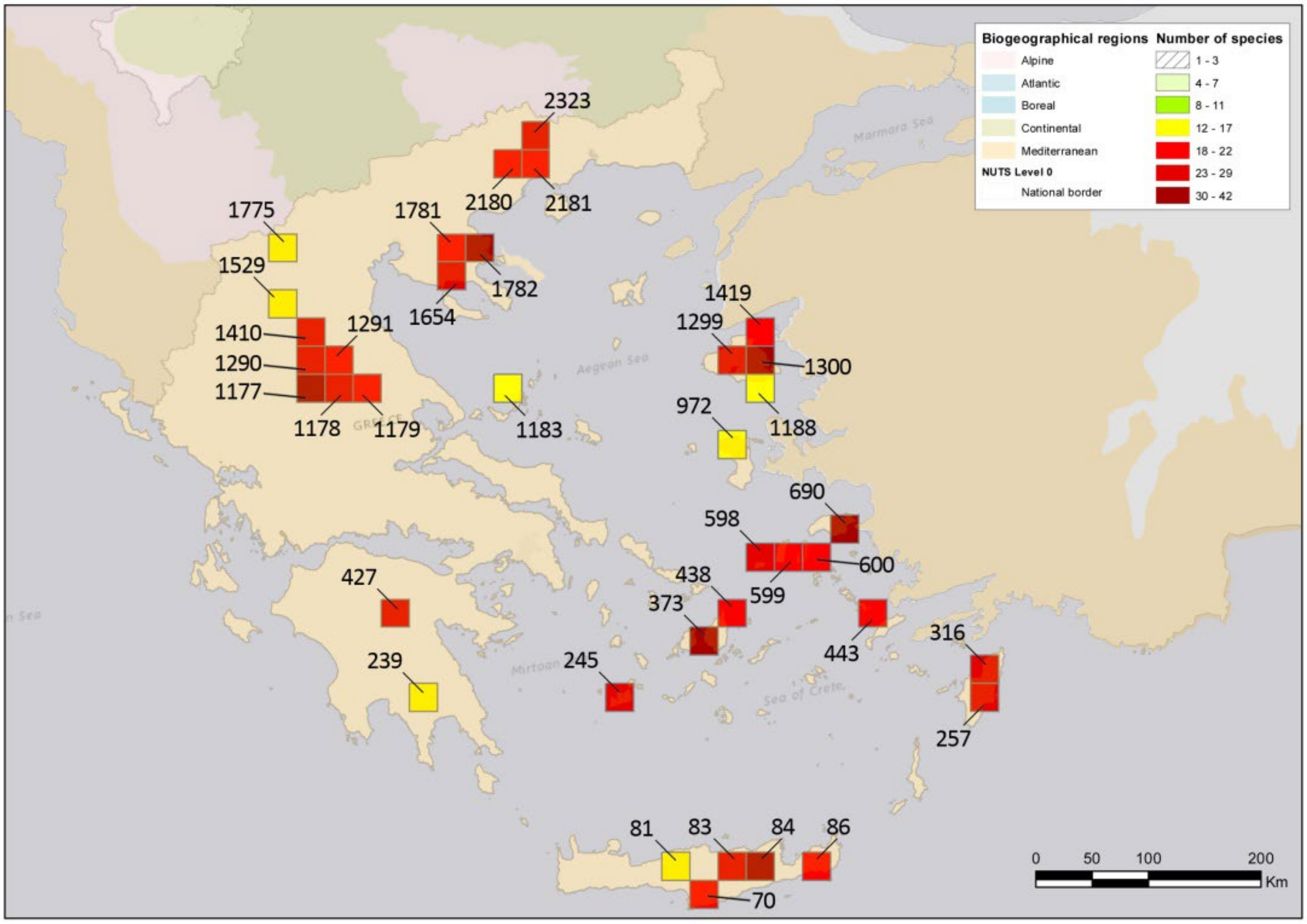

Figure 8. Geographical distribution of landrace diversity hotspots in the Mediterranean biogeographical region in Greece. Biogeographical regions and hotspot colours are according to the legend. For each hotspot, the unique ID (i.e. cell number) is also reported.

Hotspots in Portugal are mainly concentrated in the central part of the country: in the area between Porto and Coimbra cities, in Braganca, Guarda, Leiria, Lisbon, Portalegre, Santarém and Castelo Branco districts, and one towards the south in Évora (Figure 9).

