ECPGR Activity Grant Scheme – Phase X - Sixth Call

Activity Report

Inventorying wheat on-farm diversity (INWHEATORY)

01/01/2024 – 31/05/2025

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Contents

Front cover photograph: Wheat landraces from Poland. Credit: IHAR, Poland

PROJECT OVERVIEW

The project aims to inventory wheat landraces in Europe and to propose recommendations for the best management of wheat landraces on farm, starting from examples of successful cultivation. The team has been diligently working towards fulfilling these objectives, with a focus on ensuring timely delivery and adherence to quality standards.

KEY ACHIEVEMENTS

At the beginning of the project, all involved partners were contacted to provide a further brief explanation of the foreseen project activities and goals and asked to provide data on landrace cultivation and distribution in their respective countries.

Action 1

Contribution to inventorying on-farm wheat landraces, specifically contributing to the agreement on a template to record characteristics of on-farm conserved wheat landraces (Action 1.1) and using the agreed template to collect data on on-farm wheat landraces (Action 1.2).

Action 1.1

At the beginning of the project, University of Perugia (UNIPG) developed and shared with the participants an Excel template for inventorying on-farm wheat landraces in the involved countries, consisting of 16 descriptors of 6 main groups:

- LANDRACE INVENTORY IDENTIFICATION
- TAXON IDENTIFICATION
- LANDRACE/POPULATION IDENTIFICATION
- SITE/LOCATION IDENTIFICATION
- CULTIVATION AREA
- REMARKS

In compliance with the provisions of the EU General Data Protection Regulation (GDPR), the use of the template did involve the acquisition of any personal data from the farmers cultivating the inventoried local varieties.

Action 1.2

The involved partners were able to provide a total of 616 records of landrace cultivation in their countries (i.e. wheat landrace cultivation sites) using the provided Excel template. Recorded on-farm wheat landraces are distributed as follows: Finland 10 records, Germany 88, Greece 181, Italy 91, North Macedonia 104, Montenegro 6, Romania 41, Serbia 6 and United Kingdom 89. Cultivation records refer to a total of 18 different species/taxa. The highest number of different species/taxa has been found in Germany (13), followed by Greece (12) and Italy (8).
As per collected data, 303 different landrace names were recorded from the 9 target countries: 70 from Italy, 61 from Germany, 54 from Greece, 41 from Romania, 33 from North Macedonia, 28 from the United Kingdom, 10 from Finland, 3 from each Montenegro and Serbia. A summary of data collected from project partners is available in Table 1.

Table 1. Number of wheat landraces *in situ* records and landraces with different names collected in the frame of the INWHEATORY project.

Country	*In situ* wheat landrace cultivation records	Landrace with different names	Project partners that provided the data
Finland	10	10	Heinonen Maarit
Germany	88	61	Sensen Sarah and Thormann Imke
Greece	181	54	Ralli Parthenopi
Italy	91	70	Raggi Lorenzo and Negri Valeria
North Macedonia	104	33	Ivanovska Sonja
Montenegro	6	3	Jovovic Zoran
Romania	41	41	Străjeru Silvia
Serbia	6	3	Mikić Sanja
United Kingdom	89	28	Clarke Gabrielle and Maxted Nigel
Total	616	303	-

Two databases were created:

1. '*In situ* database', including all the records of landraces that occur on farm collated in the INWHEATORY project. GBIF data, quite valuable for mapping general biodiversity patterns, were not included in this work since they generally lack the landrace-level resolution. Indeed, GBIF data typically records species-level identifications and does not distinguish between improved or traditional varieties (i.e. landraces), which is crucial for *in situ* conservation strategies focused on maintaining genetic diversity within a crop species.
2. "*Ex situ* database", including records stored in Genesys database and representing the actual *ex situ* conserved landraces. In the *ex situ* database, geographical data refer to the original geographical coordinates of collection sites (i.e. of sites where the conserved *ex situ* accessions were originally collected).

With 329 records from INWHEATORY and 771 from Genesys, *Triticum turgidum* subsp*. durum* is the subspecies most abundantly found, followed by *Triticum aestivum* subsp. *aestivum* (239 and 363 from Inwheatory and Genesys, respectively). Only few records have been reported for *T. aestivum* subsp. *compactum* (2), *T. aestivum* subsp. *erythrospermumcompactoides* (1), *T. aestivum* subsp. *ferrugineum* (1) and *T. aestivum* subsp*. lutescens* (2) all recorded in Germany. Details on the number of wheat landrace cultivation sites (i.e. records) by country and by species/subspecies *in situ* and *ex situ* are reported in Table 2.

Table 2. List of species/subspecies and the corresponding number of records as provided for the different countries covered by the project. Values in brackets refer to the number of accessions conserved *ex situ* as for data stored in Genesys database.

Species/taxa	MKD	SRB	FIN	ROU	DEU	MNE	GBR	ITA	GRC	Total
Triticum aestivum	-	-	-	-	53 (0)	-	-	27 (0)	102 (198)	182 (198)
Triticum aestivum* subsp. *aestivum	101 (17)	6 (18)	9 (25)	33 (33)	0 (14)	3 (0)	87 (2)	0 (42)	0 (212)	239 (363)
Triticum aestivum* subsp. *compactum	-	-	-	-	2 (0)	-	-	-	-	2 (0)
Triticum aestivum* subsp. *erythrospermumcompactoides	-	-	-	-	1 (0)	-	-	-	-	1 (0)
Triticum aestivum* subsp. *ferrugineum	-	-	-	-	1 (0)	-	-	-	-	1 (0)
Triticum aestivum* subsp. *lutescens	-	-	-	-	2 (0)	-	-	-	-	2 (0)
Triticum aestivum* subsp. *milturum	-	-	1 (0)	-	4 (0)	-	-	-	-	5 (0)
Triticum aestivum* subsp. *spelta	1 (0)	0 (2)	-	0 (7)	13 (297)	3 (0)	1 (1)	3 (2)	3 (2)	24 (311)
Triticum aestivum* subsp. *spelta var. duhamelianum	-	-	-		2 (0)	-	-	-	-	2 (0)
Triticum monococcum	-	-	-	-	-	-	-	-	0 (7)	0 (7)
Triticum monococcum* subsp. *aegilopoides	-	-	-	-	-	-	-	-	0 (1)*	0 (1)*
Triticum monococcum* subsp. *monococcum	-	-	-	7 (0)	-	-	1 (0)	2 (2)	5 (2)	15 (4)
Triticum turgidum	-	-	-	-	6 (0)	-	-	3 (0)	3 (4)	12 (4)
Triticum turgidum* subsp. *carthlicum	-	-	-	-	-	-	-		0 (1)	0 (1)
Triticum turgidum* subsp. *dicoccum	1 (0)	0 (5)	-	-	3 (26)	-	0 (1)	53 (42)	0 (3)	57 (72)
Triticum turgidum* subsp. *durum	1 (14)	0 (10)	-	1 (6)	0 (5)	-	0 (3)	68 (191)	68 (542)	329 (771)
Triticum turgidum* subsp. *polonicum	-	-	-	-	1 (0)	-	0 (1)	-	-	1 (1)
Triticum turgidum* subsp. *turgidum	0 (2)	-	-	-	-	-	0 (1)	0 (3)	0 (2)	0 (8)
Common wheat	-	-	-	0 (6)**	-	-	-	-	0 (2)**	0 (8)**
Species/taxa total per country	**5**	**5**	**2**	**4**	**13**	**2**	**7**	**8**	**12**	**-**

* Wild species; ** Species name not reported.

Action 2

Diversity evolution and *in situ* gap analysis

The number of *in situ* wheat landrace cultivation records, retrieved in the project, and *ex situ* records, retrieved from Genesys, are summarized in Table 3 by country.

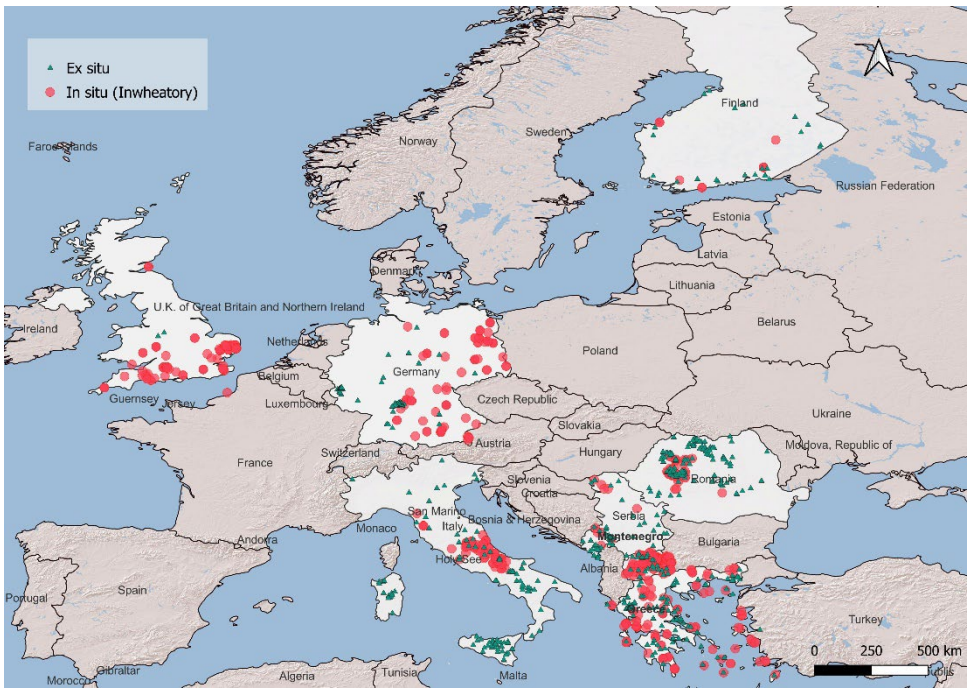
Table 3. *In situ* and *ex situ* wheat landraces records.

