



Landrace added value and accessibility in Europe: what a collection of case studies tells us

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Abstract

In the actual climate change scenario, in situ conservation of plant genetic resources for food and agriculture can significantly contribute broadening the diversity of our food system as well as increasing its resilience; nevertheless, landrace cultivation has been dramatically reduced in the last decades all over Europe. One of the most effective approaches to counteract the loss of landrace diversity in situ is facilitating its use. Aims of this study were to (i) describe how in situ maintenance of landraces occurs in different agro-environmental conditions in Europe and (ii) identify the main factors influencing landrace added values and accessibility as means to increase their adoption by new farmers. To the purpose, a collection of 95 case studies of both garden and open field landraces maintained in situ was analysed. A first description was obtained by classifying the information into 18 purposely defined categories. Data on landraces added values and accessibility were further transformed into weighted variables; the derived quantitative scores were then used as dependent variables in univariate and multivariate analyses. Results showed that farmers alone are still the main actors maintaining landraces in situ across different European biogeographical regions, mainly carrying out their activity under organic or low-input conditions, often in marginal areas. Results of the multivariate analysis showed that (i) type of actor involved in the multiplication, (ii) the main use of the product and (iii) presence of promotion actions significantly affect garden landraces added value and accessibility; presence of promotion actions was the only factor affecting added value of open field entries. Evidence arising from this work can contribute to the establishment of a fruitful ground of discussion for future European policies and strategies to protect and increase landrace use.

Keywords Landrace in situ conservation · Landraces · Case study methodology · Landrace added values · Landrace accessibility

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Introduction

Future food supplies depend on few major crops that are exposed to increasingly extreme and uncertain impacts of climate change (Nelson et al. 2009); in this scenario, we are facing an exceptionally high rate of biodiversity loss (FAO 2019). Biodiversity is central for resilience of ecosystems as it provides buffering effects to cope with drastic environmental fluctuations that affect communities within an ecosystem (Altieri 1999; Newton et al. 2009).

Agrobiodiversity—a subset of biodiversity that includes plant genetic resources for food and agriculture (PGRFA)—generally refers to the level of richness with regard to the number of species together with among- and within-species diversity, in a defined area. At species level, the presence of populations, different races and/or varieties, including their wild relatives, can counteract the current agrobiodiversity decline (CBD 1992; Maxted et al. 1997, 2002; Negri et al. 2009). Nowadays, a portion of agrobiodiversity is still managed and maintained in complex agroecosystems worldwide (van de Wouw et al. 2010), but progressively lost. Such loss is recognised as one of the major threats that agriculture faces as consequence of climate change (Lobell et al. 2008; FAO 2019).

Preservation of agrobiodiversity encompasses a range of diverse strategies and consequent actions to prevent loss of genetic, species and ecosystem diversity. Currently, a relevant portion of PGRFA is safely conserved *ex-situ* (i.e. in genebanks) since this conservation means has been regarded as the most practicable security measure ‘to save as much as possible’ from a short-term perspective (Gomez-Campo 1985). However, removing species, and their associated variability, from their environments of origin freezes their evolutionary and adaptive potential (Brush 2004; de Haan et al. 2013). A widely recognised solution to this issue is to integrate *ex situ* with *in situ* conservation by maintaining PGRFA in the areas where they have evolved over time and produced their distinctive traits (CBD 1992). This approach brings important advantages, in fact, its application can support functioning, resilience and, to some extent, productivity of agroecosystems (Tilman 1999, 2000).

In Europe, *in situ* conservation is generally associated with conservation of wild plants in protected areas; however, some actions focusing on landraces have been also carried out (Negri et al. 2013; Vetelainen et al. 2009). In the past, most of such actions arose locally or nationally and after a number of international documents and agreements (CBD 1992, 2010a, b; FAO 2001, 2012). Currently, through the formalisation of the EU Biodiversity Strategy for 2030 (European Commission 2020), the EU has created a favourable environment for the development of coordinated strategies to facilitate conservation of landraces and their sustainable use.

Although most of European agricultural production has been relying on registered and uniform cultivars, landraces, obsolete cultivars, and also other non-uniform varieties are still grown on-farm and in home gardens, i.e. *in situ* (Negri et al. 2009; Galluzzi et al. 2010). However, to date, no systematic studies were carried out to depict *in situ* conservation and use of landraces in Europe; in fact, diverse conservation situations and actors maintaining these materials make their systematic tracking rather complex and challenging at the same time. On the other hand, understanding and properly maintaining such diversified agricultural systems can favour equitable mechanisms of income generation and help society to better benefit of these resources, hence improving livelihoods and well-being (Bellon et al. 2015), whilst facing the challenge posed by the

effects of climate change (Bellon et al. 2017). It is also noteworthy that landraces still hold great variability that can support future crop improvement for sustainable farming systems (Caproni et al. 2019).