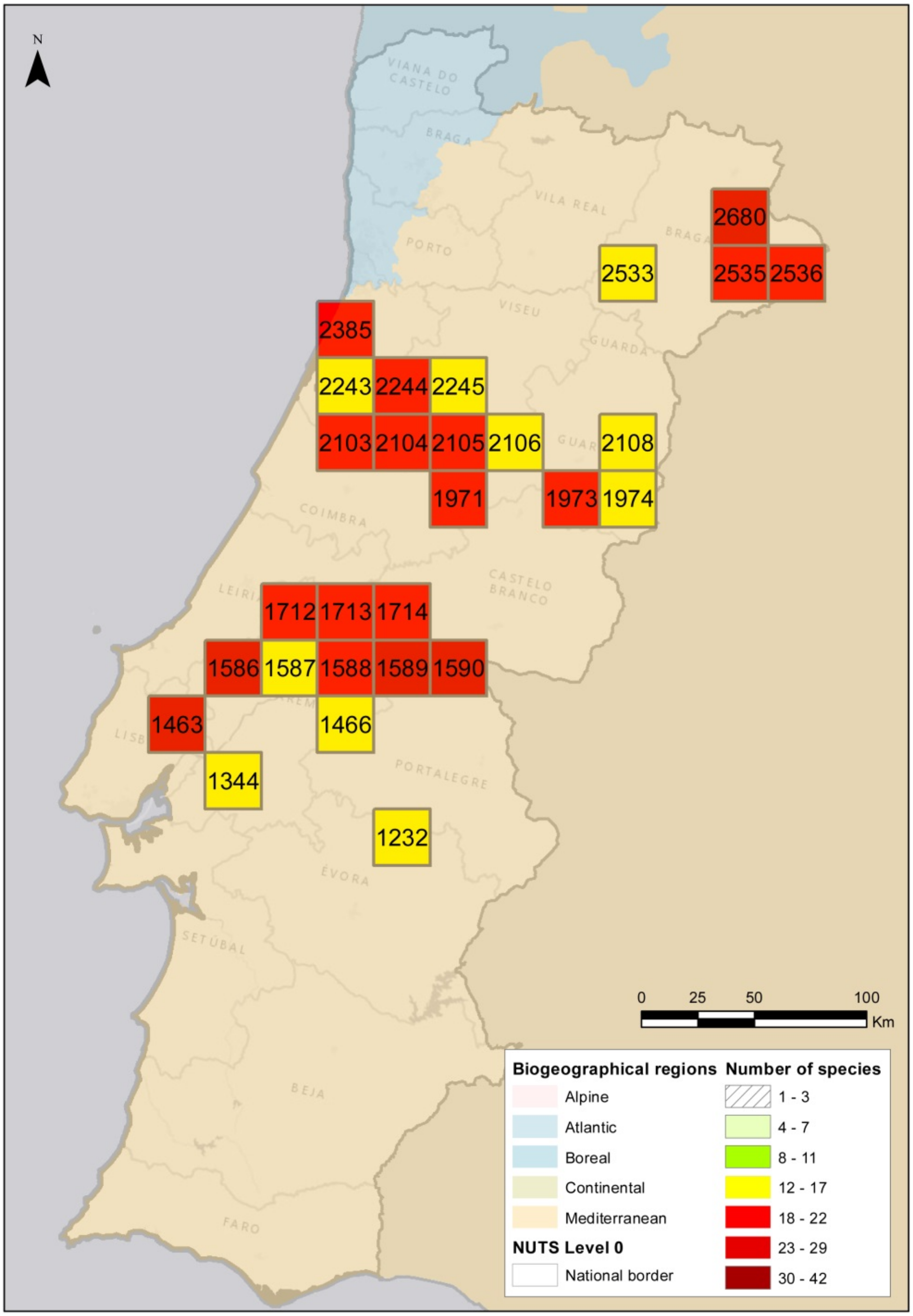

Figure 9. Geographical distribution of the Mediterranean landrace hotspots identified in Portugal. Biogeographical regions and hotspot colours are according to the legend. For each hotspot, the unique ID (i.e. cell number) is also reported.

In Italy, they are mainly located in the south of the country and, in particular, in the Basilicata, Calabria and Apulia regions; two hotspots are also present in the Lazio region, however, a lower number of landrace species are cultivated there (Figure 10). The single hotspot detected in Spain (number 397) is located in the Seville region between Arahal and Osuna cities.