Country	*In situ* wheat landrace cultivation records	*Ex situ* records from Genesys
Finland	10	25
Germany	88	342
Greece	181	790
Italy	91	296
North Macedonia	104	33
Montenegro	6	33
Romania	41	222
Serbia	6	35
United Kingdom	89	9
Total	616	1,785

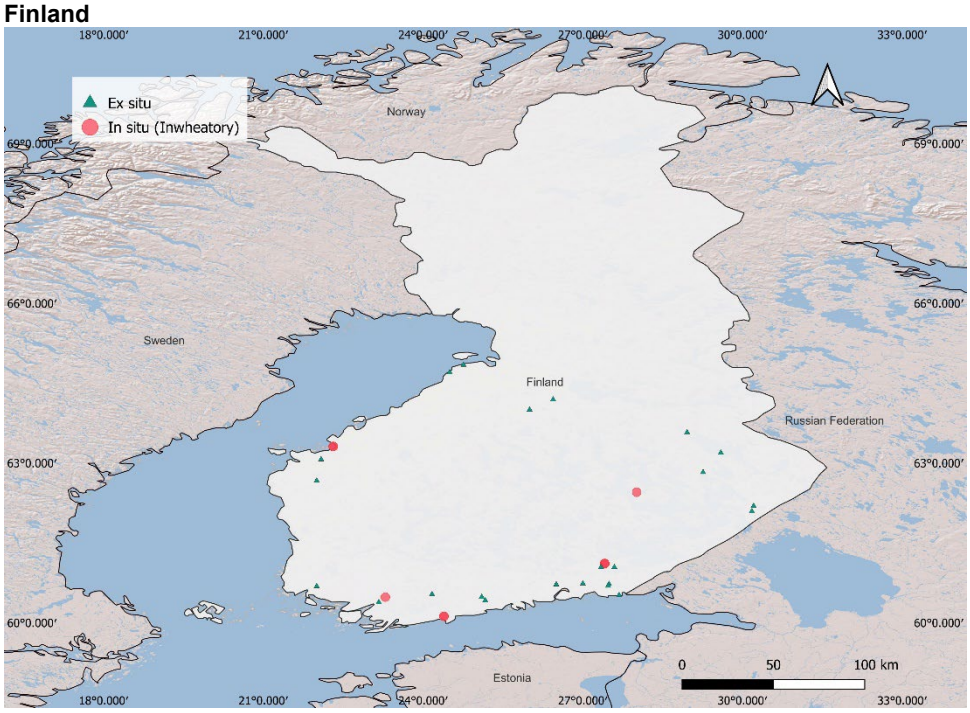
The data show significant variability among European countries regarding both the *in situ* cultivation and *ex situ* conservation of local wheat landraces.
The total number of *in situ* records is 616, with the highest values recorded in Greece (181), North Macedonia (104), Italy (91), and the United Kingdom (89). Countries such as Montenegro and Serbia display very low numbers (6 each), which may indicate either a marginal presence or limited documentation of local varieties currently under cultivation. *Ex situ* records are 1,785, mainly from Greece (790) and Germany (342), together accounting for nearly two-thirds of the total. Interestingly, the United Kingdom shows a relatively high number of *in situ* records (89) but very few *ex situ* (9); this disparity could reflect different conservation strategies, limited representation in global databases, or underutilization of *ex situ* conservation resources. In some countries (e.g. Greece, Germany, Romania), the number of accessions conserved *ex situ* is significantly higher than that of *in situ*, highlighting a well-established focus on genebank conservation but potentially less weight on dynamic on-farm conservation. However, it should be mentioned that some duplicate holdings in different genebanks might be included in GENESYS while historical data were excluded from the analysis. Greece can be regarded as an exception, considering the very high value of on-farm recorded wheat landraces. Conversely, in North Macedonia, the number of *in situ* records exceeds *ex situ* accessions (104 vs. 33), suggesting an important role of landraces in traditional cultivation but also a potential gap in the *ex situ* conservation of such materials.
A graphical comparison of the current sites where landraces are cultivated and the original collection sites of *ex situ* conserved accessions is presented below for the target countries. Results of such a comparison represent a useful basis to investigate genetic erosion in wheat landraces.

All target countries

Disclaimer: The boundaries and names shown on the maps below do not imply official endorsement or acceptance by ECPGR



Finland



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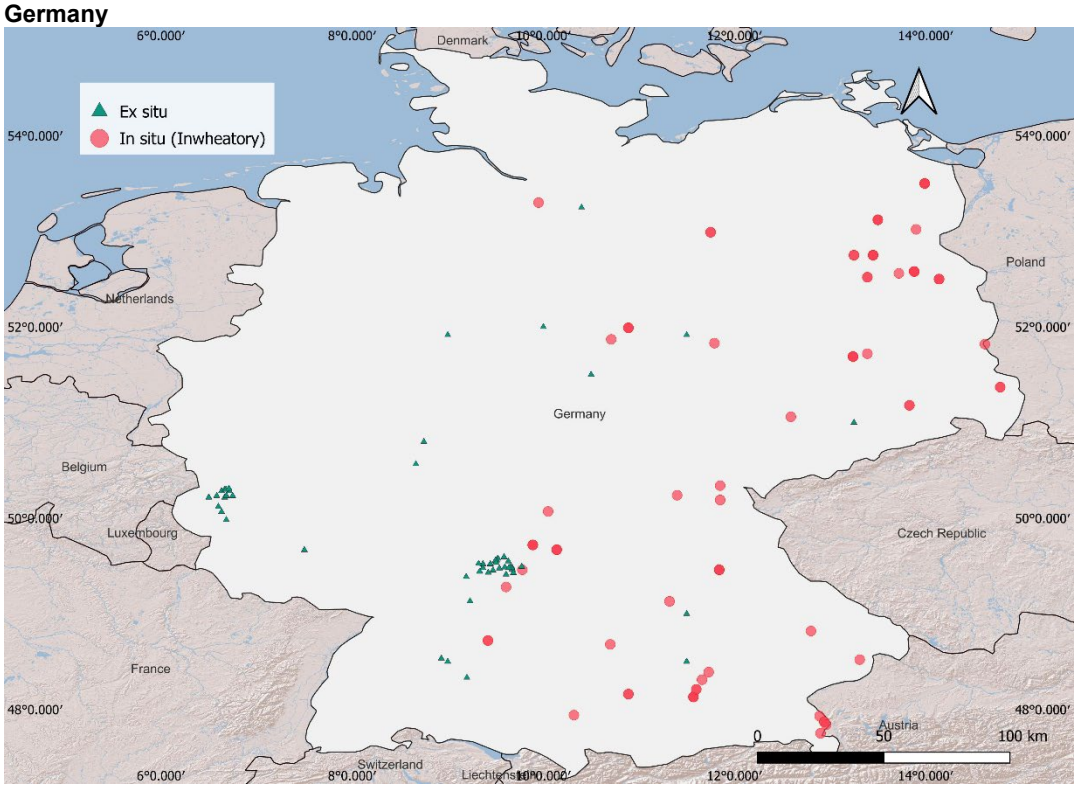