Most importantly, understanding which factors increase (i) added value of landrace products and (ii) access to their propagation materials (e.g. seeds or seedlings), can favour the establishment of appropriate policies promoting use and adoption of landraces by new farmers across Europe, in line with the principles of its Biodiversity Strategy (European Commission 2020). Understanding the state of in situ conservation of landraces across Europe is not only a matter of collecting information about where and how these resources are cultivated, but also of recognising mechanisms and actions that have been put in place to favour their cultivation; for example, in other regions, collective market actions and ad hoc labelling strategies already created virtuous landrace in situ conservation conditions (Devaux et al. 2009; Krishna et al. 2010).

In order to get insights on the current situation about landrace in situ conservation, there are two possible general approaches. The first would privilege quantitative analysis of few variables across large samples (nomothetic approach) while the other would focus on qualitative, multi-aspect, in depth study of one or few case studies (idiographic approach). This difference brings to the key matter of studying many issues in few cases or few issues in many observations. On the other hand, the use of the so-called ‘case study methodology’ (CSM) can bridge the gap between nomothetic and ideographic methods and transcend, to a certain extent, their specific limitations (Larsson 1993). CSM takes advantage of the ability of case studies to deal with processual and multiple stakeholder considerations through multisource data; the nature of case studies and their complexity can make statistical examination of patterns, through different situations, rather difficult. However, this method tries to overcome this limitation by considering large sets of case studies.

In this work CSM was used to perform quantitative analysis on a large collection of case studies, gathering information about different in situ maintained landraces crossing a range of different socio-economic, pedo-climatic and cultural contexts in Europe as such offering insights that might not be achieved using other methodological approaches. In particular, the application of this methodology, allowed to summarise some of the major elements affecting in situ maintenance of landraces in Europe and the conditions that influence their added value and accessibility, both key factors that can contribute increasing adoption of landraces by next generations of farmers.

Materials and methods

Landraces

In the literature the term *landrace* refers to a broad range of different definitions that have evolved over time (Casañas et al. 2017; Negri et al. 2009; Negri, 2003, 2005; Camacho Villa et al. 2005; Asfaw 2000; Zeven 1998; Harlan 1975; Anderson and Cutler, 1942; von Rümker 1908).

A recent approach—formalised into the *Concept for on-farm conservation and management of PGRFA* by the European Cooperative Programme for Plant Genetic Resources (ECPGR 2017)—rather than giving additional and/or broader definition to the term *landrace* itself, focused on different materials that are maintained in situ: (i) true landraces (i.e. *sensu stricto*, Polegri and Negri 2010; Negri et al. 2009); (ii) introduced landraces (i.e.

allochthonous, Zeven, 1998); (iii) selection from landraces (Raggi et al. 2019); (iv) cross-composite populations and varietal mixtures (European Commission 2014; Goldringer et al. 2006; Raggi et al. 2016a, b); (v) historical varieties (Klaedtke et al. 2017). Being characterised by a certain level of genetic heterogeneity, all the above-mentioned materials—hereafter landraces intended in a broad sense—were the object of this study.

Collection of case studies

Case studies analysed in this work were retrieved from the public repository *In situ landraces: best practice evidence-based database*, hosted by the ECPGR and available at <https://www.ecpgr.cgiar.org/in-situ-landraces-best-practice-evidence-based-database>. The online database encompasses a number of case studies of in situ maintained landraces, representing successful (or potentially successful) examples of use, management and valorisation of these resources.

When possible, information from the online database was integrated with further data from literature (Tosti and Negri 2005; Theobald et al. 2006; Negri and Tiranti 2010; Torricelli et al. 2013; Plans et al. 2013; Ciancaleoni et al. 2014; Gouveia et al. 2014; Raggi et al. 2017; Figás et al. 2017; Leino et al. 2018; Caproni et al. 2018).

Data classification

As from the original structure of the database, the units of analysis of this research are ‘the case studies’, each referring to a distinct in situ maintained landrace. Information of each case study was initially classified into 18 purposely defined categories (Table 1). Altogether, the defined categories, describe basic characteristics and cross-sectional features that show how and where landraces are cultivated, managed, promoted on the market and accessed. The case studies were categorised according to their description by ascertaining the presence of single or multiple sentences showing clear correlation with categorical values in each defined category (Table 1).

In particular, the first six categories describe basic features such as local name, taxonomic classification, type of in situ conserved resource, location where cultivation occurs and mating system of each species (Table 1). The following three (7–9, Table 1) describe actors managing the landraces, their main uses and actions to promote their products. Categories from 10 to 12 describe the agronomic contexts where landraces are cultivated and some of their management features; categories from 13 to 15 are about market extent and use of geographical indications or other labels to add value to landrace products. The last three (from 16 to 18) categorise factors that can increase landrace accessibility and their potential adoption by new farmers (Table 1).