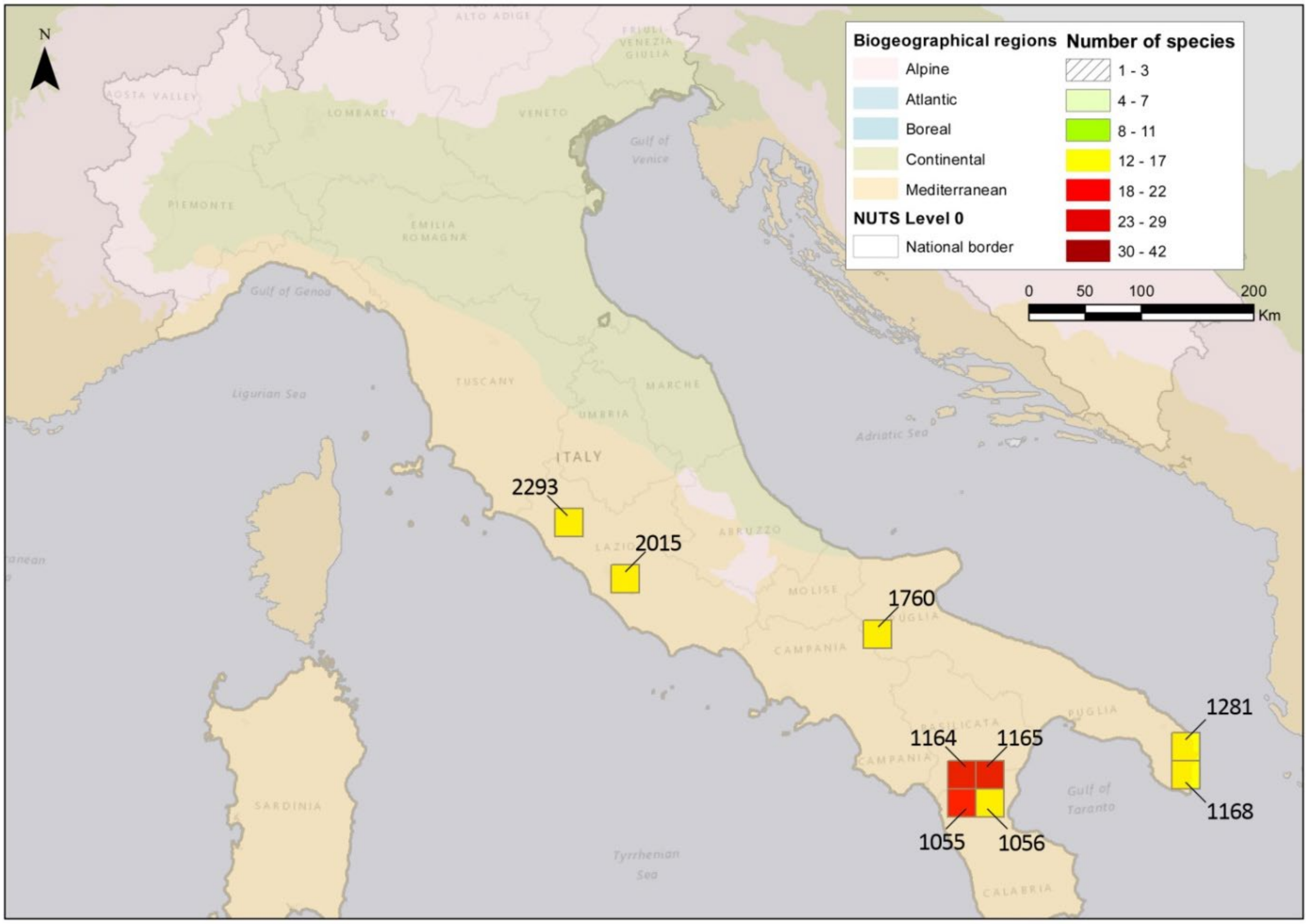

Figure 10 Geographical distribution of the Mediterranean landrace hotspots identified in Italy. Biogeographical regions and hotspot colours are according to the legend. For each hotspot, the unique ID (i.e. cell number) is also reported.

Number of records per Mediterranean hotspot ranged from a minimum of 28 (hotspot 1232, Portugal) to a maximum of 301 (hotspot 1165, Italy) (mean = 69.0, S.D. = 52.49) while the number of species from 13 (hotspot 1056, Italy) to 42 (hotspot 1177, Greece) (mean = 21.2, S.D. = 5.99) (Table 16). According to the reported data, Greece and Portugal are the two countries with the highest number of hotspots. It is also noteworthy that nine of the 10 hotspots, where the highest number of species are cultivated as landraces, are located in Greece.

Table 16. Main characteristics of the 75 Mediterranean hotpots.

Cell number	Number of records	Number of species	Records / species	Country	Biogeographic area	Rank, by number of species	Rank, by number of records	Natura 2000 site
70	35	19	1.8	EL	Mediterranean	52	81	No
81	30	17	1.8	EL	Mediterranean	63	94	Yes
83	58	24	2.4	EL	Mediterranean	19	51	No
84	78	32	2.4	EL	Mediterranean	6	29	Yes
86	35	22	1.6	EL	Mediterranean	31	82	No
239	32	15	2.1	EL	Mediterranean	76	89	No
245	71	28	2.5	EL	Mediterranean	10	33	Yes
257	54	29	1.9	EL	Mediterranean	9	55	Yes
316	45	24	1.9	EL	Mediterranean	20	71	Yes
373	148	35	4.2	EL	Mediterranean	2	9	No
427	34	23	1.5	EL	Mediterranean	26	85	Yes
438	50	22	2.3	EL	Mediterranean	30	62	Yes
443	34	20	1.7	EL	Mediterranean	46	83	No
598	58	25	2.3	EL	Mediterranean	17	52	Yes
599	47	19	2.5	EL	Mediterranean	51	69	Yes
600	28	19	1.5	EL	Mediterranean	54	100	Yes
690	124	35	3.5	EL	Mediterranean	3	12	Yes
972	30	16	1.9	EL	Mediterranean	71	92	Yes
1177	229	42	5.5	EL	Mediterranean	1	7	Yes
1178	94	25	3.8	EL	Mediterranean	16	17	Yes
1179	30	19	1.6	EL	Mediterranean	53	95	Yes
1183	35	16	2.2	EL	Mediterranean	69	80	Yes
1188	33	16	2.1	EL	Mediterranean	70	88	No
1290	66	29	2.3	EL	Mediterranean	8	41	Yes
1291	65	19	3.4	EL	Mediterranean	50	44	Yes
1299	83	26	3.2	EL	Mediterranean	14	22	Yes
1300	79	33	2.4	EL	Mediterranean	5	27	Yes
1410	69	29	2.4	EL	Mediterranean	7	35	No
1419	42	20	2.1	EL	Mediterranean	44	75	Yes
1529	78	16	4.9	EL	Mediterranean	68	28	Yes
1654	50	28	1.8	EL	Mediterranean	12	63	Yes
1775	30	17	1.8	EL	Mediterranean	64	93	Yes
1781	57	22	2.6	EL	Mediterranean	29	54	Yes
1782	85	34	2.5	EL	Mediterranean	4	20	Yes
2180	66	21	3.1	EL	Mediterranean	40	39	Yes
2181	34	20	1.7	EL	Mediterranean	45	84	No

