EU CAP Network Focus Group

'Local plant genetic resources in view of climate change and biodiversity loss'

Mini Paper 3

Boosting the use and knowledge sharing of traditional genetic resources in agriculture: practical steps for farmers and stakeholders

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Rationale

This paper tackles the challenges of using traditional genetic resources (TGRs) in farming. We need better ways to find, understand, and share information about these valuable varieties. Currently, efforts are often scattered, with individual farmers or institutions working alone. We suggest simple, practical ideas to help make these traditional varieties easier to use and more helpful for farmers.

In addition to addressing the main challenges of using TGRs in farming, it is important to also focus on making sure farmers can easily access TGR-related knowledge. Using TGRs effectively is about having them available to use them properly in their fields. We propose practical solutions to improve the physical accessibility of these resources and strengthen knowledge transfer mechanisms, ensuring that both farmers and institutions have a deeper and applicable understanding of how to sustainably and advantageously use these resources.

Description of key issues

1. Protecting TGR related knowledge

Farmers' intergenerational knowledge vital for TGR conservation, cultivation, and cultural practices is being lost due to modernization. Rapid action is crucial to preserve both genetic resources and associated wisdom. Systematic surveys and community collaboration are needed, alongside expanding accessible programs like ECPGR (https://www.ecpgr.org/) and adapting initiatives like Cultiva (https://www.mapa.gob.es/va/desarrollo-rural/temas/relevo-generacional/visitas-formativas) for knowledge transfer. Clear communication between local actors and gene banks is essential for joint conservation efforts. Accessible inventories of TGRs and their knowledge are needed at the European level. Reliable assessment through molecular and morphological validation is crucial to avoid confusion (see MUNQ/PUNQ best practice below). Effective TGR management requires valuing traditional knowledge and developing innovative characterization tools.

2. Unlocking the potential of underused traditional cultivars by a deeper and better characterisation

Following inventory, in-depth study of TGR properties is crucial to uncover valuable traits like pest resistance, drought tolerance, unique flavours, and nutritional benefits. Urgent characterization, encompassing genetic, phenotypic, and agronomic analysis, is needed to preserve biodiversity and explore modern applications. Advanced molecular techniques like genome sequencing and metabolomics can reveal resilience

and flavour advantages. Multi-site planting across diverse conditions will assess adaptability to climate change, requiring standardized evaluation protocols for data homogeneity. This information facilitates the (re)introduction of local, traditional cultivars in breeding programs, for a more sustainable farming and climate resilience, strengthening cultural heritage. Integrating modern genetic tools enhances accurate preservation and utilization of TGRs as well as improving their added-value, fostering sustainable agricultural practices for present and future challenges.

3. Transfer of knowledge

Knowledge transfer is being transformed by ICTs (information and communication technologies); expanding platforms like EURISCO. Including local TGRs and traditional knowledge would enhance diversity and resilience. For example, proper training and knowledge transfer in propagation techniques would empower growers to independently preserve perennial crops' genetic resources through methods such as rooting, cuttings, and grafting. Although these practices are generally simple and accessible to most growers, they are often perceived as complicated. However, practical know-how also requires in-person training like on-farm exchanges and peer mentoring. Agricultural advisors act as crucial "knowledge brokers" linking research and practice. Continuous professional development for all stakeholders ensures an updated and innovative agricultural sector. Combining digital resources with human interaction is key for effective TGR knowledge transfer.

State-of-the-art of research need from practices

Track of traditional agricultural knowledge

Across Europe, conservation and characterization of perennial plant genetic resources currently involve few initiatives. For example, the European Cooperative Programme for Plant Genetic Resources (ECPGR, https://www.ecpgr.org/) supports efforts across the continent, contributing to the biodiversity and sustainability of agriculture. Other examples as operational groups VinGO (https://eu-cap-network.ec.europa.eu/projects/vingo-identification-enhancement-and-international-marketing-minority-grape-varieties_en) which focuses on minor, local varieties and promotes biodiversity and economic opportunities through targeted conservation and marketing efforts of these unique products. Additionally, the European Evaluation Network (EVA, https://www.ecpgr.org/eva/about-eva) has expanded its scope to include networks for legumes and is establishing new ones for perennial plants, showing proactive development in the use of plant genetic resources for agriculture.