Due to the positive effects that product added value and improved accessibility can have in increasing current and future use of landraces—by increasing the value of their product and the number of actors able to access their propagation materials—the categories describing these aspects, added value (13–15) and accessibility (16–18), were converted into weighted variables. This transformation allowed to weight differences among categorical values in creating added value or improving access to propagation materials (Table 2).

In particular, as for categories defining the added value, an increasing value from 1 to 7 was assigned from products having no market, used for self-supply only (value = 1), up to products characterised by an international market (value = 7) passing through local (value = 3) and national market (value = 5) (Table 2). The selected weighted values

Table 1 List of 18 categories used to classify information from landrace case studies

Category	Description	Categorical values
1. Landrace name	Local name	—
2. Species	Binomial name	Name of the species
3. Country	Where cultivation occurs	Name of the country
4. Biogeographical region	Where cultivation occurs	Name of the biogeographical region
5. Type	Type of in situ resource	Historical variety; Introduced landrace; Landrace; Population ^a ; Selection from a landrace
6. Mating system	Reproductive biology of the species	Allogamous; Autogamous
7. Multiplication actor	Who multiply the landrace	Farmer; Farmer's consortium; PDO consortium; Private foundation; Public body; Seed company
8. Use	Main use of the landrace product	Sold on the Market; Home-supply
9. Promotion	Level of promotion based on actions in place	Absent, Local, National, International
10. Size	Size of the area where the landrace is cultivated	Small; Medium; Large
11. System	Farming management system	Low-input/organic; Conventional
12. Marginality	Whether cultivation occurs in a marginal area	Marginal; Non-marginal
13. Market Extent	Extent of the landrace market	Self-supply; Local; National; International
14. Geographical Indication	Label related to a specific area	PDO; PGI; Other
15. Commercial label or designation	Presence of other commercial labels and brands	Yes; No
16. Ex situ backup	Existence of an ex situ backup	Yes; No
17. Access status	Whether seed, seedlings or other propagation materials can be accessed	Available; Conditioned
18. Inventory	Type of inventory in which the landrace is listed	Absent; Local; National; European;

^aCommission Implementing Decision of 18 March 2014 (European Commission 2014)

Table 2 List of categories, categorical values and their corresponding weighted variables used to calculate 'Added Value Quantitative Score' (AddValQS) and 'Access Quantitative Score' (AccQS)

Category	Categorical value	Weighted value
'Added Value Quantitative Score' (AddValQS)		
13. Market extent	Self-supply	1
	Local	3
	National	5
	International	7
14. Geographical indication	No geographical indication	0
	PDO; PGI; Other	5
15. Commercial label or designation	No label or designation	0
	Yes	3
'Access Quantitative Score' (AccQS)		
16. Ex situ backup	Absent	0
	Present	5
17. Access status	Conditioned	1
	Available on the seed or seedling market	7
18. Inventory	Absent	0
	Local	1
	National	3
	European	5

reflect the idea that an increasing market extent can directly contribute to add value to a local product allowing to reach a larger number of potential consumers. Regarding labels, it has been demonstrated that concerning high quality food products, consumers value more those holding a Geographical Indication (GI), in comparison to non-GI labelled products (Menapace et al. 2009). In addition, the promotion of linkages between local producers, their local areas and their food products through GIs has been recognised as a crucial pathway to nutritious food systems and sustainable development for rural communities by both Food and Agriculture Organisation (FAO) and the European Bank for Reconstruction and Development (Vandecandelaere et al. 2018). For these reasons, a weighted value of 5 was assigned to landrace products holding a GI label while of 0 to those without any. Similarly, a weighted value of 3 was assigned to products holding other types of quality labels while of 0 to those without (Table 2). As for categories defining accessibility of landraces propagation material, the highest weighted value (7) was only assigned to entries for which seeds or seedlings are available on the market (Table 2); indeed, in these cases, a relevant number of seeds or seedlings is expected to be accessible with no restrictions. On the contrary, a lower weighted value (5) was assigned to landraces whose propagation material can only be accessed

from ex situ storage facilities due to some limitations imposed to their access, such as the signature of a Standard Material Transfer Agreement, and low number of seeds that can be retrieved from gene banks. Finally, increasing weighed values were assigned to landraces listed in local, national or international inventories (1, 3 and 5, respectively) since the inclusion in such lists can help landraces to reach potential users at local, national or international level. Weighed values were assigned to each entry according to the corresponding categorical values (Table 2).

For each entry, an 'Added Value Quantitative Score' (AddValQS) was calculated as the sum of the assigned weighted values for the categories from 13 to 15 (Table 2); the same procedure, applied to categories from 16 to 18 (Table 2), was used to estimate the 'Accessibility Quantitative Score' (AccQS).