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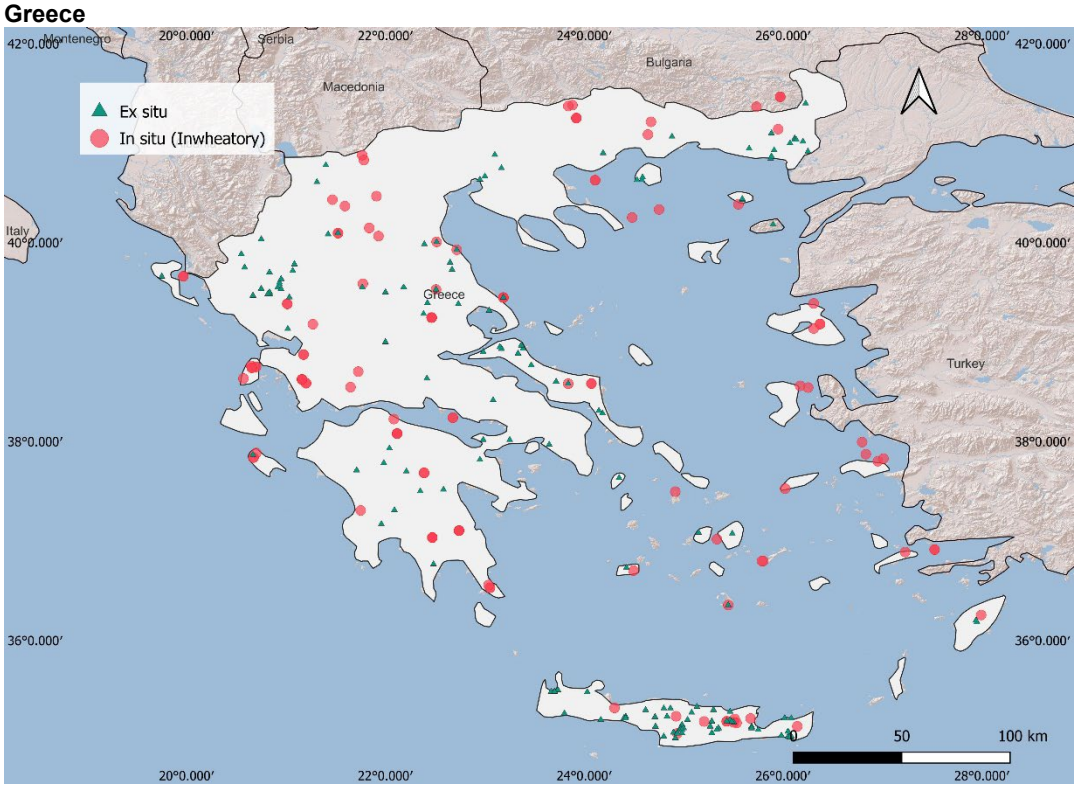
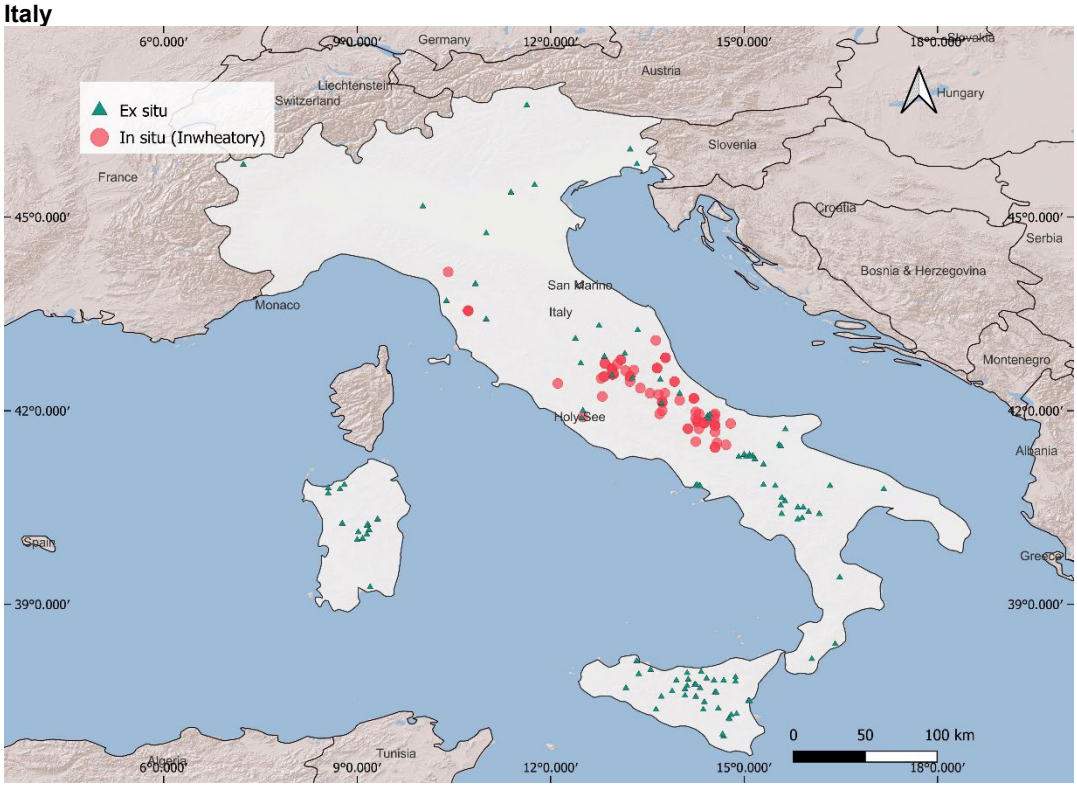
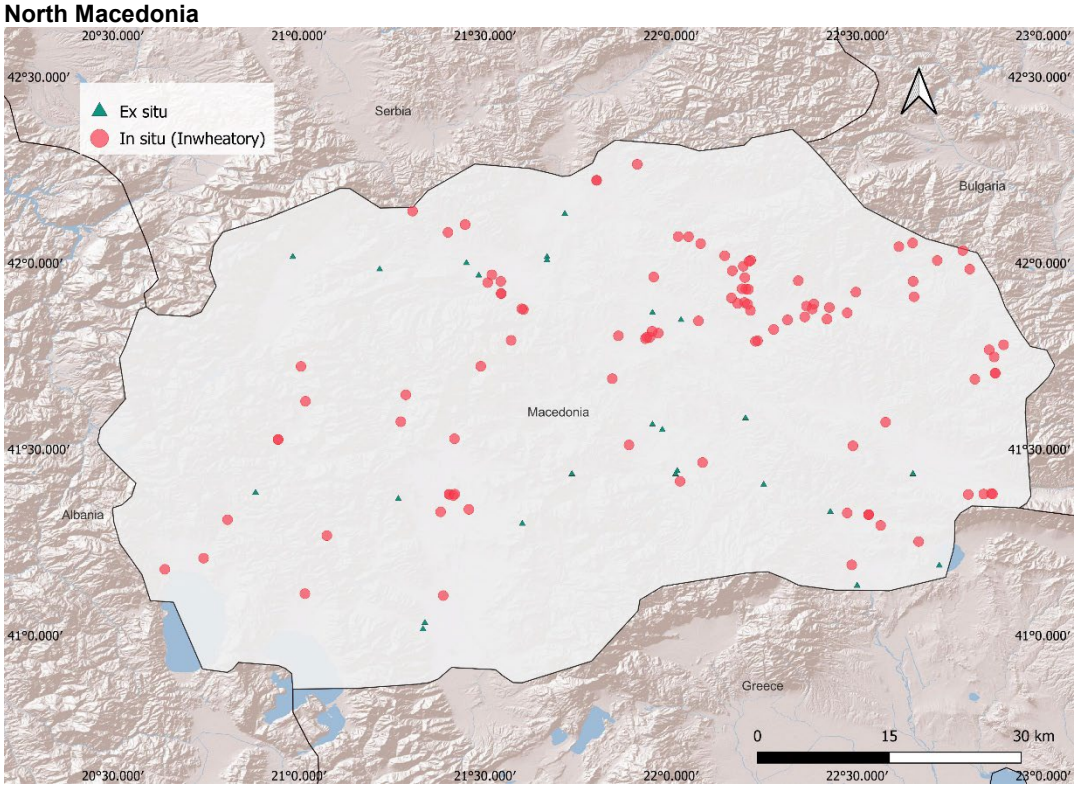