However, direct policy support for producers maintaining local, perennial varieties is still too limited. The gap between the potential benefits of perennial crops and the support available to farmers highlights the need for enhanced policies and support systems to fully leverage these agricultural benefits in Europe.

Deeper & better characterisation of traditional, local cultivars

Characterization of traditional cultivars has advanced significantly via genome sequencing, agronomy, and data science, enabling the study of traits related to resilience and adaptation (Cui et al., 2020; Lezzi et al., 2023). Genomic tools identified alleles for stress tolerance, pest resistance, though mostly applied to annual crops (except the RefPop initiative (Jung et al., 2020)).

Phenotypic analysis uses remote sensing (drones) and precision agriculture to monitor plant health and environmental responses, integrated with climate models for future predictions (Araus & Cairns, 2014). Local knowledge offers valuable insights but needs integration with high-throughput techniques for the development of comprehensive databases linking genetic and cultural/usage significance. Up to now, databases were specialized to omics (see NCBI, https://www.ncbi.nlm.nih.gov/) or ethnobotanical databases, Eweé and ebDB, (do Nascimento Fernandes de Souza & Hawkins, 2020; Skoczen & Bussmann, 2006). Too few exist linking both omics and cultural heritage like Aotearoa genomics initiative in New Zealand in which Māori traditional knowledge is linked to multi-omics or/and genetic data.

Collaborative efforts among farmers, researchers, and gene banks are crucial for participatory characterization and breeding but are nevertheless very limited in perennial crops. Metabolomics and phenomics could help to deepen our understanding of biochemical and medicinal added-value, revealing compounds affecting nutrition and environmental responses, which can be integrated with traditional breeding (Figure 1) (Malhotra et al., 2022; Righetti et al., 2016).

Artificial Intelligence (AI) and machine learning enhance predictive models for cultivar performance across environments, aiding in optimizing choices in varieties to plant depending on the growing conditions, pest/disease management, and breeding strategies. Ecological studies increasingly focus on perennial cultivars' role in agroecosystems (soil health, biodiversity), highlighting their sustainability value (Rusch, 2025).

These multidisciplinary characterization efforts increasingly recognize the value of local perennial cultivars for food security and sustainability, with evolving technologies

and collaborations ensuring their preservation and contribution to modern agriculture. Moreover, collaborative efforts between local farmers, researchers, and curators of national repositories should help to foster the preservation and use of crop diversity through participatory characterisation and breeding programs (see figure 1 below).