Data analysis

A general picture of the dataset was initially obtained by calculating the distributions of the case studies into the 18 categories, expressed as percentages. For each case study, average latitude and longitude of the cultivation area were retrieved and imported into GIS. The distribution of the landrace cultivation areas into the different European biogeographical regions was obtained by mapping the entries against 'the cartographic elaboration of the European biogeographical regions', obtained from the European Environment Agency web site (<https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3>).

In order to reduce complexity of the dataset, and make comparisons among more homogeneous groups, case studies were divided into garden and open field entries according to their usual classification and not on the average size of the area in which a specific landrace is cultivated.

In the univariate analysis, differences in medians of AddValQS and AccQS among the categories *Multiplication actor*, *Use* and *Promotion* were initially tested by means of non-parametric Kruskal–Wallis test (Rohlf and Sokal 1980). In addition, to test the effect of a specific categorical value of the same categories on AddValQS and AccQS, a set of binary variables were created (Calvet-Mir et al. 2011) as follows: (1) *Multiplication actor*, took the value of 1 if the landrace is multiplied by 'Farmers' and 0 otherwise; (2) *Use*, took the value of 1 if the landrace is mainly used as 'Home-supply' and 0 otherwise and (3) *Promotion*, took the value of 1 if the level of promotion of the landrace is limited to maintainers or local actors only and 0 otherwise. In the multivariate analyses, the above-described binary variables were used as independent variables against AddValQS and AccQS, used as dependent variables. In the analysis, distinct models were tested for garden and open field entries and case studies characterised by ≥ 1 missing data were not included.

Limitations

The dataset analysed in this work is vast and complex, encompassing entries of different crops species cultivated using different agricultural practices and, most notably, cultivated for different purposes. In addition, the unit of analysis is 'the landrace', not 'the farm', 'the farmer' nor 'the gardener'; this limit questions that can potentially be addressed. Finally, not all the European countries are covered.

Results

The collected case studies

A number of 95 case studies (hereafter entries) were retrieved from a total of 105; the remaining 10 case studies were discarded being related to non-European materials (Bellon and Brush 1994) or to fruit trees, which investigation is beyond the scope this work.

Entries belong to 46 different crop species classified as garden and open field; the most represented crops are: *Solanum lycopersicum* (tomato, 12), *Phaseolus vulgaris* (common bean, 8) and *Secale cereale* (rye, 6); 8 cereal entries belonging to the *Triticum* genus are also present (Table 3).

The collection encompasses entries from 15 different European countries; Italy, Spain and Hungary are represented with the highest number: 16, 13 and 13, respectively (Table 3). As from the geographical distribution of entries across Europe, almost all the main European biogeographical regions are covered: Mediterranean (31 entries), Continental (16), Atlantic (14), Pannonian (14), Boreal (11), Alpine (7) and Macaronesia (2) (Fig. 1). Garden entries appear to be mostly located in southern Europe while, for open field, no clear geographical distribution can be observed (Fig. 1).

Most of the case studies were classified as 'Landrace' (i.e. true landraces) (73.9%) followed by 'Introduced landrace' (20.7%), 'Historical variety' (3.3%), 'Selection from a landrace' (1.1%) and 'Population' (1.1%) (total number of entries with available information $n=92$). The 50.5% of the case studies describe landraces belonging to species characterised by a predominantly autogamous mating system, while 49.5% are predominantly allogamous ($n=95$).

Farmers—single (84.1%) or grouped in consortia (6.8%)—are the main actors carrying out landrace multiplication ($n=88$). The 27.4% of the entries resulted mostly cultivated for 'Home-supply' while the rest for commercial purposes ($n=95$). According to the categorised data, the level of promotion (based on actions supporting the landrace) is 'Absent' in the 20.7%, 'Local' in 39.5%, 'National' 34.1% and 'International' in the 6.1% of the entries ($n=81$).

When the relative size of the cultivation area is considered 46.8% of entries are categorised as 'Small', 39.4% 'Medium' and 13.8% 'Large' ($n=94$). Most entries (83.3%) are cultivated under 'Low-input/organic' conditions and the others following conventional agronomic practices (16.7%) ($n=72$). Interestingly, about half of the entries (43.3%) is cultivated in marginal areas (i.e. areas characterised by unfavourable conditions) ($n=90$). The full list of 95 case studies with the corresponding categorical values is available in Table S1 (Supplementary Materials).