Cell number	Number of records	Number of species	Records / species	Cou ntry	Biogeographic area	Rank, by number of species	Rank, by number of records	Natura 2000 site
2323	66	28	2.4	EL	Mediterranean	11	40	Yes
397	30	15	2.0	ES	Mediterranean	77	91	No
1055	235	22	10.7	IT	Mediterranean	32	6	Yes
1056	48	13	3.7	IT	Mediterranean	99	65	Yes
1164	257	24	10.7	IT	Mediterranean	22	4	Yes
1165	301	24	12.5	IT	Mediterranean	21	3	Yes
1168	37	15	2.5	IT	Mediterranean	78	78	No
1281	33	13	2.5	IT	Mediterranean	100	86	No
1760	33	14	2.4	IT	Mediterranean	87	87	Yes
2015	49	16	3.1	IT	Mediterranean	72	64	No
2293	111	13	8.5	IT	Mediterranean	98	15	No
1232	28	14	2.0	PT	Mediterranean	90	97	No
1344	36	15	2.4	PT	Mediterranean	81	79	No
1463	72	24	3.0	PT	Mediterranean	24	31	No
1466	42	17	2.5	PT	Mediterranean	66	74	Yes
1586	138	24	5.8	PT	Mediterranean	23	11	Yes
1587	39	15	2.6	PT	Mediterranean	80	76	No
1588	63	20	3.2	PT	Mediterranean	47	46	No
1589	82	26	3.2	PT	Mediterranean	15	24	No
1590	68	24	2.8	PT	Mediterranean	25	36	Yes
1712	43	21	2.0	PT	Mediterranean	42	73	No
1713	50	22	2.3	PT	Mediterranean	37	61	No
1714	58	22	2.6	PT	Mediterranean	36	50	No
1971	69	19	3.6	PT	Mediterranean	55	34	Yes
1973	59	22	2.7	PT	Mediterranean	35	48	No
1974	58	15	3.9	PT	Mediterranean	79	49	Yes
2103	46	20	2.3	PT	Mediterranean	48	70	No
2104	59	19	3.1	PT	Mediterranean	56	47	No
2105	47	18	2.6	PT	Mediterranean	59	68	No
2106	53	16	3.3	PT	Mediterranean	73	56	Yes
2108	28	16	1.8	PT	Mediterranean	74	99	No
2243	65	17	3.8	PT	Mediterranean	65	42	Yes
2244	142	21	6.8	PT	Mediterranean	41	10	No
2245	67	14	4.8	PT	Mediterranean	88	37	No
2385	65	18	3.6	PT	Mediterranean	58	43	Yes
2533	30	14	2.1	PT	Mediterranean	89	90	No
2535	84	22	3.8	PT	Mediterranean	33	21	No
2536	79	22	3.6	PT	Mediterranean	34	26	No
2680	53	23	2.3	PT	Mediterranean	27	59	YES

Landraces of 121 different species that are cultivated in the 75 identified Mediterranean hotspots (Table 17).

Table 17. List of landrace species cultivated in the 75 Mediterranean hotspots.

Species	Species	Species	Species
Abelmoschus esculentus	*Crataegus laevigata*	*Luffa acutangula*	*Prunus persica*
Allium ampeloprasum	*Cucumis melo*	*Luffa cylindrica*	*Punica granatum*
Allium cepa	*Cucumis sativus*	*Lupinus albus*	*Pyrus communis*
Allium porrum	*Cucurbita ficifolia*	*Maclura pomifera*	*Raphanus sativus*
Allium sativum	*Cucurbita maxima*	*Malus baccata*	*Rorippa nasturtium-aquaticum*
Amaranthus retroflexus	*Cucurbita moschata*	*Malus domestica*	*Satureja hortensis*
Anethum graveolens	*Cucurbita pepo*	*Malus pumila*	*Secale cereale*
Apium graveolens	*Cuminum cyminum*	*Matricaria recutita*	*Sesamum indicum*
Arachis hypogaea	*Cynara cardunculus*	*Medicago sativa*	*Setaria italica*
Arbutus unedo	*Cynara scolymus*	*Mentha pulegium*	*Sinapis arvensis*
Avena sativa	*Daucus carota*	*Mentha spicata*	*Solanum lycopersicum*
Beta vulgaris	*Diospyros kaki*	*Mespilus germanica*	*Solanum melongena*
Brassica juncea	*Elettaria cardamomum*	*Morus alba*	*Solanum tuberosum*
Brassica napus	*Eriobotrya japonica*	*Morus nigra*	*Sorbus domestica*
Brassica nigra	*Eruca sativa*	*Nicotiana tabacum*	*Sorghum bicolor*
Brassica oleracea	*Eruca vesicaria*	*Ocimum basilicum*	*Spinacia oleracea*
Brassica rapa	*Ficus carica*	*Olea europaea*	*Trifolium pratense*
Calendula officinalis	*Foeniculum vulgare*	*Origanum majorana*	*Trigonella foenum-graecum*
Capsicum annuum	*Gossypium hirsutum*	*Origanum vulgare*	*Triticum aestivum*
Capsicum chinense	*Helianthus annuus*	*Oryza sativa*	*Triticum spelta*
Capsicum frutescens	*Hordeum vulgare*	*Panicum miliaceum*	*Triticum turgidum*
Castanea sativa	*Hypericum perforatum*	*Petroselinum crispum*	*Vicia ervilia*
Chaenomeles japonica	*Juglans regia*	*Phaseolus coccineus*	*Vicia faba*
Cicer arietinum	*Lablab purpureus*	*Phaseolus vulgaris*	*Vicia sativa*
Cichorium endivia	*Lactuca sativa*	*Pimpinella anisum*	*Vigna unguiculata*
Cichorium intybus	*Lagenaria siceraria*	*Pisum sativum*	*Vitis vinifera*
Citrullus lanatus	*Lathyrus clymenum*	*Prunus armeniaca*	*Zea mays*
Coriandrum sativum	*Lathyrus ochrus*	*Prunus avium*	*Ziziphus jujuba*
Cornus mas	*Lathyrus sativus*	*Prunus cerasus*	-
Corylus avellana	*Lens culinaris*	*Prunus domestica*	-
Crataegus azarolus	*Linum usitatissimum*	*Prunus dulcis*	-