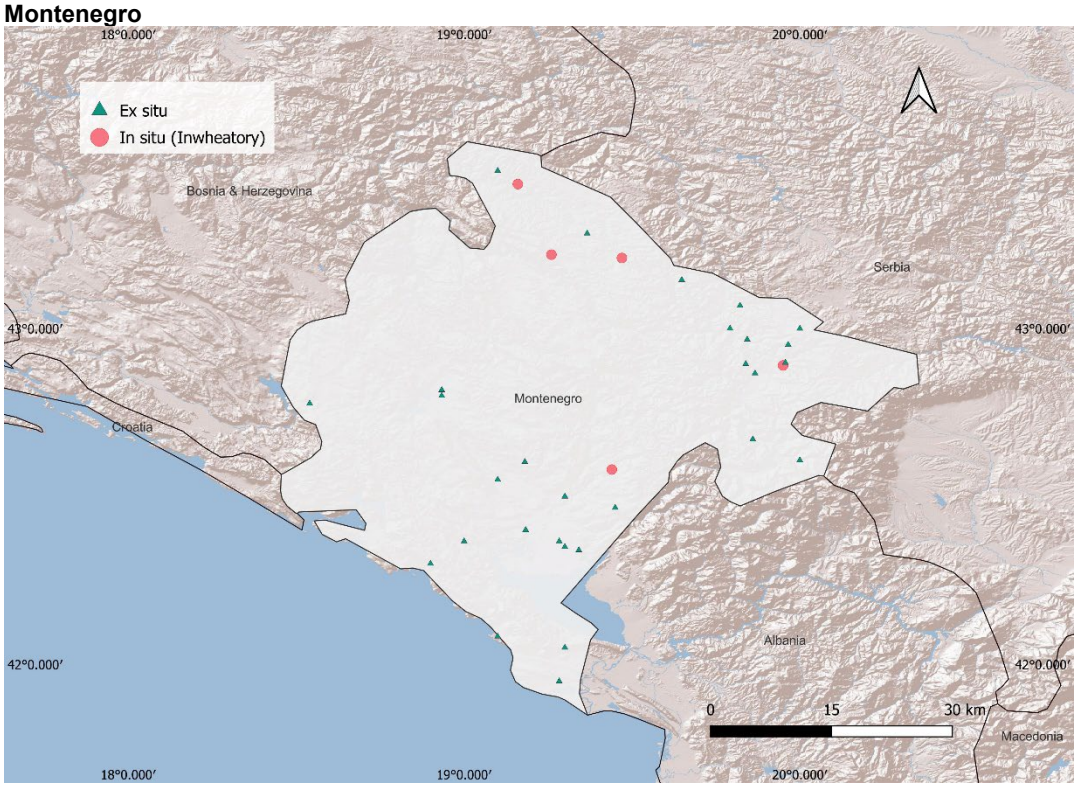
Italy



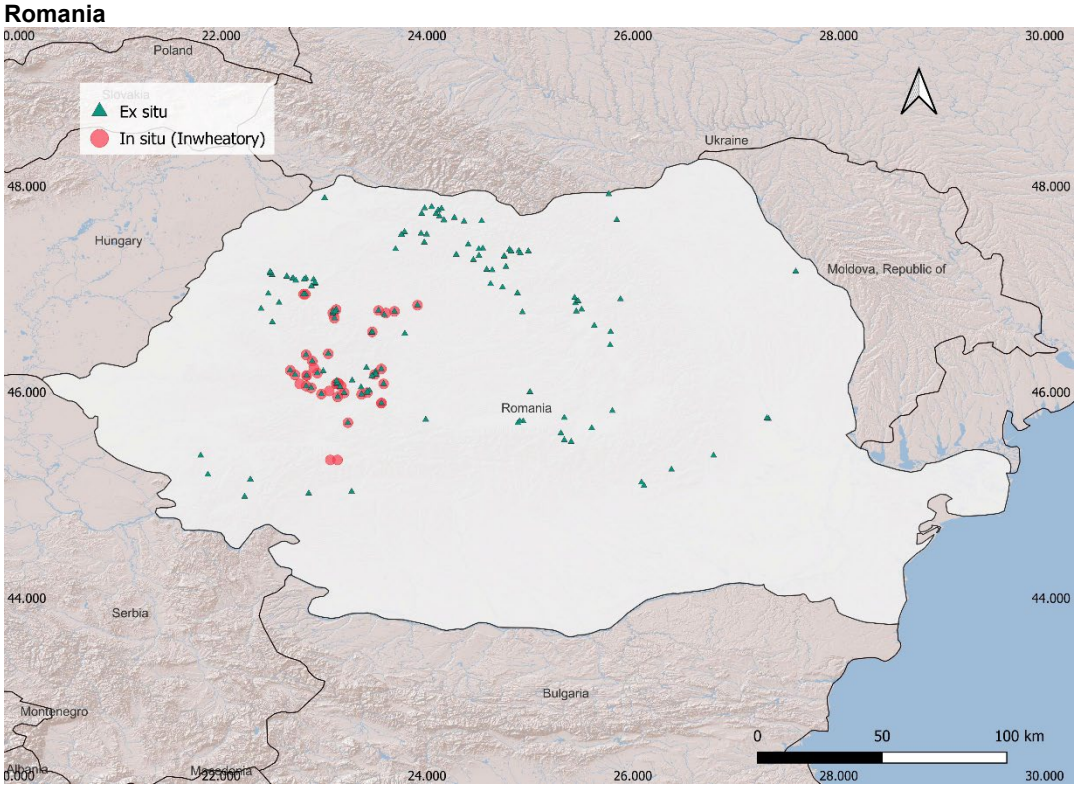
North Macedonia



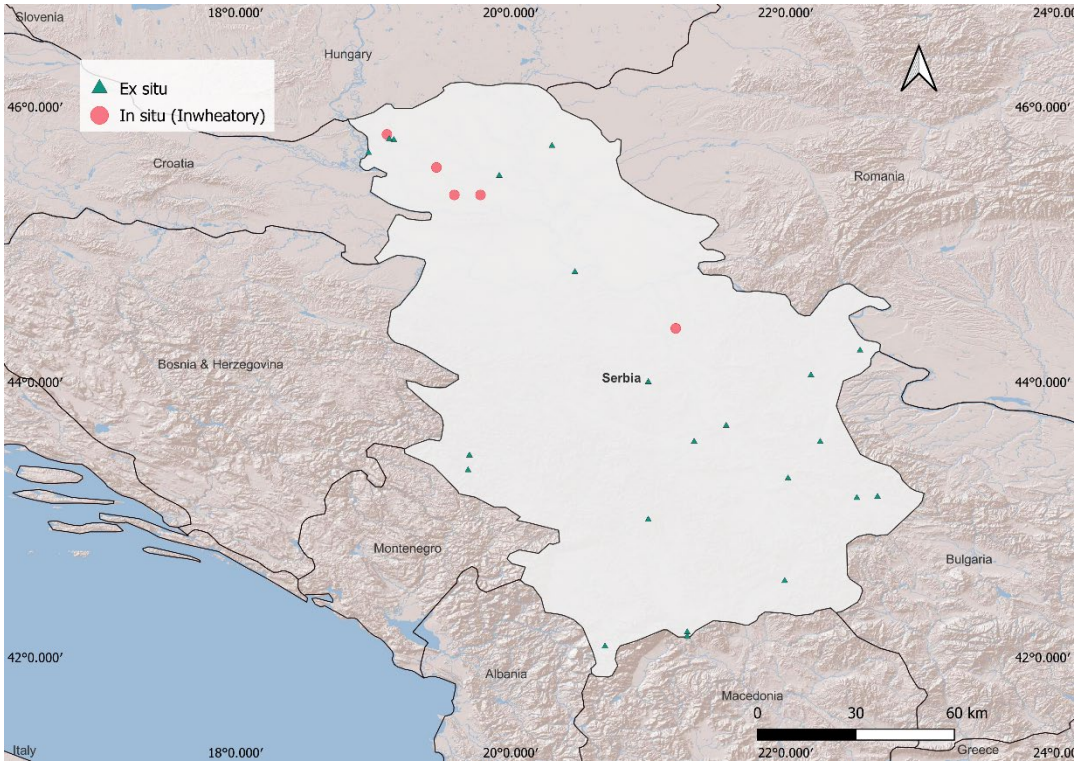
Montenegro



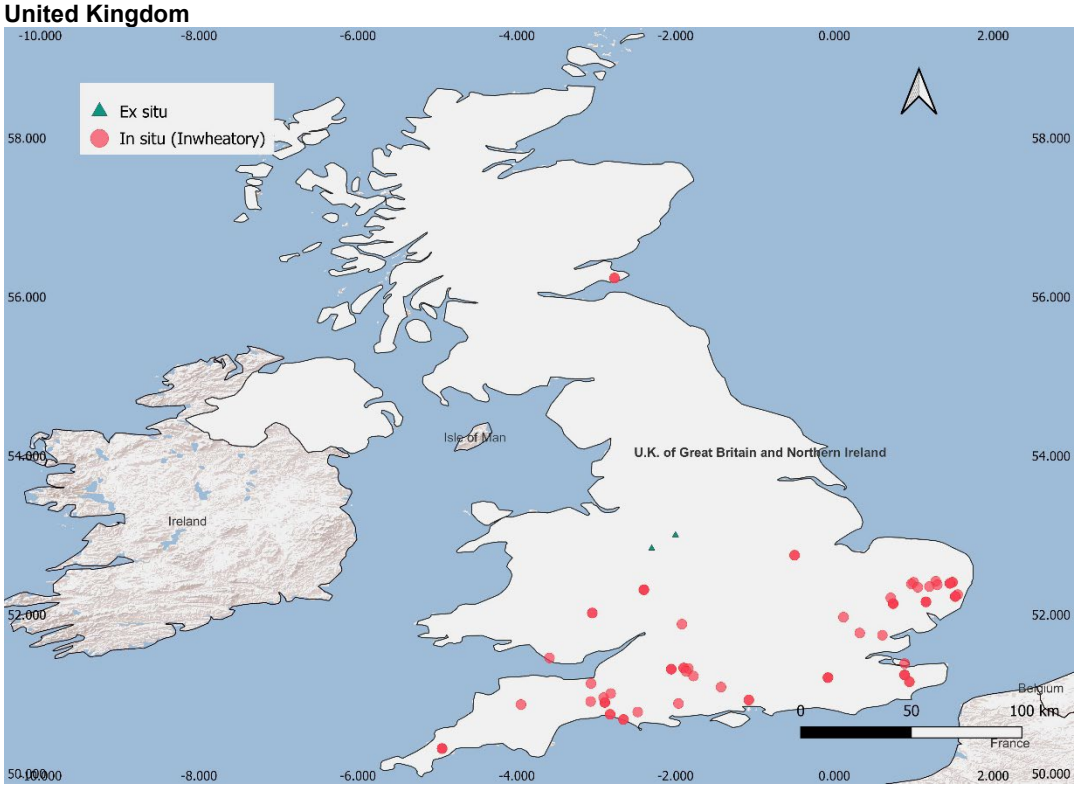
Romania



Serbia



United Kingdom



Action 3

Contribution to good practices elaboration through collection of case studies on wheat landrace cultivation (Action 3.1) and elaboration of a guide of good practices for the on-farm conservation of wheat landraces (Action 3.2).

- UNIPG prepared and distributed a MS Word template for recording case studies of successful examples of wheat landrace cultivation and use in the different countries involved. Organized as in Raggi *et al.* (2021), the template allows to record the following information: landrace main characteristics (e.g. local name, taxonomic classification, type of *in situ* conserved resource, location where cultivation occurs), the reason sustaining the cultivation (e.g. possible agronomic value for farmers or specific adaptation to specific environments or tolerance to abiotic and biotic stresses, or special quality characteristics), the agronomic contexts and management features, landrace main uses and actions to promote their products, market extent and methods used to add value to landrace products.
- The template was successfully used by the partners to describe a total of 25 detailed wheat landrace cultivations (available here) meant to be added to the ECPGR '*In situ* landraces: best practice evidence-based database landrace database'. Positive farmer response and their willingness to share knowledge and experience significantly contributed to the successful implementation of the planned activities. Landrace name, country of cultivation are summarized in Table 4.
- Information gathered in the case study, together with competences from the different involved partners, allowed the compilation of the document entitled *Guide for good practices for on-farm conservation and sustainable use of wheat landraces* (see Annex 1).

Table 4. List of the 25 case studies of wheat landrace cultivation collected in the frame of the project, divided by country.