Raw or processed landrace products are mainly commercialised in local markets (58.9%) and, to a minor extent, at national level (23.3%), while a lower but significant portion is cultivated by gardeners or farmers only to satisfy their needs (14.4%); in few cases the products are commercialised in other countries (international markets, 3.3%) ($n=90$). In most cases no geographical indication to promote raw or processed products on the market is reported (82.1%); indeed, only few entries hold a EU geographical indication (10.6%) or other types of geographical indication (7.4%) ($n=95$). However, for 35.4% of the case studies other types of commercial indications or brands are present such as 'Slow Food Presidium', 'Green heritage' and 'Pro Specie Rara'. Finally, only six case studies hold a geographical indication and another brand or indication at the same time. Regarding accessibility of seed or seedlings, most of landraces can be obtained through ex situ

Table 3 List of species with relative number of entries and country of origin of 95 in situ maintained landraces case studies

Species	n	Country	Species	n	Country
<i>Allium ampeloprasum</i>	1	ITA	<i>Lathyrus clymenum</i>	1	GRC
<i>Allium cepa</i>	4	AUT, GRC, PRT, SWE	<i>Lathyrus sativus</i>	1	GRC
<i>Allium sativum</i>	1	ROU	<i>Lens culinaris</i>	2	AUT, GRC
<i>Apium graveolens</i>	1	ITA	<i>Papaver somniferum</i>	1	HUN
<i>Armoracia rusticana</i>	1	FIN	<i>Phaseolus coccineus</i>	2	ESP, HUN
<i>Asparagus officinalis</i>	1	DNK	<i>Phaseolus lunatus</i>	1	HUN
<i>Avena strigosa</i>	1	GBR	<i>Phaseolus vulgaris</i>	8	ESP (2), HUN, ITA (3), PRT, SWE
<i>Beta vulgaris</i> var. <i>rapacea</i>	1	DNK	<i>Phleum pratense</i>	1	GBR
<i>Brassica napus</i> var. <i>napobrassica</i>	2	SWE	<i>Pisum sativum</i>	1	CHE
<i>Brassica oleracea</i> subsp. <i>capitata</i>	1	GBR	<i>Pisum sativum</i> subsp. <i>sativum</i> var. <i>arvense</i>	3	DEK, ITA, SWE
<i>Brassica oleracea</i> var. <i>acephala</i>	1	PRT	<i>Secale cereale</i>	6	FIN (3), PRT (2), GBR
<i>Brassica oleracea</i> var. <i>italica</i>	2	ITA	<i>Solanum lycopersicum</i>	12	AUT, GRC, HUN (6), ITA, ESP (3)
<i>Brassica rapa</i> subsp. <i>rapa</i>	2	CHE, ESP	<i>Solanum melongena</i>	1	ESP
<i>Brassica rapa</i> subsp. <i>syvestris</i> var. <i>esculenta</i>	1	ITA	<i>Solanum tuberosum</i>	3	CHE, FIN, GBR
<i>Capsicum annuum</i>	2	GRC, HUN	<i>Trifolium pratense</i>	1	FIN
<i>Cichorium intybus</i>	1	CZE	<i>Trifolium repens</i>	1	GBR
<i>Citrus limatus</i>	2	ESP, HUN	<i>Triticum aestivum</i> subsp. <i>aestivum</i>	3	AUT, GBR, ITA
<i>Cucurbita pepo</i>	1	ESP	<i>Triticum aestivum</i> subsp. <i>spelta</i>	1	GBR
<i>Cynara cardunculus</i> subsp. <i>cardunculus</i>	1	CHE	<i>Triticum monococcum</i> subsp. <i>monococcum</i>	2	GRC, ROU
<i>Daucus carota</i>	3	CHE (2), ROU	<i>Triticum turgidum</i> subsp. <i>dicoccum</i>	1	ITA
<i>Helianthus tuberosus</i>	1	CHE	<i>Triticum turgidum</i> subsp. <i>durum</i>	1	GRC
<i>Hordeum vulgare</i>	2	GBR, ITA	<i>Vicia faba</i>	1	ITA
<i>Ipomea batatas</i>	1	ESP	<i>Vigna unguiculata</i>	1	ITA
<i>Lactuca sativa</i>	3	ESP (2), HUN	<i>Zea mays</i>	3	CHE, ITA, PRT