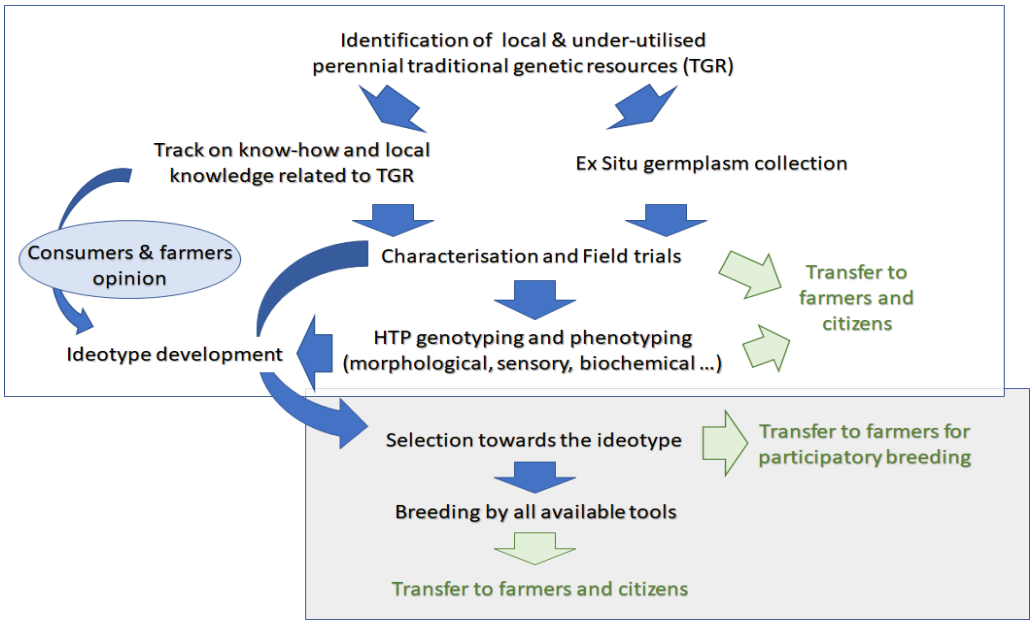

Figure 1: Flow chart of the multi-actors' implication towards a better characterization and use of perennial local varieties (Source: figure created by the authors)

Transfer of knowledge, including operability (database, tools to share knowledge, know-how and training)

Effective TGR knowledge transfer increasingly relies on **Information & Communication Technologies ICT** tools for organizing, storing, and disseminating information to researchers, farmers, and policymakers. Digital databases like EURISCO (https://www.ecpgr.org/resources/germplasm-databases/eurisco-catalogue) and platforms like Digital Green (https://digitalgreen.org/) facilitate the sharing of plant genetic resource data, connecting traditional knowledge with contemporary information. Expanding these platforms to include more local and underutilized cultivars enhances agricultural diversity and climate resilience.

Multilingual interfaces, **open-access policies**, and **user-friendly designs** are key to ensure inclusivity in rural areas where digital literacy may be low. Combining digital

tools with video-based learning, virtual farmer meet-ups, and peer-to-peer mentoring encourages real-time knowledge exchange and practical innovation

Beyond databases, **on-farm training**, **demonstration plots**, and **farmer-led knowledge hubs** are vital for building confidence in TGR cultivation and conservation. Field level innovations, such as 2D tree training systems for fruit tress (e.g. peach, cherry, and pear), provide hands-on methods to reduce inputs and improve biodiversity while enhancing fruit quality, all crucial traits in TGRs.

Agricultural advisory services such as Agro Q (https://www.agroq.gr/), act as effective ''knowledge brokers'', adapting techniques to local conditions, translating science into actionable guidance, and fostering co-learning through practical demonstrations. Field-based experimentation, helps both advisors and farmers tailor sustainable methods to their specific agro-ecological zones..

A state-of-the-art knowledge transfer system integrates databases, ICT tools, practical training, and collaborative advisory services to promote the efficient use of TGRs. Strengthening these mechanisms ensures accessible, shareable, and applicable knowledge for sustainable agricultural development and climate resilience.

Current Best Practices and Tools

Mechanical Summer Thinning and Pruning (OG: MECHANIPEACH - M16ΣΥΝ2-00110)

Mechanical summer thinning and pruning are sustainable farming techniques supporting TGR cultivation, especially perennial fruits because those were not initially selected to current cultivation practices. These techniques improve canopy architecture, reduce fruit overload, and enhance tree health and resilience without genetic alteration. By limiting disease pressure, improving air flow and light penetration, and mitigating extreme weather effects, they foster microclimatic stability. Reduced chemical needs align with TGRs' low-input systems, supporting biodiversity and soil health. Mechanization lowers labour demands, making the cultivation of diverse, traditional varieties more economically viable. However, proper implementation requires localized adjustments and continuous training. Agro-advisors are key actors in interpreting field conditions, customizing techniques, and ensuring knowledge transfer through peer learning and on-farm demonstrations.

Molecular fingerprinting of perennial cultivars: MUNQ Malus UNiQue genotype code for grouping apple accessions corresponding to a unique genotypic profile.