Country	Species	Subspecies	Common name	Landrace local name
Bosnia and Herzegovina	*Triticum aestivum*	*spelta*	Spelt wheat	*Sitnica*
Bosnia and Herzegovina	*Triticum aestivum*	*aestivum*	Bread wheat	*Podrašnica*
Bosnia and Herzegovina	*Triticum aestivum*	*aestivum*	Bread wheat	*Previja*
Germany	*Triticum aestivum*	*spelta*	Spelt wheat	*Zuchtvesen*
Germany	*Triticum aestivum*	*aestivum*	Bread wheat	*Dickkopf*
Germany	*Triticum aestivum*	*aestivum*	Bread wheat	*Gelber Igel*
Germany	*Triticum aestivum*	*aestivum*	Bread wheat	*LaufenerLandweizen*
Germany	*Triticum aestivum*	*aestivum*	Bread wheat	*Roter Saechsischer Land*
Italy	*Triticum turgidum*	*dicoccum*	Emmer wheat	*Farro di Monteleone di Spoleto*
Italy	*Triticum turgidum*	*dicoccum*	Emmer wheat	*Farro della Garfagnana*
Montenegro	*Triticum aestivum*	*spelta*	Spelt wheat	*Krupnik*
Montenegro	*Triticum aestivum*	*aestivum*	Bread wheat	*Stara pšenica*
North Macedonia	*Triticum aestivum*	*spelta* (uncertain)	Spelt wheat	*Krupec*
North Macedonia	*Triticum aestivum*	*aestivum*	Bread wheat	*Osatka*
North Macedonia	*Triticum turgidum*	*dicoccum* (uncertain)	Emmer wheat	*Limec*
North Macedonia	*Triticum turgidum*	-	Durum wheat	*Bela Vardarka*
Romania	*Triticum aestivum*	*aestivum*	Bread wheat	*Grâu de Alba*
Romania	*Triticum monococcum*	*monococcum*	Einkorn wheat	*Alac de Apuseni*
Serbia	*Triticum aestivum*	*aestivum*	Bread wheat	*Stara Banatka*
Serbia	*Triticum aestivum*	*aestivum*	Bread wheat	*Crvenica*
Slovenia	*Triticum aestivum*	*aestivum*	Bread wheat	*Osječka šišulja, Korićeva*
Slovenia	*Triticum aestivum*	*aestivum*	Bread wheat	*Zlatna dolina*
United Kingdom	*Triticum aestivum*	*aestivum*	Bread wheat	*April Bearded*
United Kingdom	*Triticum aestivum*	*aestivum*	Bread wheat	*Squareheads master*
United Kingdom	*Triticum aestivum*	*aestivum*	Bread wheat	*Rouge d'Ecosse*

CONCLUSION

In conclusion, the project has made significant progress in understanding current wheat landraces cultivation across Europe as well as in highlighting gaps in *ex situ* conservation that could pragmatically guide future *in situ* (on-farm) and *ex situ* conservation activities. Although still incomplete, what is presented here is a large collection of wheat cultivation sites covering an important part of Europe and could represent a first, important step toward the development of national and European wheat landrace catalogues. Such catalogues appear as a necessary foundation for the implementation of the different EU provisions on biodiversity, especially those related to landrace conservation and sustainable use. Indeed, without knowing what exists and where it is cultivated, it is rather difficult for national governments to properly plan and implement the systematic conservation and sustainable use of landraces. From what is presented in this work, it clearly appears that different political and socio-economic backgrounds, as well as actions for *in situ* conservation, have had a strong impact on conserved materials and data availability; this must be carefully considered when comparing conservation levels in different countries. Results and evidence from data analysis underscore the necessity of complementarity between *in situ* and *ex situ* conservation approaches. In addition, the marked discrepancies between the two, at least in certain countries, highlight the need for integrated policies to strengthen both strategies, improve monitoring, and ensure the long-term preservation of wheat genetic diversity.

Annex 1. Guide for good practices for on-farm conservation and sustainable use of wheat landraces.

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Purpose, objectives, and scope

The approach used to produce this document is based on the analysis of a set of case studies of *in situ* (i.e. on-farm) maintained wheat landraces, collected across Europe. The information arising from the resulting evidence, together with an accurate scientific literature review, draws recommendations and guidelines that will help the user community (e.g. farmers) to improve their wheat landrace management practices. *In situ* accessibility to landrace reproductive materials was also analysed. Evidence collected in the document "*In situ landrace propagation management and access guidelines*", produced by Caproni and colleagues (2020) in the frame of the Farmer's Pride Project, was also considered.

Case studies analysis

In INWHEATORY project the involved partners were invited to provide relevant case studies of on-farm maintained wheat landraces representing successful (or potentially successful) examples of valorisation and/or use. Among other, the following information were requested: basic features (e.g. local name, taxonomic classification, type of *in situ* conserved resource,

location where cultivation occurs), the reason sustaining the cultivation (e.g. possible agronomic value for farmers or specific adaptation to specific environments including tolerance to biotic and/or abiotic stresses, special quality, the agronomic contexts and management features (including seed storage conditions and conservation methods), landrace main uses and actions to promote their products, market extent and methods used to add value to landrace products. Case studies reporting information on 42 different wheat landraces from 11 European countries were successfully collected in the frame of the project. Positive farmer response and their willingness to share knowledge and experience significantly contributed to the successful implementation of the planned activities. Main characteristics of collected case studies are reported in (ANNEX 1).

Management

Being wheat an open-field highly autogamous species (i.e. a self-pollinating species), no isolation is generally applied for landrace seed production even when different landraces are maintained in the same farm. Suggested minimum distances from plots where other sexually compatible plants are grown (i.e. other plants mainly of the same species), range of minimum cultivated area along with the minimum area (%) devoted to landrace multiplication are reported in Table 1.

Since in most of the collected case studies local varieties are cultivated for self-consumption, the sowing areas are in general quite small, often not exceeding 1 ha. Relevant exceptions are the landrace “Farro di Monteleone di Spoleto” and “Farro della Garfagnana” that, according to the last data available, are cultivated over an area of about 50 hectares in Umbria Region (Italy) and 200 hectares in Toscana Region (Italy), respectively. In the UK, niche farmer also grows some wheat landraces for specialist markets either specialist grains for bread making or long-straw for thatching.

Concerning the management, most of the analysed landraces are adapted to be cultivated under organic or low-input agronomic conditions. In these cases, no chemicals are used for plant protection, nor herbicides. At this regard, denser sowing (250-300 kg/ha), in comparison to standard conditions is recommended as well as the use of materials characterised by high early vigour is recommended to manage weeds; however, this is not always possible since specific production protocols and regulations for Protected Designation of Origin (DOP) or Protected Geographical Indication (IGP) varieties require the use of seed doses lower than those suggested here.

Table 1. Minimum recommended distance cultivated area and percentage of the cultivation area related to on-farm wheat landraces multiplication.

Name, scientific	**Name, common**	**Minimum recommended distance (m)**	**Minimum recommended cultivated area (m^2)**	**Minimum area devoted to landrace multiplication (%) ***	**References**
Triticum aestivum L. subsp. *aestivum*	Soft wheat	4-8	3,000	4-10	Mipaaf 1971; Lorenzetti et al. 2018
Triticum monococcum L. subsp. *monococcum*	Einkorn wheat	4-8	3,000	5-10	Mipaaf 1971; Lorenzetti et al. 2018
Triticum turgidum L. subsp. *durum*	Durum wheat	4-8	3,000	4-10	Mipaaf 1971; Lorenzetti et al. 2018

Similarly, in Greece landraces are cultivated in small areas for self-consumption or to cover the needs of local market. Exceptions are some of the local varieties registered in the Catalogue of Conservation Varieties according to the EC Recommendation 2008/62/EU of the 20th June 2008 (L 162)" and the Joint Ministerial Decision (Government Gazette B 2038/21.9.2009): "Kaploutzas", "Deves", "Oreino", "Limnos" and "Dilofos". "Deves" and "Dilofos", according to the last available data, are cultivated over an area of about 100 and 1000 hectares in Thessaly and Central Greece, respectively and "Oreino" is cultivated over an area of 100 hectares in Thessaly (Greece). Finally, "Kaploutzas" and "Limnos" are cultivated almost all over Greece of about 120 and 110 hectares, respectively. "Kaploutzas" is cultivated in Central and Western Macedonia, Thessaly and Central Greece; the obsolete variety "Limnos" is cultivated mostly in Limnos island, Lesvos island, Central Macedonia, Thessaly and Central Greece. These landraces have very good quality characteristics and are cultivated under low-input agronomic conditions. Other registered conservation wheat varieties and landraces with Greek origin are "Saritsam" (*Triticum durum* Desf.) from Lesvos island area, "Kopaida" a repatriated *Triticum turgidum* ssp. *dicoccon* (Schrank ex Schübl.) Thell. landrace from Central Greece. Few other collected landraces in Greece are *Triticum aestivum* L. "Ntopio" from Arcadia Peloponnese, "Aspratheri" from Karpathos, "Kokkinostaro" from Milos island (Protonotariou et al., 2023), "Zoulitsa" from Western Macedonia and Peloponnese, "Grinias" from Lefkada and Zakinthos islands and Achaia prefecture and *Triticum turgidum* L. subsp. *durum* "Skordoliaris" from Paros island, "Mavratheri" from Aegean islands and Crete, "Mavragani" from Peloponnese, Thessaly, Ionian and Aegean islands, etc (Stavropoulos et al., 2008).
In Bosnia and Herzegovina, it is still possible to find old wheat cultivars that were cultivated before the Second World War; these old varieties are generally characterized by a small genetic potential and greater protein content. In the mountainous areas old wheat genotypes can be found planted together with rye (Kondić et al., 2020, 2018; Kondić and Đurić, 2024).