A comparison of the number of species and the number of records in the Mediterranean hotspots is reported in Figure 11. Spain was not included in this analysis since only one hotspot was identified in this country. Data analysis showed that a high variability of number of records per cell exist in Italy (from 33 to 301, Figure 11a, red line) while distributions are flatter and more similar in Greece and Portugal (from 30 to 229 and from 28 to 142, Figure 11a, blue and green lines, respectively). When compared to both Portugal and Italy, the number of different species per cell is significantly higher in Greece (p<0.01, Mann–Whitney test, Figure 11b). Also in this case the distribution of values is quite similar in Greece and Portugal.

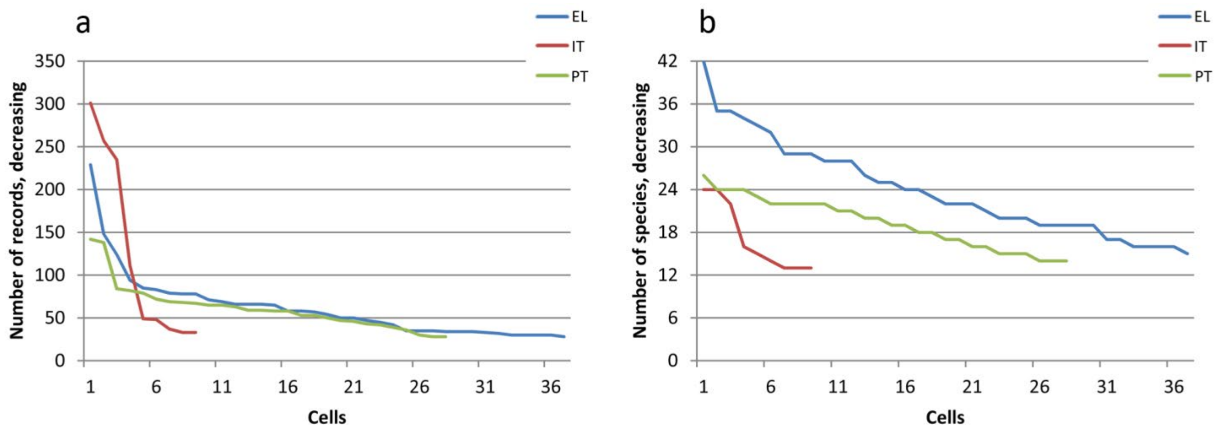

Figure 11. Number (decreasing) of records (a) and of species (b) recorded in the Mediterranean hotspots of Greece (EL, blue line), Italy (IT, red line) and Portugal (PT, green line).

In addition to the above described diversity hotspots mainly located in Greece, Portugal, Italy and Austria, additional sites of interest are also proposed for all the countries that provided data on *in situ* occurrence of landraces (Table 18) and Figure 12. Even if by applying the parameters used in this study they cannot be considered diversity hotspots, these sites deserve attention since they are characterised by the cultivation of the highest number of different species in comparison to all the other sites in the same country.

Table 18. Main characteristics of the 44 proposed sites of interest, including number of records, and of species, biogeographical region and whether it occurs within a Natura 2000 site.

Cell number	Number of records	Number of species	Records/ species	Country	Biogeographic area	Natura 2000 site
6485	57	5	11.4	CZ	Continental	No
5869	49	4	12.3	CZ	Continental	Yes
5975	16	4	4.0	CZ	Continental	Yes
7162	15	6	2.5	DE	Continental	Yes
7014	26	5	5.2	DE	Continental	No
6788	13	4	3.3	DE	Continental	No
6924	19	4	4.8	DE	Atlantic	No
7161	14	4	3.5	DE	Continental	No
7899	21	9	2.3	DK	Continental	No
8057	7	5	1.4	DK	Continental	Yes
8058	5	5	1.0	DK	Continental	No
8055	4	4	1.0	DK	Continental	Yes

Cell number	Number of records	Number of species	Records/ species	Country	Biogeographic area	Natura 2000 site
8249	5	4	1.3	DK	Continental	No
8901	5	4	1.3	EE	Boreal	Yes
8781	3	2	1.5	EE	Boreal	No
8843	3	2	1.5	EE	Boreal	No
339	21	12	1.8	ES	Mediterranean	No
265	19	11	1.7	ES	Mediterranean	No
400	15	10	1.5	ES	Mediterranean	No
1038	11	10	1.1	ES	Mediterranean	No
268	28	9	3.1	ES	Mediterranean	No
9242	9	4	2.3	FI	Boreal	No
9247	3	3	1.0	FI	Boreal	No
9378	3	3	1.0	FI	Boreal	No
9380	3	3	1.0	FI	Boreal	No
9419	6	3	2.0	FI	Boreal	No
3201	8	5	1.6	HR	Mediterranean	No
4208	3	1	3.0	HR	Alpine	Yes
4210	1	1	1.0	HR	Alpine	Yes
6083	26	10	2.6	RO	Continental	No
5907	19	9	2.1	RO	Continental	Yes
5506	18	5	3.6	RO	Continental	No
6084	11	4	2.8	RO	Continental	Yes
5411	6	4	1.5	RO	Continental	No
8252	6	3	2.0	SE	Boreal	No
8353	4	3	1.3	SE	Boreal	No
8611	5	3	1.7	SE	Boreal	No
9858	5	3	1.7	SE	Boreal	No
8060	2	2	1.0	SE	Continental	No
7119	7	7	1.0	UK	Atlantic	No
7597	10	7	1.4	UK	Atlantic	No
7354	8	6	1.3	UK	Atlantic	No
8634	17	4	4.3	UK	Atlantic	Yes
7777	6	4	1.5	UK	Atlantic	No