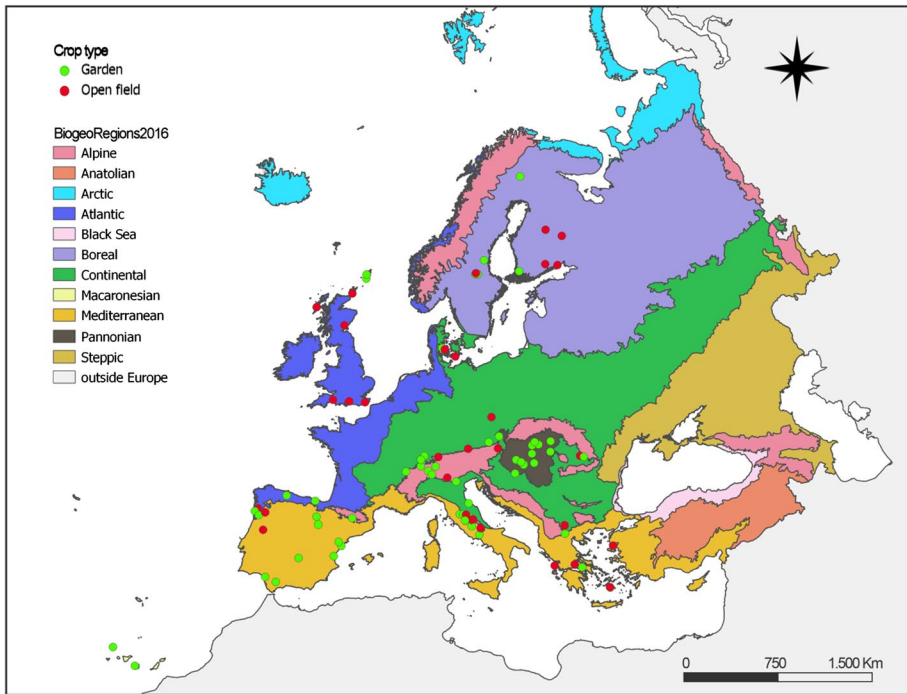


Fig. 1 Geographical location of the 95 entries within respective biogeographical regions. Entries are displayed as dots and coloured according to crop type as showed in the legend. Due to dots overlapping, multiple records with similar geographic coordinates can appear as a single dot

facilities, being already present in genebanks (91.4%) ($n = 70$); notably, some of them can also be found on the seed or seedling market, being commercialised as conservation varieties (32.7%) (European Commission 2008), amateur varieties (1.0%) (European Commission 2009) or populations (1.0%) (European Commission 2014). In the other cases it is unclear how seeds or seedlings can be accessed. Whether 17.0% of entries is not present in any register, others are listed in ‘Local’ (12.8%), ‘National’ (22.3%), ‘European’ (17.0%) registers ($n = 95$).

Added values and accessibility quantitative scores

When garden entries are considered, the added value quantitative score (AddValQS) reached a maximum value of 15 in the case of the Italian *Aglione della Val di Chiana* (*Allium ampeloprasum*)—the only landrace characterised by having an international market and both geographical indication and commercial labels—followed by the broccoli *Broccolo Fiolaro di Creazzo* (13) and the Finnish potato *Puikula* (12). Among open field entries, highest AddValQS characterise the bread wheat *Solina* (13), the maize *Rheintaler Ribelmals* (10) and the grass pea *Fava Feneou* (10). Regarding the accessibility quantitative score (AccQS) more than one entry scored the maximum value (17): six garden tomatoes from Hungary, the pepper *Glikokafteri Mpachovou* and, among open field entries, the maize *Nostrano di Storo*, the barley *Mix48*, the einkorn wheat *Kaploutzas* and the emmer

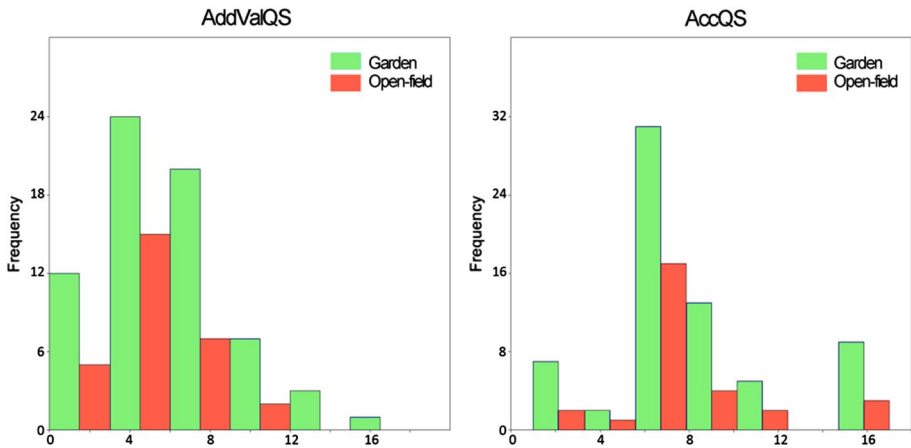


Fig. 2 Distributions of quantitative scores measuring added value (AddValQS) and accessibility (AccQS) of the 95 analysed in situ landraces

Table 4 Results of multivariate analysis for garden (n=51) and open field entries (n=25)

	Garden				Open field			
	AddValQS		AccQS		AddValQS		AccQS	
	Coefficient (SE)	P	Coefficient (SE)	P	Coefficient (SE)	P	Coefficient (SE)	P
Multiplication actor	-3.65 (1.183)	**	0.32 (1.674)	ns	1.18 (1.622)	ns	-4.19 (2.243)	●
Use	-3.36 (0.881)	***	2.88 (1.247)	*	0.23 (1.848)	ns	-4.47 (2.555)	●
Promotion	-2.26 (0.875)	*	-2.82 (1.237)	*	-3.23 (1.183)	**	0.58 (1.636)	ns
R ²	0.42	***	0.19	*	0.28	ns	0.22	ns

Not significant (ns); significant at $P \leq 0.1$ (●); $P \leq 0.05$ (*); $P \leq 0.01$ (**) and $P \leq 0.001$ (***)

wheat *Saritsam* (Table S2, Supplementary Materials). Distributions of AddValQS and AccQS values among garden and open field entries are reported in Fig. 2.