Multiplication procedures and seed selection

As for analysed case studies, farmers usually multiply their seeds by saving some quantities from the harvest for the next sowing; in few cases the harvest is done manually. Nevertheless, to preserve within-population (i.e. within-landrace) genetic diversity, a high number of mother plants is needed to produce seed for the following generation even when wheat landraces are multiplied. Indeed, from a genetic point of view, wheat landraces are expected to be constituted by a mix of pure lines homozygous for potentially different alleles. The use of an adequate number of mother plants is therefore crucial to maintain such diversity also considering the low recombination possibilities of the alleles in strict autogamous species like wheat. Generally, for open-field crops, it is not useful to recommend a specific number of plants to be used for seed production but a percentage of the total number of the grown plants (see Table 1). However, for cereals like wheat it has been suggested that a minimum of 30,000 plants should be multiplied to reduce possible undesired effects caused by genetic drift that could negatively affect the level of within-landrace maintained diversity (Enjalbert et al., 1999; Goldringer et al., 2006). Indeed, genetic drift can be particularly negative in small populations of strictly autogamous species like wheat (Charlesworth and Charlesworth, 1987).

Regarding the selection of seed material, as from the collected case studies, many farmers do not follow well-established criteria; however, in some cases the largest and healthy seeds, isolated taking advantage of a mechanical/optical selector, are selected for multiplication. Selection is anyway recommended to maintain landrace identity, good agronomic performances − in terms of yield and other peculiar characteristics of the resource − and good phytosanitary conditions of the propagation material. At the same time, the question arises as to whether the identity of a landrace should remain unchanged. At this regard, it can be also argued that landraces should continue to evolve, as they historically have, rather than being preserved as static entities or "open-air museums"; indeed, adaptation to changing environmental and agronomic conditions is an essential consideration. Furthermore, as landraces are primarily managed by farmers, it is important to recognize their autonomy in making decisions that best suit their needs and circumstances.

At the same time, even if increased seed size, one of the more commonly used selection parameters applied to harvested wheat caryopsis intended for landrace multiplication, is associated with an increase of potential yield and early vigour, selection criteria on the seeds should not be too strict so to allow for a certain level of diversity to be maintained within each landrace. Conserving within-landrace diversity is indeed crucial for adaptation to current and future environmental conditions. A similar approach applied to a barley population (another autogamous annual species like wheat) has proven effective in maintaining sufficient diversity, enabling adaptation to a broad range of extreme pedo-climatic conditions (Raggi et al., 2022, 2016b, 2016a). Although there are specific production protocols and regulations for DOP or IGP varieties, such as ‘Farro di Monteleone di Spoleto’ or ‘Farro della Garfagnana’ in Italy, the applied selection methods are generally not disclosed. In the case of ‘Farro della Garfagnana’, for example, it is only specified that the seeds used for sowing must be hulled.

Another key factor in the cultivation of local wheat varieties is the sowing period, which can be autumn or spring; maintaining the traditional sowing time associated with a specific local variety is crucial. Indeed, a shift in sowing period could dramatically affect the variety’s genetic composition due to selective pressures different from those that have historically shaped its diversity. To safeguard genetic identity, the sowing period should remain unchanged, even if a different timing could enhance yield potential or extend the growing season, also because of the climate change. However, as with seed selection and broader landrace management, it is important to balance the goal of preserving genetic identity with the need for ongoing adaptation to evolving environmental conditions and the practical choices made by farmers (see above).

For the Greek conservation varieties registered in the Catalogue, such as “Limnos”, there are specific protocols for seed productions and DUS criteria (Distinct, Uniform, and Stable) must be respected to a certain extent. ELGO-DIMITRA and the Institute of Plant Breeding and Genetic Resources are responsible for the conservation and seed production; although, in many cases, farmers multiply their own seeds under slightly different agronomic conditions, and they use them the next season. The multiplication procedure ensures ‘Limnos’ adaptation to the cultivation area and preservation of useful within population genetic diversity. Regarding “Skliropetra” wheat farmers sow each year the seed they produced the previous growing season, without making any special selection. Applying the

rule of keeping seed from their best field. This system, free from selection, allows the crop to adapt naturally to local environmental conditions without altering its genetic composition; the “better field” is the one free from off-type plants, weeds and diseases. “Zoulitsa” wheat farmers sustain an independent farm cycle by re-seed their own seeds every year; also, this cycle that is independent of intentional selection enables the crop to naturally adapt to environmental conditions in an area without altering its genetic composition. The key components of this customary system include: a) Closed Seed Cycle: every farm generates its own seed stock for future plantings with minimal external inputs, b) Purity Maintenance: farmers select fields free from weed contamination and genetic mixture to ensure seed purity and c) Limited Seed Exchange: exchanges between farms take place only when absolutely required — generally because of low production or the requirement to increase cultivation — and only if the initial seed has been tainted by off-types or weeds. Through the absence of artificial selection, Zoulitsa wheat becomes adjusted to local agroecological stresses, making it more resilient. The restricted seed exchange also safeguards the population heterogeneity, ensuring the landrace's long-term sustainability. This low-input approach serves as a fine illustration of the ability of traditional practices to effectively conserve crop biodiversity. At this regard it must be noted that, as stated above, a cereal landrace can be highly heterogeneous and consist of many varietal forms (i.e. lines homozygous for different alleles) (Pinheiro de Carvalho et al., 2013).
Integrating information on the conservation and sustainable use of local wheat landraces into the training programs of advisory services can significantly contribute to the preservation of their genetic diversity.

Exchange of multiplication materials

Very often, local varieties are grown by a few farmers or by a single farmer. Generally, local farmers multiply their own seed, but a seeds’ exchange between farmers is possible, especially between relatives. However, to promote specific local adaptation, seed exchange may be intentionally limited, as in the case of the Zoulitsa Greek wheat mentioned above. In the UK many individual farmers do not have the necessary harvesting equipment, so a few farmers multiply and sell to a larger number of farmers who grow for sale (Maxted N, personal communication).
Many authors reported that the level of multiplication material exchange among farmers using a certain landrace within the same area can condition level and structure of the conserved diversity (Khan et al., 2020; Negri and Tiranti, 2010; Torricelli et al., 2013; Tosti and Negri, 2005). To encourage the progressive diffusion and adaptation of the native variety in its original cultivation area, a single farmer should donate his seeds to neighbouring farmers who are willing to cultivate the native variety. These neighbours, in turn, should then donate their own propagated materials to other neighbours, and so on (Figure 1). Since for a cereal like wheat it has been suggested that a minimum of 30,000 plants should be multiplied to reduce possible undesired effects caused by genetic drift and (Enjalbert et al., 1999; Goldringer et al., 2006); this same minimum threshold could also be applied when planning seed exchanges. Additionally, it is recommended that not only seeds, but also cultivation skills and knowledge, be shared among farmers. Finally, conservation schemes should be implemented to protect the most vulnerable landrace resources from potential loss (Scholten et al., 2009).

Market

Almost all the case studies reported that landraces are cultivated without a commercial purpose, and that they are only produced to address domestic consumption needs. Usually, the production obtained does not exceed the needs of the grower, therefore a niche market is not developed for these agricultural products. In a few cases, the marketing is intended for local bakers or occasionally for local markets. In Italy, specific production protocols and regulations must be followed for the marketing and commercialization of Protected Designation of Origin (PDO) and Protected geographical indication (PGI) varieties such as 'Farro di Monteleone di Spoleto' and 'Farro della Garfagnana' that are quite relevant exception also in this case. According to Raggi et al. (2021) the 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 traits, the link with the cultural and traditional values of the territory and can contribute to link the genetic resources (and local knowledge) with the market (Vandecandelaere 2011). FAO (2009) and Veteläinen et al. (2009) also showed that geographical indications can be used as a driver for a sustainable development of rural areas. The use of a geographic indication is not extensive in the analysed dataset suggesting that there is still room for improvement that should be pursued. In Greece, almost all wheat landraces are cultivated for domestic consumption needs. Although, some landraces' products are intended for local markets due to their nutritional value and use in traditional recipes. Especially, 'Limnos' wheat products, such as groats and flour, have a national market due to their exceptional quality.

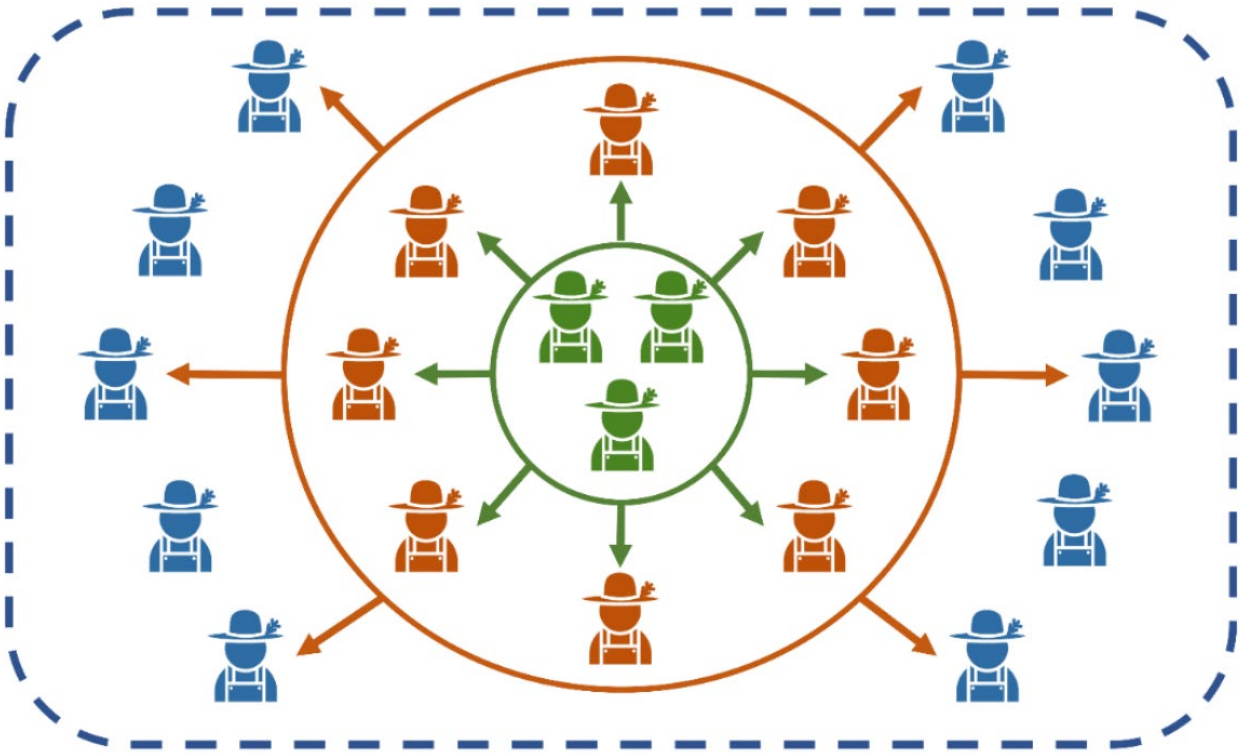

Figure 1. Schematic representation of a possible actuation of diffusion of a landrace within its adaptation area (dotted blue line). Single farmers that initially keep the resource (central nucleus in green) donate propagation material to neighbouring farmers (dark orange) that wish to cultivate and

multiply the resource continuously over time. The latter in turn do the same with their neighbours (blue). From Caproni et al. 2020.