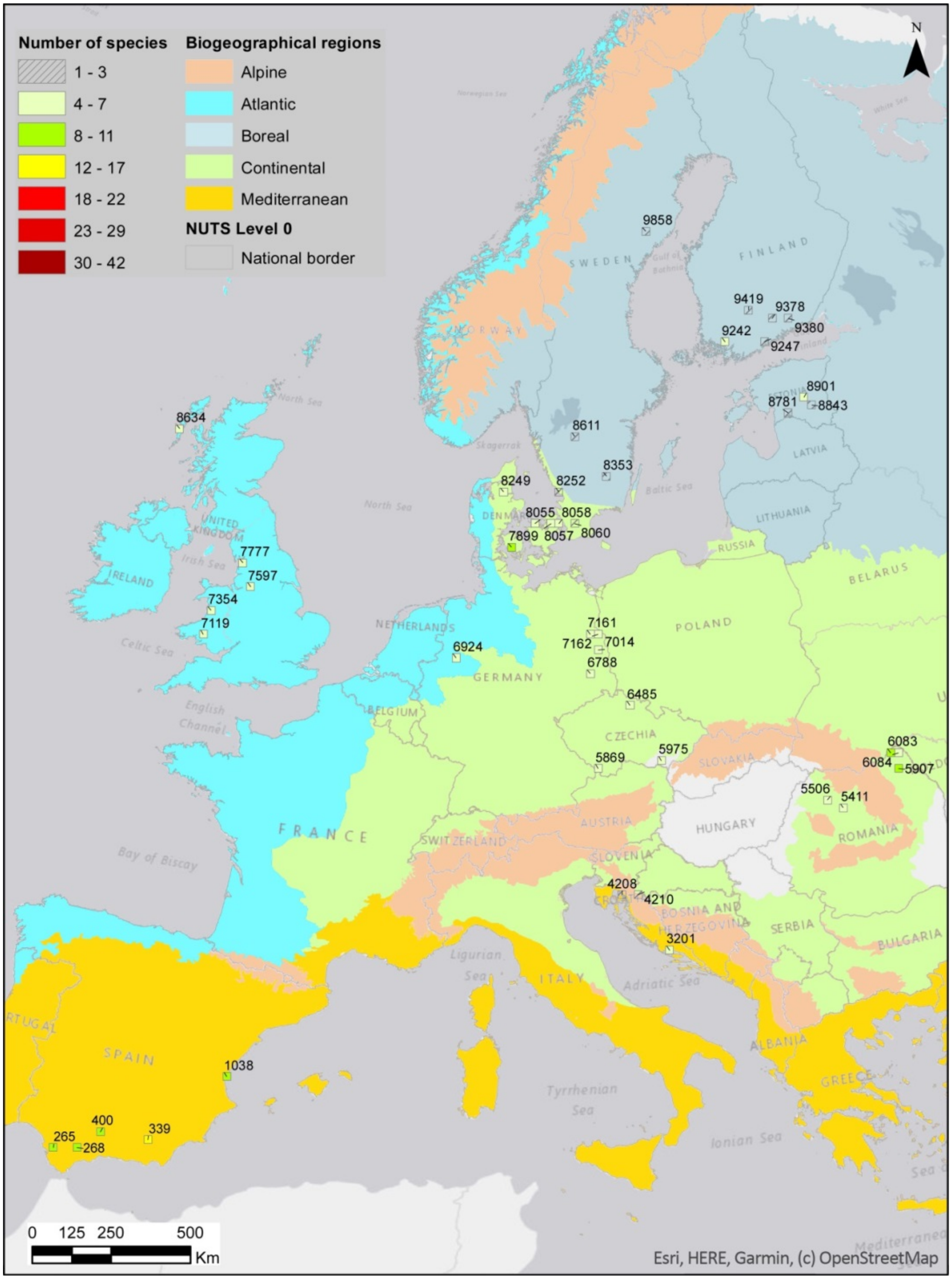

Figure 12 Geographical distribution of the identified additional sites of interest. Biogeographical regions and cell colours are according to the legend. For each cell, the unique ID (i.e. cell number) is reported.

Finally a number of sites of interest were located in Switzerland where a relevant number of landraces of different species are cultivated (Table 19).

Table 19. Main characteristics, in relation to the record and species numbers, of the 15 proposed sites of interest for Switzerland.