Factors affecting landrace added values and their accessibility

Regarding garden crops, results of the Kruskal–Wallis test revealed the existence of significant differences among medians of the AddValQS for *Multiplication actor* ($P \leq 0.05$, n=59), *Use* ($P \leq 0.001$, n=62) and *Promotion* ($P \leq 0.001$, n=55), while AccQS values were different among medians of the category *Promotion* ($P \leq 0.05$, n=55). Regarding open field crops, AddValQS was only different among categorical values of *Promotion* ($P \leq 0.05$, n=32), while AccQS among the categorical values of *Use* ($P \leq 0.05$, n=41).

Results of the multivariate regressions (Table 4), where the explanatory variables *Multiplication actor*, *Use* and *Promotion*—coded as binary—were considered at the same time, were quite consistent with those obtained in the univariate analysis.

In particular, the added value quantitative score (AddValQS) of garden entries increases when:

- the multiplication is carried out by consortia, seed companies or public bodies. In other words, it is expected that when the seed or seedling production of a landrace is managed by organised actors, instead of non-organised farmers, the final product has wider market and holds single or multiple indications or brands;
- the use of the landrace is mainly intended for the market, meaning that it is rather difficult that a landrace used for self-supply holds a geographical or a commercial label;
- the promotion has been developed at National or International level, in comparison to local promotion or absence of promotion, meaning that extensive promotion actions positively affect market size and labels held by a certain landrace.

For the same type of entries (garden) accessibility quantitative score (AccQS) increases when:

- entries are used for self-supply being frequently in *ex situ* collections, listed in registers or sold on the market;
- promotion has been carried out at national or international level, in comparison to no or local promotion, meaning that when a landrace underwent international or national promotion actions it is likely to be more accessible for potential new users.

Regarding open field entries, promotion at national or international level is the only factor positively affecting the added value quantitative score (AddValQS); it means that also for open field entries promotion actions positively affect market size and presence of labels (Table 4). None of the three factors significantly affects accessibility quantitative scores (AccQS) (Table 4). In this case, the low number of case studies strongly reduced our ability to predict open field entries AddValQS and AccQS starting from the values of the three considered binary variables.

Discussion

This collection of 95 case studies gives a cross-sectional picture of some of the key features that can contribute sustaining and possibly increase landrace cultivation across Europe. Indeed, a better understanding of factors positively affecting added value and accessibility of such genetic resources can be the ground of discussion for future measures aiming at improving the wealth of landrace cultivation. In fact, it has been already suggested that an effective, sustainable and long-term *in situ* conservation of landraces can only occur with adoption in cultivation by new farmers (Casañas et al. 2017; Maxted et al. 2009); these conditions are fostered when landraces are characterised by an appealing market potential (i.e. added values) and by clear rules and protocols that favour their accessibility (Spataro and Negri 2013). Today, the need of passing landraces in the hands of new generations is more important than ever, as a matter of facts it has been shown that European farmers using landraces are elderly (Calvet-Mir et al. 2011).

From the beginning, the idea behind the analysis of a large set of case studies was to include as much information as possible about the main features that characterise *in situ* conservation of crops' diversity. This brought the need of including, together with true landraces, examples of a range of different cultivated materials such as introduced landraces, historical varieties, selections from landraces and other types of populations that also encompass an intrinsic genetic diversity. Indeed, nowadays, cultivation and use of these

materials is seen as positive means to foster a diversified and more sustainable food system, able to support, to a certain extent, healthy agro-ecosystems, their functioning, resilience and productivity, especially in low-input conditions (ECPGR 2017). The CSM approach used in the present study helped in overcoming major drawbacks of single case study analysis, that is usually characterised by the inability of examining cross-sectional themes and to generalise conclusions and findings to large and diversified systems (Larsson 1993). For this reason, even considering the complexity of this topic, we are fairly confident that the evidence arising from this work well describes the context of in situ conservation of landraces as well as its diversified features. Indeed, collated information covers many diverse in situ conservation contexts that characterise Europe; in fact, as many as 46 crop species, of both garden and open field crops, are represented and the case studies are well distributed over the main European biogeographical regions.