Identifies unique apple varieties and resolves homonyms (different varieties with the same name) and synonyms (the same variety with different names) with already-known modern cultivars or ancient landraces to limit confusion and misleading in their agronomic evaluation and prevent wasted resources. In this context, The MUNQ system (Denancé, Muranty, & Durel, 2020) is:

- a system for identifying unique apple varieties using genetic markers
- can be expanded to other TGRs for a true-to-type validation and TGR characterization

To date, the MUNQ assignment was performed to more than 30,000 accessions from 16 mostly European apple germplasm collections after their genotyping with up to 16 SSR, generating 10,000 Malus Unique Genotypes. An initiative that needs to be extended to other omics such as metabolomics, transcriptomics etc. An example of MUNQ use for Croatian Apple TGR characterisation was recently released (Čiček et al., 2025), illustrating the interest of broadly applying a similar approach for the identification of duplicates, synonyms, and mislabelled accessions.

Multi-Site Testing of common TGRs to address adaptation to climate changes

- an experimental design to evaluate TGRs in different environments to understand adaptability and promote their use (e.g., Apple, Peach, Apricot reference collections also called RefPop)

Multi-site trials enable the identification of which TGR thrives best in specific environments, allowing for targeted recommendations and improved orchard management practices for farmers. Moreover, testing across diverse environments helps to identify varieties that are more tolerant to climate fluctuations, such as drought or extreme temperatures, ensuring future orchard sustainability. This methodology provides a wealth of data regarding the performance of the tested TGRs, which can be utilized to improve breeding programs, and inform farmers on the best cultivation methods (Jung et al., 2020; Laurens et al., 2018). RefPops of apple, peach, apricot and even apricot wild relatives are currently implanted in 3 to 6 EU countries, in various pedoclimatic environments, they were established in the frame of the FP7 FRUITBREEDOMICS, PRIMA FREECLIMB and Horizon Europe FRUITDIV (www.fruitdiv.eu/workpackages/ WP3) projects. An example of use is shown by (Jung et al., 2020).

Collaborative platforms for farmers and stakeholders

Collaborative platforms could help to fill the gap between farmers' practical knowledge and scientists' technical expertise in the characterization of perennial genetic resources. They enable farmers to contribute real-world and European-wide observations on local varieties, enriching scientific datasets with valuable contextual information. By working closely with farmers, scientists can tailor their research to address farmers' specific challenges, ensuring that characterization efforts are relevant and applicable in the field. This synergy accelerates the identification of desirable traits and the development of improved varieties. It also allows the sharing of know-how and local, practical knowledge from various pedo-climatic environments.

Database name	Description	link
GEN4OLIVE	An initiative that brings together international olive germplasm banks to improve cultivar characterization through unified scientific protocols.	https://www.uco.es/ucolivo/gen4olive
CartograPlant	A participatory platform in the US supporting the evaluation of forest genetic resources, enabling participatory germplasm characterization.	https://treegenesdb.org/ct
EPICOLLECT	A web platform for data collection, geotagging, and image sharing, useful in field studies and variety characterization.	https://five.epicollect.net/
Grapevine Rootstock Selector tool	A tool to help vine growers to select the most appropriate rootstock according to pedo-climatic conditions and availability of irrigation or other resources.	www.grapevinerootstock.com

An example of 'practitioner-friendly' collaborative platform was developed by the GEN4OLIVE consortium, targeting Olive producers all over Europe (Figure 2). Five international olive germplasm banks collaborated to define and implement unified scientific protocols for the phenotypic characterization of olive cultivars. These protocols address a critical gap in many perennial crops: the historical lack of standardized and comparable data across germplasm banks and research centres. This unprecedented effort has generated a valuable, openly accessible dataset for over 600 traditional olive varieties, available through the online GEN4OLIVE database.