First Administration	Second Administration	Number of records	Number of species	Records/ species	Country	Biogeographic area	Natura 2000 site
GE	Genève	34	14	2.4	CHE	-	-
VS	Erschmatt	39	19	2.1	CHE	-	-
BL	Liestal	16	5	3.2	CHE	-	-
SO	Solothurn	42	22	1.9	CHE	-	-
AG	Hottwil	242	43	5.6	CHE	-	-
AG	Niederrohrdorf	60	22	2.7	CHE	-	-
LU	Ruswil	244	50	4.9	CHE	-	-
TI	Minusio	111	3	37.0	CHE	-	-
GR	Thusis	13	11	1.2	CHE	-	-
GR	Filisur	35	2	17.5	CHE	-	-
SH	Beggingen	57	24	2.4	CHE	-	-
SZ	Gross	13	3	4.3	CHE	-	-
ZH	Hedingen	52	6	8.7	CHE	-	-
TG	Neukirch a.d. Thur	273	5	54.6	CHE	-	-
AR	Heiden	75	64	1.2	CHE	-	-

4. Discussion

The distribution of the hotspots, as well as their differences in both number of landrace records and of cultivated species, are certainly related to real differences on on-farm maintained materials, but could also be influenced by the different level of knowledge and data available for these analyses. Different countries also possibly use different approaches for landrace identification (e.g. in Finland DNA verification is commonly used for the acceptance of materials to national lists of varieties). It is then probable that the reported numbers are an underestimation of real ones. For example, in Finland the inventory of landraces of pears has not been done fully and some vegetables have not been inventoried at all (e.g. asparagus, Jerusalem artichoke, top onions, berries and musk strawberry) although it is known that there are some landraces still in cultivation/maintenance (Heinonen M., personal communication). In Croatia, the presence of more landraces than here recorded are expected, especially of olives, grapevines, various fruits, medical and aromatic plants, vegetables and cereals; however such materials are still unknown also being grown by small-scale farmers difficult to reach or involved in such studies (Kutnjak H., personal communication). For Germany, data were available for landraces of the most important arable crops; other landraces of these crops are recorded in the Red List of endangered native crops in Germany, but their current extent of cultivation on-farm is not known (Thorman I., personal communication). A current national inventory of georeferenced landraces is still lacking in Spain and the image resulting in this document could show an unbalanced conservation between regions that is often driven from differences on data management (Iriondo Alegria J.M., personal communication).

Unfortunately, at this stage it was also not possible to collect data on landrace cultivation sites from all the European countries as they didn't all replied to our request. Filling the gaps of the dataset used in this study is certainly desirable, especially to get information from countries with a strong agricultural vocation (e.g. France) and where local varieties are certainly still grown (e.g. different countries in the former Yugoslavia). Nonetheless, given the variable nature of landrace cultivation sites, a periodic update of the data presented is necessary in any case. In fact, landrace cultivation is a very dynamic process where each year farmers decide which landraces deserve to be cultivated depending on annual farm needs and market opportunities. However, it is expected that the content of this document will stimulate the missing countries to provide data for the next iteration of the process. Nevertheless, the results presented here are certainly relevant for the identification of landrace diversity sites to be part of the costituenda European network for *in situ* conservation and sustainable use of plant genetic resources, due to the high level of conserved landrace diversity found there.

It is widely recognised that European and national seed legislations – intended to protect both consumers health and rights of breeders over cultivars – drastically reduced the numbers of landraces grown as well as the knowledge associated with their cultivation (Negri et al., 2009). Therefore, the highest longer-term priority issues for landrace *in situ* conservation appears to be related to both promotion of a more comprehensive knowledge of materials still existing in different countries and of European legislation in favour of *in situ* conservation. Since, it is challenging to conserve all the landrace diversity still existing *in situ*, hotspots of biodiversity (i.e. areas particularly rich in species, rare species, threatened species, or some combination of these attributes) can help in setting up priorities for conservation (Reid, 1998). In fact, concentrating conservation efforts on areas particularly rich in species, the potential payoff from safeguarding measures would be the greatest (Meyers, 2000). Such an approach would allow conservationists to engage in a systematic response to the challenge of large-scale loss of *in situ* diversity related to crops.

The method used in this study to identify the landraces' hotspots took into consideration the number of sites with the highest number of species still cultivated as landraces, their diversity in number of species and their climatic differences. In particular, to consider the distribution of hotspots in relation with the different ecogeographical areas of Europe (Roekaerts, 2002) appears to be a useful means of investigation, since different landraces of the same species, cultivated and adapted to different geographical areas, can potentially hold different traits for adaptation to specific pedoclimatic conditions. The prevalence of hotspots in the Mediterranean biogeographic region (75% of the total) supports the goodness of the applied method. Indeed the Mediterranean area is a classical centre of diversity proposed by Vavilov (1927) and a hotspot for landraces diversity (Hammer and Diederichsen, 2009). As for Italy, the proposed hotspots in the Mediterranean area are in Basilicata, Apulia and Calabria regions that are consistent with previous reports suggesting Southern Italy as a hotspot of diversity for vegetable and minor crops (Hammer and Diederichsen, 2009). Several examples of the wide availability of genetic resources for the typical Apulia vegetables are reported in the literature (Fanizza et al., 1992; Calabrese et al., 2003; La Malfa and Bianco, 2006; Elia and Santamaria, 2013).