Supporting actions that added value to landrace products

Generally, among the case studies, the farmers do not receive any support, nor the government provide specific support for on-farm conservation. In Germany there are support measures for the cultivation of landraces. In Italy there are specific supporting actions and groups promoting the consumption and market of certified products such as 'Farro di Monteleone di Spoleto' and 'Farro della Garfagnana'. Under Italian legislation governing economic support for local varieties, some resources could lose financial assistance in the future if the "risk" coefficient reaches a level indicating that the landrace is no longer at risk of genetic erosion. This could be the consequence of renewed interest on the resource and increased number of farmers relaying on this landrace and cultivated hectares. In Greece subsidies were given in the past from the Ministry of Rural Development and Food to the farmers under "Agro-environment measures" for the conservation of extensive crops, threatened by genetic erosion and their cultivation for five years (started from 2006). More recently the registration of landraces in the Catalogue of Conservation Varieties helped the local communities to continue landraces cultivation and on-farm conservation.
In certain counties, the decoupled payment system has proven to be a beneficial tool in the promotion and sustainable use of these resources.

Accessibility

Some landrace seeds are deposited for mid-term or long-term storage in Gene Banks or Institutes of Field and Vegetable Crops. In a few cases, like in Serbia, local community seed banks, mostly self-financed, has been founded to preserve seeds *ex situ* and facilitate farmers' access to seeds via exchange. The main characteristics of the landraces analysed as a case study are reported in Table 2 below. Further efforts should be directed towards exploring novel opportunities to enhance their accessibility.

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Table 2. Main characteristics of the analysed wheat landrace case studies.

Country	Landrace name	Crop name	Cultivation and multiplication procedures	Materials exchange	Market	Supporting actions	Accessibility
North Macedonia	Bela Vardarka	*Triticum turgidum* L.	- Traditional agriculture - Largest seeds, passed through a selector, are used for the next season	Local farmers multiply his own seed	Own use only	None	Faculty of Agricultural Sciences and Food in Skopje
North Macedonia	Krupec	*Triticum aestivum* L. subsp. *spelta* (L.) Thell. (uncertain)	- Dense sowing (250 kg/ha) - Field fertilized only during basic preparation with NPK (15:15:15) - No chemicals - Largest seeds, passed through a selector, are used for the next season	Cultivated and mantained only in the Monastery St Gavril Svetogorec	Own use only	None	Faculty of Agricultural Sciences and Food in Skopje (uncertain)
Montenegro		*Triticum aestivum* L. subsp. *spelta* (L.) Thell.	- Organic production; - Sowing rate of 200-240 kg per hectare; - Strong competitive ability against weeds; - Satisfactory yields even on less fertile soils; - Produced without synthetic chemicals; - Constantly increasing market	Farmers use seeds from previous cultivation	Flour is predominantly sold at doorsteps and at the local market	The Ministry of Agriculture, Forestry and Water Management provides incentives through decoupled payment system	Plant Gene Bank located at the Biotechnical faculty in Podgorica at University of Montenegro
North Macedonia	Limec	*Triticum turgidum* L. subsp. *dicoccon* (Schrank ex Schübl.) Thell.	- Dense sowing (300 kg/ha) - Field fertilized only during basic preparation with NPK (15:15:15) - No chemicals - Largest seeds, passed through a selector, are used for the next season	Cultivated and maintained only in the Monastery St Gavril Svetogorec	Own use only	None	Faculty of Agricultural Sciences and Food in Skopje (uncertain)
North Macedonia	Osatka	*Triticum aestivum* L.	- Dense sowing (300 kg/ha) - Field fertilized in spring with potassium nitrate - No chemicals - Selected seeds from best plants with the highest yield are passed through a selector and used for the next season	Cultivated and maintained only within one farm in the village of Kazandol, near Valandovo	Own use only	None	Faculty of Agricultural Sciences and Food in Skopje (uncertain)

Serbia	Stara Banatka	*Triticum aestivum* L.	- Organic or low input farming systems - Largest seeds are used for the next season	Seed exchange is not common (only few farmers interested)	Potential market not yet fully explored	- Monetary contribution provided by the government - GRAINEFIT, PR-166-Serbia project	Serbian national Plant Gene Bank
Serbia	Rumska crvenka	*Triticum aestivum* L.	- Organic or low input farming systems	Local women maintain the landrace and exchange seeds	Local women use the landrace to make straw art (straw figures, postcards, ornaments and pictures) and sell these second products on local markets market.	- Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture project - GRAINEFIT, PR-166-Serbia project	- Institute of Field and Vegetable Crops in Novi Sad - Serbian national Plant Gene Bank - Svalbard Global Seed Vault
Serbia	Crvenica	*Triticum aestivum* L.	- Low input farming systems - Conventional farming systems	Landrace seeds are multiplied by only one farmer in the region. There is no data on the seeds exchange.	Own use only	- Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture project - GRAINEFIT, PR-166-Serbia project	- Institute of Field and Vegetable Crops in Novi Sad - Serbian national Plant Gene Bank - Svalbard Global Seed Vault
Romania	Grâu de Alba	*Triticum aestivum* L. subsp. *aestivum*	- Traditional agriculture - No chemicals	Farmers do not exchange seeds (exceptionally, only between relatives)	- Family consumption - Occasionally for sale in local markets	No technical or scientific support is currently provided	Suceava Genebank
Romania	Alac de Apuseni	*Triticum monococcum* L. subsp. *monococcum*	Traditional agriculture without the use of chemical fertilizers or pesticides	Local farmers use seeds from their own harvest. When the stock is insufficient, seed from other local farmers is used.	Own use only	There is no technical, financial, or any type of support from the formal sector.	Suceava Genebank

Germany	Babenhauser Zuchtvesen	*Triticum aestivum* L. subsp. *spelta* (L.) Thell. (uncertain)	- Organic or low input farming systems	Each farmer multiplies his own seed. Seeds exchange between farmers is possible.	Co-operation between farmers, a mill and two bakeries	Supported by the administration of the Öko-Modellregion Günztal	IPK genebank
Germany	Alter Pommerscher Dickkopf	*Triticum aestivum* L.	- Organic or low input farming systems	Each farmer multiplies his own seed. Seeds exchange between farmers is possible.	In the Biosphere Reserve “Oberlausitzer Heide- und Teichlandschaft” in Saxonia there are some marketing strategies for this old variety	- Organic farms are organized in grain network of “Verein für Erhaltung und Rekultivierung von Nutzpflanzen - VERN e.V.” (Association for the conservation and recultivation of crops) - Supporting measures in Brandenburg and Saxonia - "Preservation of Heritage Grains” project in Biosphere Reserve “Oberlausitzer Heide- und Teichlandschaft” in Saxonia	- IPK genebank - VERN e.V.
Germany	Gelber Igel	*Triticum aestivum* L. subsp. *compactum* (Host) Mac Key	- Organic or low input farming systems	Each farmer multiplies his own seed. Seeds exchange between farmers is possible.	Opportunities and suggested label "Berg-Binkelweizen" (mountain club wheat)	- Organic farms are organized in grain network of “Verein für Erhaltung und Rekultivierung von Nutzpflanzen - VERN e.V.” (Association for the conservation and recultivation of crops) - Supporting measures in Brandenburg and Saxonia	- IPK genebank - VERN e.V.
Germany	Laufener Landweizen	*Triticum aestivum* L.	- Organic or low input farming systems - Low sowing density of 130 to 160 kg/ha - Light to moderate fertilization or manure fertilization	Each farmer multiplies his own seed. Seeds exchange between farmers is possible.	Marketed directly by organic farmers as flour and grains. Also used in bakeries and breweries.	- Supported by the Biosphere Region’s administrative office. - Network of organic farms and processing companies committed to preserve this variety through the biosphere region Berchtesgadener Land.	- IPK genebank - Biosphere Region’s administrative office