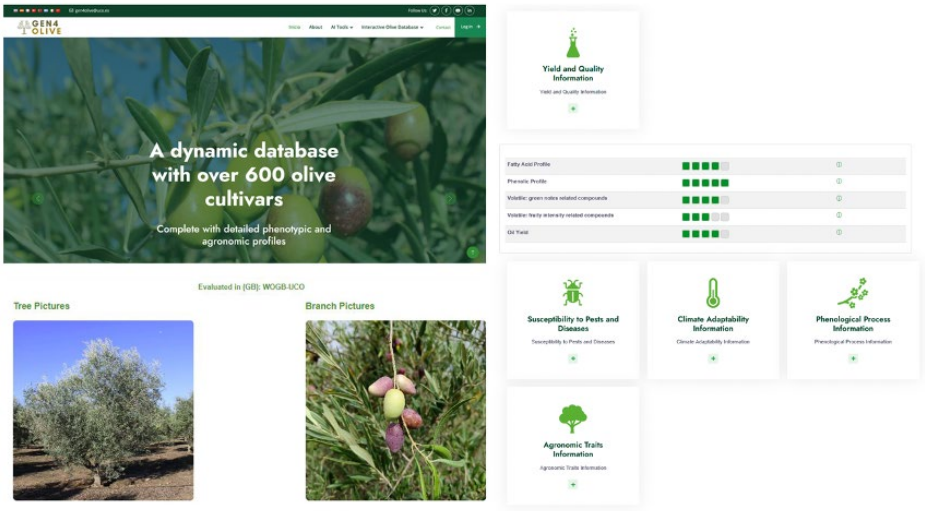

Figure 2: GEN4OLIVE online database (Source: https://www.uco.es/ucolivo/gen4olive)

Olive sector can now benefit from this database, which significantly contributes to:

- The conservation and characterization of traditional Olive cultivars.
- The conservation and public availability of the knowledge associated with traditional Olive cultivars.
- Support farmers in the selection of cultivars better adapted to their needs.
- Develop better breeding strategies and research projects based on robust, comparable data.

Artificial Intelligence (AI) tools for farmers

AI models could contribute to the conservation and characterization of plant genetic resources by enabling efficient, accurate, and large-scale analysis, at a lower cost. These technologies are particularly valuable for the automated identification and classification of plant species and cultivars. AI-powered image recognition and deep learning models can accurately identify plant species, detect genetic traits, and classify plant varieties.

Tool Name	Description	link
PlantVillage	App to assist small farmers in enhancing farm productivity through advices on plant health and optimal growing conditions	https://plantvillage.psu.edu/
Olive Variety Recognizer	A tool developed by the European GEN4OLIVE project using deep learning models to identify olive varieties from images of clean endocarps.	https://www.uco.es/ucolivo/gen4olive/varietyrecognizerguide

Olive Disease Recognizer	Tool identifying the 13 most significant pests and diseases affecting olive trees, using image analysis to diagnose symptoms.	https://www.uco.es/ucolivo/gen4olive/diseaserecognizerguide

For example, the Olive Variety Recognizer developed by the European project GEN4OLIVE utilizes advanced deep learning models to identify local varieties from images of clean endocarps. Trained on more than 40,000 endocarp images provided by five germplasm banks, this tool can currently recognize 132 traditional olive cultivars. Farmers or researchers just upload a photo, and the tool gives the top 3 likely matches, along with a confidence score to help with decision-making (Figure 4).

A similar approach has been developed for pest recognition, PestNet (https://www.pestnet.org/) adapted to the Olive sector (https://www.uco.es/ucolivo/gen4olive/diseaserecognizerguide) for pest and disease in orchards. It identifies symptoms of the 13 most significant pests and diseases affecting olive trees using image-based analysis. It also provides the top three predictions with confidence scores. Both tools are also available as mobile applications, to be used easily in the field.

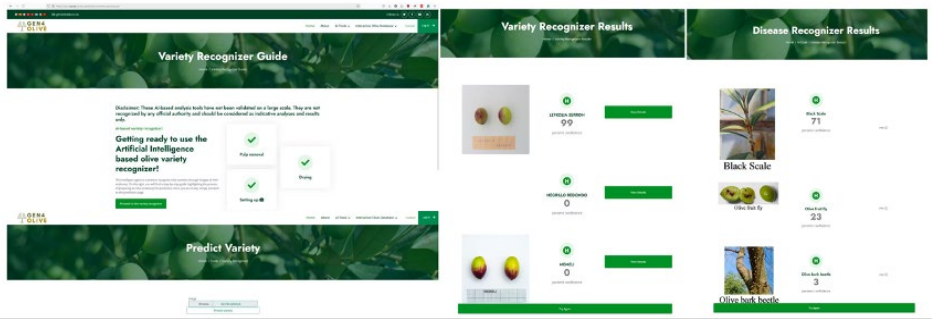

Figure 3: GEN4OLIVE Disease recognizer (Source: https://www.uco.es/ucolivo/gen4olive/diseaserecognizerguide)

Conclusions

A comprehensive and collaborative approach is needed to conserve, utilize, and promote TGR. This involves not only better characterization and management of these resources but also ensuring that local agricultural knowledge is integrated into modern agricultural practices. By leveraging technology, fostering farmer empowerment, and promoting knowledge-sharing, we can create a resilient and sustainable agricultural system that preserves the invaluable biodiversity and cultural heritage associated with traditional genetic resources.