Even if it has been reported that replacement with modern cultivar resulted in the extinction of many landraces in Greece (Bennett 1971), Greece is the country where the highest number of hotspots has been identified, both in islands and in the peninsula. It is noteworthy that as many as five landrace diversity hotspots are located in a relatively small area on Crete where a better situation with regard to landrace conservation has been reported (Laghetti et al., 2008). The observations of Ralli (2010) and Stavropoulos and colleagues (2008) that in Greece landraces are usually maintained by elderly residents of the islands and mountainous regions of mainland– either because they are part of the local tradition or because they are well-adapted to harsh environmental conditions – is supported by our data. Indeed, more than half of the landrace diversity hotspots in the Mediterranean part of this country are in islands (21) and in the Alpine area of North Greece mainland (4). The lack of landrace diversity hotspots in the other Mediterranean main islands (e.g. Sicily, Sardinia and Corsica) may be due to the imposed limited number of sites of interest (i.e. we wanted to initially focus on the 100 top sites across Europe only) and/or low population density of islands in comparison with the mainland, a factor that can negatively affect cultivated landrace diversity. With regard to this this, hotspots are also lacking in scarcely populated countries, like Finland, although a relatively high number of *in situ* conserved landraces exist there compared to the human population extent (Heinonen M., personal communication).

Even if a limited number of hotspots were observed in the other biogeographical areas considered (i.e. Alpine, Continental and Atlantic), landraces cultivated in those sites are, anyway, of great interest potentially holding unique traits involved in local adaptation processes and/or specific of certain peculiar pedoclimatic conditions. This is particularly true for the Continental area that, with a total of 237 cells located in nine different countries is second to the Mediterranean one only when the geographical extension is considered; in addition, as this area is particularly devoted to agriculture, landraces cultivated may be of even more interest. The future application of the complementarity analysis proposed by Rebelo et al. (1992; 1994) to our dataset would further increase the panorama of candidate sites.

Aiming at identifying key sites for both landraces and crop wild relatives *in situ* conservation, to facilitate a rationale and effective building of the network for in situ conservation and sustainable use of plant genetic resources, we compared the distribution of landrace proposed hotspots with those proposed by Vincent and colleagues (2019) for crop wild relatives. By means of species distribution modelling, climate change projections and geographic analyses applied to 1261 crop wild relative species of 167 major crop genepools, the authors identified 150 key geographical areas where 65.7% of the crop wild relatives species considered can be conserved for future uses. Among the five top geographical areas identified in Europe, the one in the Laconia district (Peloponnese region, Greece) is adjacent to landrace diversity hotspot number 239 identified in our study. A clear overlap also exists between the key geographical area in the *southern* part of the *Italian Peninsula* and the landrace hotspots number 1055, 1056, 1164 and 1165 located in Basilicata, Calabria and Apulia regions. As for the other key geographical areas proposed by Vincent et al. (2013) in Europe, those in Greece seem to overlap with other landrace hotspots here proposed and, in particular, those located in Thessaly and West Macedonia. However, more details on geographical distribution of sites proposed for crop wild relatives would be needed to confirm these observations.

In our analysis we also considered the presence of landrace diversity hotspots in Natura 2000 sites. The Natura 2000 network is an ecological network of sites designated under the Birds Directive (Special Protection Areas or SPAs) (European Commission, 1979) and the Habitats Directive (Sites of Community Importance or SCIs, and Special Areas of Conservation or SACs) (European Commission, 1992). As already argued by Maxted et al. (2008), the Natura 2000 network holds a great potential in supporting *in situ* conservation of crop wild relatives. Indeed, according to Rubio Teso et al. (2020) 404,351 populations of 519 European priority crop wild relative taxa (351 species and 168 taxa at intraspecific levels) occur in Natura 2000 sites.

The high percentage of landrace diversity hotspots in Natura 2000 sites proposed here shows how European Union (EU) policies, originally aimed at protecting the wild part of nature, also had a great impact in protecting that part whose evolution was driven by humans. It is in fact recognised that in protected areas, where organic or low input agricultural techniques are encouraged, landraces are the best material to be cultivated due to their specific adaptation and their intrinsic diversity which can contribute to realising good agricultural productions (Raggi et al., 2017; Caproni et al., 2018; Ciancaleoni and Negri, 2020 and references therein).

5. Conclusions

A specific agro-biodiversity conservation plan is needed for Europe because the region includes the Mediterranean basin biodiversity hotspot and is rich in both crop wild relatives and landraces that are still cultivated (Vetelainen et al., 2009; Kell et al., 2012; Landucci et al., 2014; Raggi et al., 2020), while the highly dense population, the widespread industrial and agricultural activities and the effects of climate change makes biodiversity vulnerable. In fact, biodiversity decline was not halted in recent years (European Parliament Resolution 2016; EU Biodiversity Strategy for 2030), in spite of all the EU support given to biodiversity safeguarding (e.g. network of protected areas, promotion, setting and updating of quite detailed information systems on nature conservation and of biodiversity related common agro-environmental policies).

In this scenario, it is important to adopt a "systematic conservation planning" process to identify areas with a high level of biodiversity, e.g. hotspots, (Margules and Pressey 2000; Sarkar et al., 2006), taking into account local, ecological, social, economic, political and cultural factors and identifying areas in which to programme conservation action over extensive time periods in the entire EU territory. The identification of priority agro-biodiversity hotspots to be conserved will support the highest level of diversity at the least cost (Myers, 1990). Indeed, the EU makes significant funding available each year for various forms of agro-environmental schemes. The support to the development of a European network for *in situ* conservation and sustainable use of plant genetic resources that includes the proposed landrace diversity hotspots in Natura 2000 sites would reasonably allow the maximum possible payoff from safeguarding measures that it is expected the EC will economically support.

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