Germany	Roter Sächsischer Landweizen	*Triticum aestivum* L.	- Organic or low input farming systems	Each farmer multiplies his own seed. Seeds exchange between farmers is possible.	Marketed by local bakers	- Organic farms are organized in grain network of “Verein für Erhaltung und Rekultivierung von Nutzpflanzen - VERN e.V.” (Association for the conservation and recultivation of crops) - No official management plan	- IPK genebank
Slovenia, Croatia	U1 (or Osječka šišulja or Koricéva)	*Triticum aestivum* L.	Standard farmer practice systems	Seeds exchange between farmers is possible.		Landrace management completely relies on farming activities in the area	Only on-farm conservation (two farms in north-east Slovenia)
Slovenia, Croatia	Zlatna dolina	*Triticum aestivum* L.	Standard farmer practice systems	Seeds exchange between farmers is possible.		Landrace management completely relies on farming activities in the area	Only on-farm conservation (two farms in north-east Slovenia)
Republic of Srpska, Bosnia and Herzegovina	Podrašnica	*Triticum aestivum* L.	- Traditional agriculture	Farmers use seeds from previous cultivation	Only for household needs	- Landrace management completely relies on farming activities in the area - On farm multiplication supported by Foundation "Alica" Community Seed Bank - Research financially supported by Ministry for Scientific and Technological Development, Higher Education and Information Society of the Republic of Srpska	Republic of Srpska Gene Bank (Institute of Genetic Resources University of Banja Luka)

Republic of Srpska, Bosnia and Herzegovina	Previja	*Triticum aestivum* L.	- Traditional agriculture	Farmers use seeds from previous cultivation	Only for household needs	- Landrace management completely relies on farming activities in the area - On farm multiplication supported by Foundation "Alica" Community Seed Bank - Research financially supported by Ministry for Scientific and Technological Development, Higher Education and Information Society of the Republic of Srpska	Republic of Srpska Gene Bank (Institute of Genetic Resources University of Banja Luka)
Republic of Srpska, Bosnia and Herzegovina	Sitnica	*Triticum aestivum* L. subsp. *spelta* (L.) Thell.	- Traditional agriculture	Farmers use seeds from previous cultivation	Only for household needs	- Landrace management completely relies on farming activities in the area - On farm multiplication supported by Foundation "Alica" Community Seed Bank - Research financially supported by Ministry for Scientific and Technological Development, Higher Education and Information Society of the Republic of Srpska	Republic of Srpska Gene Bank (Institute of Genetic Resources University of Banja Luka)
Montenegro	Stara pšenica	*Triticum aestivum* L.	- Organic or low input farming systems - Sowing density of 200 kg/ha	Farmers use seeds from previous cultivation	Exclusively flour is sold in local market	The Ministry of Agriculture, Forestry and Water Management provides incentives through decoupled payment system	Plant Gene Bank located at the Biotechnical faculty in Podgorica at University of Montenegro
United Kingdom	April Bearded	*Triticum aestivum* L. subsp. *aestivum*	- Organic or regenerative farming practices free from artificial fertiliser	Farmers tend to save seed. Seed exchange is uncommon.	Grain is milled and sold either locally or nationally	No technical or scientific support is given.	- John Innes Centre's Genetic Resource Unit - Listed on the 'BBA wheat portal'

United Kingdom (Scotland)	Rouge d'Ecosse	*Triticum aestivum* L. subsp. *aestivum*.	- Organic or low input farming systems	Farmers save their own seed for the next cropping cycle	Grain is milled and sold as flour	No technical or scientific support is given.	- John Innes Centre's Genetic Resource Unit - Listed on the 'BBA wheat portal'
Italy	Farro della Garfagnana	*Triticum turgidum* L. subsp. *dicoccum* (Schrank ex Schübler) Thell.	- Cultivation technique detailed by a legal regulation as Protected Geographical Indication (IGP) product		Marketed as pearled grain	Garfagnana IGP Farro Consortium	Unione dei Comuni della Garfagnana – Banca Regionale del Germoplasma (LR 64/04) c/o Centro la Piana di Camporgiano
Italy	Farro di Monteleone di Spoleto	*Triticum turgidum* L. subsp. *dicoccum* (Schrank ex Schübler) Thell.	- Cultivation technique detailed by a legal regulation as Protected Designation of Origin (DOP) product		Marketed in four distinct types of product: Integrale, Semiperlato, Spezzato, Semolino di Farro.	- "Farro di Monteleone di Spoleto" Association - Protected Designation of Origin (DOP)	Regional Germplasm Bank of Herbaceous Species Seeds, S. Andrea D'Agliano (PG)
Finland	Sarkalahti	*Triticum aestivum* L. *subsp. aestivum*	Organic or low input farming systems	Use of own seed	Currently only for household needs. Some market potential for a rare whistling-free dark brown grained landrace wheat	During 2020-2023 the national landrace cereal project (Diversity to fields) offered technical support for multiplication. Potential for a conservation variety	Nordic Genebank (NordGen)
Finland	Rusutjärvi	*Triticum aestivum* L. *subsp. aestivum*	Cultivation technique detailed by a conservation variety Organic farming systems	Use of own seed. Seed marketed in South Finland	Yield used for flour for baking	As registered a conservation variety subsidy for the maintenance. During 2020-2023 the national landrace cereal project (Diversity to fields) offered technical support for multiplication.	Nordic Genebank (NordGen). As a conservation variety in the European Common Catalogue of Conservation Varieties seed available from the farmer

Greece	Limnos	*Triticum turgidum* L. ssp. *durum* Desf.	- Seed production technique detailed by a regulation for conservation varieties and DUS criteria. - In many cases farmers multiply their own seeds under slightly different agronomic conditions and they use them the next season. -Low input farming systems and adaptability to the conditions of the region	ELGO-DIMITRA and the Institute of Plant Breeding and Genetic Resources are responsible for the conservation and seed production.	Marketed nationally for its high-quality products such as groats and flour.	- Registered in the Catalogue of Conservation Varieties. - Subsidies were given in the past from the Ministry of Rural Development and Food to farmers for the conservation of extensive crops, threatened by genetic erosion	Institute of Plant Breeding and Genetic Resources of ELGO-DIMITRA
Greece	Skliropetra	*Triticum aestivum* L. subsp. *aestivum*	- Farmers sow each year the seed they produced the previous growing season, without making any special selection. - Low input farming systems and adaptability to different agricultural environments	Each farmer keeps its own seed	Marketed in local markets for bread, trahana and use in traditional recipes.	No support	Genebank and Institute of Plant Breeding and Genetic Resources of ELGO-DIMITRA
Greece	Zoulitsa	*Triticum aestivum* L. subsp. a*estivum*	-Farmers sow their own seeds every year. -Low input farming systems and adaptability to mountainous and semi-mountainous regions, where cooler and more humid climatic conditions prevail.	Each farmer keeps its own seed	Marketed in local markets for its superior nutritional quality products	- Subsidies were given in the past from the Ministry of Rural Development and Food to farmers for the conservation of extensive crops, threatened by genetic erosion	Genebank and Institute of Plant Breeding and Genetic Resources of ELGO-DIMITRA
Greece	Leventis	*Triticum polonicum* L.	- Organic or low input agriculture	The farmer keeps his own seed	Only for household needs. Kept only by one farmer	- None	Farmer. (Thanopoulos et al., 2024) (Protonotariou et al., 2023)
Greece	Kopaida	*Triticum dicoccum Schrank*	- Seed production technique detailed by a regulation for conservation varieties and DUS criteria			Registered in the Catalogue of Conservation Varieties	The Property Management and Development Company Agricultural University of Athens

Greece	Asprositi/Asprostaro Arkadias	*Triticum turgidum L. ssp. durum Desf.*	-Traditional agriculture	Each farmer keeps its own seed	Only for household needs	No support	(Thanopoulos et al., 2021)
Greece	Xilokastro. It is a selection from the landrace “Tsougrias” developed by Papadakis. It is an obsolete variety (Thomas et al., 2013).	*Triticum aestivum* L.	- Traditional agriculture	The farmer keeps his own seed	Only for household needs	- None	(Thomas et al., 2013)
Greece	Asprostaro (Lesvos)	*Triticum turgidum* L. ssp. *durum* Desf.	- Traditional agriculture	Each farmer keeps his/her own seed	Only for household needs	No support	(Douma et al., 2016)
Greece	Saritsam (Lesvos)	*Triticum turgidum* L. ssp. *durum* Desf.	- Seed production technique detailed by a regulation for conservation varieties and DUS criteria Low input conditions	https://www.ecpgr.org/in-situ-landraces-best-practice-evidence-based-database/landrace?landraceUid=13559		Registered in the Catalogue of Conservation Varieties	Koutis Kostas. AEGILOPS NGO
Greece	Sparos (Lesvos)	*Triticum turgidum* L. ssp. *durum* Desf.	- Traditional agriculture	Each farmer keeps his/her own seed	Only for household needs	No support	(Douma et al., 2016)
Greece	Mavragani Arkadias	*Triticum turgidum* L. ssp. *durum* Desf.	- Traditional agriculture	Each farmer keeps his/her own seed	Only for household needs	None	(Thanopoulos et al., 2021)
Greece	Tsougrias (Arkadia)	*Triticum turgidum* L. ssp. *durum* Desf.	- Traditional agriculture	Each farmer keeps his/her own seed	Only for household needs.	No support	(Thanopoulos et al., 2021)
Greece	Arapositi Arkadias	*Triticum turgidum* L. ssp. *durum* Desf.	- Organic or low input farming systems	Each farmer keeps his/her own seed	Only for household needs	None	(Thanopoulos et al., 2021)
Greece	Mavragani (Messinia)	*Triticum turgidum* L. ssp. *durum* Desf.	Organic or low input agriculture.	Each farmer keeps his/her own seed	Only for household needs.	No support	(Thanopoulos et al., 2024)
Greece	Mavragani Skyros	*Triticum turgidum* L. ssp. *durum* Desf.	- Organic or low input farming systems		Only for household needs	None	(Protonotariou et al., 2023)