Key takeaways:

- TGRs are vital for sustainable agriculture.
- Local knowledge is irreplaceable.
- A collaborative, farmer-centred approach is crucial.
- Technology & multi-omics approaches can enhance TGR characterization and knowledge sharing as well as documenting the added-value of TGR.
- Practical training and support are essential for farmer adoption.
- Policy support must be strengthened.
- The "Farmers-First-and-Last" model emphasizes the active farmer involvement in research.

Research needs

a. Enhanced and high-throughput characterization of TGRs

Keywords: multi-omics, multiple site network
Problem: There is still a significant lack of detailed information on the genetic, nutritional and agronomic qualities of TGRs, in terms of added value in comparison with modern cultivars.
Solutions:

- Use advanced genetic tools (genome sequencing, metabolomics) to identify valuable traits.
- Conduct multi-site field trials to assess adaptability.
- Develop standardized evaluation protocols.
- Validate the true-to-type status of traditional cultivars.
- Create databases that include genetic and cultural information.

Geographical area(s): Any rural farming area in Europe
Sector(s) where the issue is relevant: Research programs dealing with fruit tree sector, rootstocks included.

b. AI-powered virtual assistants for agricultural knowledge transfer

Keywords: Artificial Intelligence, AgriTech, Digital gap
Problem: We need to bridge the digital gap in rural farming
Solution:

- Personalized, Real-Time Advice as AI assistants trained on comprehensive agricultural databases and providing tailored recommendations to farmers and advisors.

- Multilingual Support easily accessible via mobile devices and office solutions, to overcome connectivity barriers and provide access to vital information.
- Decision Support Systems based on predictive models fine-tuned by real-time information on weather, soil, scientific data, and market trends etc...
- Facilitated Peer-to-Peer Learning on AI platforms that incorporate features for farmers to share best practices, success stories, and field-tested methods, fostering a collaborative learning environment.

Geographical area(s): Any rural farming area in Europe
Sector(s) where the issue is relevant: Farmers & support services from cooperatives, agricultural extension and advisory services.

Ideas for innovations

a. Recover & preserve lost traditional Knowledge

Keywords: Knowledge transfer, cultural and practice heritage, agrobiodiversity
Problem: Valuable farming knowledge is disappearing due to urbanization, aging farmers, and changing food systems.
Solutions:

- Document traditional knowledge systematically through field surveys and farmer interviews.
- Create local, multilingual, open-access repositories that respect cultural heritage and Intellectual Property Rights.
- Support (economic, policy, structural) the minority "knowledge keepers'' who maintain these varieties.
- Create easy ways to communicate between local stakeholders and national germplasm collections.

Geographical area(s): Remote rural farming area(s) in Europe to cover various pedo-climatic conditions
Sector(s) where the issue is relevant: Fruit tree & grape sector, rootstocks and minor perennials included.

b. Develop a more efficient Knowledge Transfer System

Keywords: Digital literacy, knowledge broker
Problem: Farmers and stakeholders need better access to information and training on TGRs while they often lack digital literacy
Solution:

- Develop user-friendly databases and online platforms (like EURISCO and Digital Green) for sharing TGR information.
- Provide on-farm training, farmer-to-farmer exchanges, and peer to peer learning.
- Train agricultural advisors to act as "knowledge brokers." to translate scientific information into actionable guidance.
- Promote blended learning approaches (online + field based) including short videos.
- Include feedback to allow farmers to report field experiences, creating dynamic, evolving knowledge systems.