Results of this research indicated that landrace cultivation frequently occurs in marginal areas contributing to the income of farmers working in conditions in which conventional agriculture cannot be easily carried out. Landraces, and especially true landraces—the majority of entries in this study—have adapted, and are continuously adapting, to the specific environmental conditions in which they have been cultivated. For this reason, such materials are of particular interest for marginal areas as well as for being used under organic and low-input management systems, where few external inputs are available for counteracting limiting factors. As a matter of facts, most of entries in our dataset are cultivated under organic or low input conditions.

Going deep into the case study descriptions it emerges that several entries seem to be characterised by peculiar adaptive traits making their cultivation still attractive in specific pedo-climatic conditions. For example, tolerance to different types of limiting factors are reported for many entries. One of the most interesting examples is the Greek tomato landrace *Tomataki Santorinis*, traditionally cultivated in the volcanic island of Thira (Santorini), where soil is poor in organic matter and water, and plants undergo stressful conditions also due to high temperatures and radiation (Koutsika-Sotiriou et al. 2016); another example is the Austrian onion landrace *Laaer Zwiebel* that can be cultivated without any irrigation. Among the conservation varieties, the Finnish *Hermann* and *Iivo* rye landraces are characterised by winter hardiness and Italian *Solina* wheat by adaptation to the specific conditions of the mountain area where it is cultivated (Porfiri et al. 2001).

There is evidence in the literature that local actions like local fairs (Castellini 2005), meals associated with particular recurrences (Papa 1999) and contests for the best landrace product (Mendes-Moreira et al. 2014) have a positive impact on the maintenance of landraces in situ (Negri 2012). Our data also showed that creation of added value is often linked to attribution of geographical indications (e.g. PDO, PGI), trademarks and quality labels. Such labels ascertain the uniqueness of the landrace product—in comparison with others—its particular traits, the link with the cultural and traditional values of the territory or, simply, the way it was obtained. However, the use of a geographic indication resulted not so extensive in the analysed dataset suggesting that there is still room for improvement. In some recent reports FAO (2009) showed that geographical indications can be used as a driver for a sustainable development of rural areas; indeed, geographical indications can link the European heritage of food diversity, genetic resources and local knowledge with the market dimension (Vandecastelaere 2011).

As from the description of the analysed case studies, a high number of landraces underwent different types of promotion initiatives so that we decided to test the effect of promotion on landraces added value (AddValQS) and access (AccQS) measured as quantitative scores; according to our results, promotion was the only factor increasing AddValQS and

AccQS of both garden and open field entries (Table 4). Starting from this evidence—in order to make landraces more appealing and accessible to the next generation of European farmers—we would suggest that policies should leverage on actions promoting landraces at national and international level. The application of this strategy could rise landraces use in Europe as a consequence of the potential higher added value of their product and of an easier access to their propagation materials.

From our analysis, other key elements to sustain future cultivation of landraces across Europe emerged. Indeed, results showed that farmers are the main actors carrying out landrace multiplication being, *the facto*, the most relevant players in managing, using and conserving landrace diversity. From what we observed, seed companies have only a marginal role in producing and commercialising landrace seeds or seedlings. However, testing the effect of different multiplication actors against landraces added value and accessibility, it emerged that products derived from garden landraces have higher added values (AddValQS) when managed by farmer consortia, seed companies or public bodies while this effect was not observed for open field entries (Table 4). In other words, the creation of consortia around specific landraces can enhance added values of their commercial products resulting in a wider market and acquisition of geographical indications or labels, at least in the case of garden crops. In this regard, it is noteworthy that the European seed legislation frame offers several possibilities to register landraces as ‘conservation varieties’, ‘amateur varieties’ or ‘populations’ (European Commission 2008, 2009, 2014) favouring the involvement of private seed companies and other stakeholders in the use of landraces. Then, while a small portion of landraces took advantage of these potentially beneficial tools (Spataro and Negri 2013), registration might represent an important means to scale up conservation and accessibility, use and market of garden landraces. Indeed, when seeds or seedlings are present on the market the access is facilitated considering both possible use and the number of seeds/seedlings that can be retrieved. It has already been reported that landraces in situ conservation is favoured by incentives to farmers and collaboration with institutions and social organisations (Bellon 2004; Brush 2004; Zimmerer 2010); in this context an external source of support mainly assumed the form of promotion activities to increase added value and visibility of landrace products on the market, calling consumer attention and interest.

Conclusions

Future policies aimed at promoting landrace conservation and their sustainable use should leverage on strategies favouring promotion to add value and increase accessibility. Indeed, factors that positively affect these aspects should properly be considered when planning national or European actions that want to increase and promote use of landraces in situ. We believe that a joint European long-term strategy can foster in situ conservation by helping the transition of these resources to the next generation of farmers, on behalf of a future diversified European agriculture.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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