Geographical area(s): Remote rural farming area(s) in Europe
Sector(s) where the issue is relevant: Farmer(s) training and education, extension and advisory services.

a. Enhance tools for better access to knowledge and advisory support

Keywords: Farmer network, On-farm training, advisory support
Problem: Lack direct contact with trained agronomists and advisory services, limiting producers' ability to implement innovative and sustainable farming practices
Solution:

- Deploy user-friendly mobile applications and platforms (like WhatsApp) powered by AI, to deliver direct advice on cultivation to farmers.
- Farmer-Lead Learning Networks: Support local farmer networks to foster peer-to-peer learning through field days, workshops, and knowledge-sharing platforms, promoting the exchange of practical, context-specific expertise.
- Integrate On-Farm Training with Digital Resources: Combine traditional on-farm training and demonstrations with digital resources (videos, guides,) to cater to diverse learning styles ensuring farmers have continuous access to best practices.
- Encourage participatory tool development, ensuring digital tools are co-created with farmers, not just for them.

Geographical area(s): Rural and remote agricultural regions where digital infrastructure and training opportunities are limited
Sector(s) where the issue is relevant: Researchers and agricultural support services, agricultural extension and advisory services, adult education centres.

b. Upgrading genetic resources networks by integrating AI-powered tools of analysis and curation.

Keywords: Genetic Resources, Artificial Intelligence, Data integration
Challenge: Enhancing the efficiency and accessibility of genetic resources networks (e.g., ECPGR, EUFORGEN) by integrating AI-powered tools for data analysis and curation. The project aims to interconnect these networks and create a common mega_platform for the characterisation local genetic resources.
Geographical area: EU-wide.
Sector: Genetic resource management, digital innovation.

Potential EIP Operational Groups

a. Network of farmers testing practices for a Climate-Resilient Farming.

Keywords: Climate Adaptation, Sustainable Agriculture, Drought Resistance
Challenge: Addressing climate risks in agriculture by developing and promoting sustainable methods such as drought-resistant crop varieties and efficient water management. To provide farmers with tools to adapt to changing climatic conditions and ensure long-term productivity.
Geographical Area: European regions affected by climate change (e.g., Mediterranean, continental, and arid zones).
Sector: Agriculture in a context of climate adaptation.

b. Network of demonstration Farms for Genetic Resources' Exchange

Keywords: Demonstration Farms, Genetic Exchange, Farmer Education
Challenge: Establishing a network of farms that showcase and exchange genetic resources between regions with similar or even distinct agro-climatic conditions. Enhances conservation efforts and supports climate adaptation by providing farmers with practical experience in growing resilient varieties.
Geographical Area: Various European regions with comparable or very distinct climate conditions, similar to a *twinning* network.
Sector: Genetic resource conservation, sustainable farming

c. Network of actors aiming at reviving underutilized TGRs

Keywords: Traditional Varieties, Biodiversity, Resilient orchard
Challenge: Reviving and promoting the cultivation of underutilized traditional genetic resources (TGRs) by combining modern technologies with sustainable farming

practices together with actors of the local and national market. Providing farmers with viable alternatives for diversification and resilience.
Geographical Area: EU-wide, focusing on regions with TGR potential.
Sector: Pomology, biodiversity conservation.

d. In-farm conservation and characterization networks

Keywords: On-Farm Conservation, Perennial Resources, collaborative research
Challenge: Establishing a coordinated network for in-farm conservation and characterization of underutilized perennial genetic resources. Operational Group will be organized in multiple pedo-climatic zones and connected through a platform managed by ECPGR, fostering collaboration and resource-sharing.
Geographical Area: National or EU-wide.
Sector: Genetic resource conservation, research collaboration.

e. Networking actors from farm-to-fork for the development of sustainable business models for traditional varieties

Keywords: Value Chains, Market Innovation, Sustainability
Challenge: Developing innovative business models and market strategies that promote the *in situ* conservation of traditional varieties. The OG will integrate these varieties into sustainable value chains and leveraging financial incentives and quality certifications, ensuring their economic viability and long-term preservation.
Geographical Area: EU-wide, with a focus on rural and traditional farming regions.
Sector: Agriculture, market development

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